A Retrospective Study of the Extra-alveolar Screw Placement on Buccal Shelves

ABSTRACT

Background: Previous studies on inter-radicular screw insertion have shown that there was a significantly higher failure rate for screws inserted through moveable mucosa compared to attached gingiva. Furthermore, there are no reports about the stability of the extra-alveolar screw insertion into the buccal shelf of the mandible. This is an important area of research because extra-alveolar miniscrews placed in the buccal shelf are effective anchorage, for retracting the entire lower dentition to correct Class III malocclusion. It is important to understand the success rate and stability for buccal shelf miniscrews placed in different locations.

Objective: Compare the failure rates for buccal shelf screws inserted through movable mucosal (*MM*) as opposed to attached gingiva (*AG*).

Design: Retrospective review.

Participants: 840 patients (*405 males; 435 females, with the age of 16 ± 5 years*) received buccal shelf screw placements that were performed by the same orthodontist between 2009 and 2012, using standardized procedures.

Methods: A total of 1680 miniscrews (*2x12mm, stainless steel*) were placed on buccal shelves; 1286 miniscrews were in movable mucosa and 394 miniscrews penetrated attached gingiva. All miniscrews were placed as parallel as possible to the lower 1st and 2nd molars roots (*extra-alveolar approach*). Screw heads, at the insertion point, were at least 5mm above the soft tissue. All mini-screws were immediately loaded with a force ranging from 8oz. to 14oz., according to the patients' age. The stability of the buccal shelf screws was tested up to 4 months after placement.

Result: 121 miniscrews out of 1680 failed during the course of study. Failure was defined as loose screws that were exfoliated or removed by the clinician. The overall failure rate was 7.2% for the entire sample (*n=1680*). In the movable mucosa group, 94 out of 1286 (*7.31%*) failed; 27 out of 394 (*6.85%*) failed in the attached gingiva group. A Chi-square test showed there was no statistical significance of the failure rates between miniscrews inserted through MM compared to AG.

Discussion & Conclusions: Buccal shelf mini-screws can be placed in either the movable mucosa or attached gingiva. In terms of stability, there was a high success rate for both groups (~93%). This is clinically valuable information because bone buccal to the roots of the teeth is more directly accessible by penetrating the movable mucosa apical to the mucogingival

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junction. Also many patients have a minimal width of attached gingiva buccal to the molars. Thus in this retrospective study, the majority of the buccal shelf miniscrews (*1286/1680*) were placed through movable mucosa. Due to the elevated position of the screw head, mucosal insertion does not jeopardize the health of the soft tissue. For extra-alveolar screw placement, insertion through the movable mucosa is often the preferred procedure for buccal shelf miniscrews, because it accesses more bone volume, facilitates the surgical procedure, and is usually more comfortable for the patient. It is important for the clinician to realize that these advantages can be achieved without sacrificing screw stability. (*Int J Ortho Implantol 2013;32:80-89*)

INTRODUCTION

In Asia, skeletal anchorage[1-7] is the key in our daily practice, particularly in the treatment of bimaxillary protrusion[1] and Class III malocclusion.[2] Back in 1997 Kanomi[8] introduced the miniscrew for orthodontic anchorage, and it soon gained wide acceptance in the orthodontic profession. In the following years more refined mini-screws have been brought into the markets;[9,10] miniscrews have now become the main stream in orthodontic anchorage. The diameters of orthodontic miniscrews range from 1 to 2.3mm and the length from 4 to 21mm.[11-25]Although a few well designed studies and some case reports have been published on success rates, research so far has shown promising results and treatment efficiency, but has often lacked evidence-based information.[25,26] Therefore studies on screw design and surgical protocol are vital in order to evaluate their success rates.

In dental literature, success rates of orthodontic mini-screws as temporary anchorage range from 57% to 95.3%, with most studies reporting success rates of around 84%.[26-28] Several studies have attempted to find out the factors responsible for the success of orthodontic miniscrews. Primary stability is generally accepted to be the most important factor and can be measured by evaluation of insertion torque, removal torque, and pull-out strength. Variables that result in higher primary stability include smaller pilot hole diameters,[23] increased cortical bone thickness,[29-32] increased bone density, and use of self-drilling miniscrews.[33,34]

In conclusion, there are three key factors that dramatically affect initial stability: 1. bone quality; 2. screw design; 3. placement technique. These three factors are inter-related. For example, one will have totally different success rates if varying screw designs and placement techniques are used on the same patient. Thus, it is imperative to understand and control these variables.[35]

1. Bone quality:

Given that orthodontic miniscrews are based on mechanical locking, instead of osseointegration,[36] our job as a clinician is to find the bigge st and the best quality bone for the screw engagement. Cortical bone provides us with the answer for that high quality bone. How can we get more cortical bone engagement? The screw design and placement technique could provide the answer.[1,2]

2. Screw design:

Screws with diameters of 1.2mm or greater have universally achieved success rates of above 70% in the current available studies. Another significant factor is length; Chen et al[18] increased the success rate from 72% to 90% by using 8mm instead of 6mm long screws. Three other studies also reported higher success rates using longer screws without increasing the diameter.[17,19,21] However, increasing the screw diameter and length can also add to the possibility of root damage during screw placement. Nevertheless, this issue could be easily resolved by a new placement technique, such as extra-alveolar insertion.[1,2]

3. Placement technique

One major technical part related to the screw success rate is the insertion angle. Park et al[16] evaluated the angle between miniscrews' long axis and cortical bone. They asserted that although no major differences were found in terms of success rates, they contended however, that placing screws not perpendicular to the bone surface, but at an obtuse angle, lowered the risk of root damage and increased the screw's contact with cortical bone. In conclusion, a steeper angle, for example extra-radicular insertion,[1,2] will increase the cortical bone contact which will , in turn, enhance the stability of the screw. Besides, this upright position of the screw will also reduce root damage.

In terms of success rate differences between maxilla and mandible after screw placement with immediate loading, one study compared placement in beagles and found out that the mandibles had greater primary stability than the maxillae.[31]However, in humans, the success rates of miniscrews placed in the maxilla are consistently greater than those placed in the mandible in all[26, 38-40] but one study.[23] Recent studies have significantly supported the maxilla as a more suitable placement for

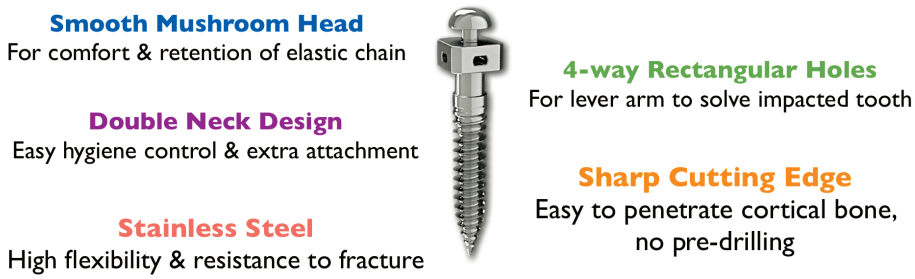

Fig. 1:

Special design of the orthodontic bone screw (2x12 stainless steel) used in current study illustrates the strength of this skeletal anchorage device that fits into the extra-alveolar approach on buccal shelves.

miniscrews.[12,17,24] All three studies interpreted the lower success rate in the mandible as a consequence [12,17,24] of overheating the bone during drilling. They suggest that sufficient watering must therefore be used while pilot drilling. In addition, mandibular miniscrews might be more exposed to soft tissue interference.[1,2] This suggests that other factors may be important in determining the success of miniscrews in the mandible, such as insertion in various zones of soft tissue.

Previous studies on inter-radicular screw insertion have shown that there was a significantly higher failure rate for screws inserted through movable mucosa compared to attached gingiva. Furthermore, there are no reports about the stability of the extra-alveolar screw insertion into the buccal shelf of the mandible.[41-45] This is an important area of research because extra-alveolar miniscrews placed in the buccal shelf are effective anchorage for retracting the entire lower dentition to correct Class III malocclusion.[2] Therefore, it is vital to understand the success rate and stability for buccal shelf miniscrews placed in different areas of soft tissue. The aim of this research is to compare the failure rates of buccal shelf screws inserted through movable mucosal (*MM*) as opposed to attached gingiva (*AG*).

MATERIAL AND METHODS

840 patients (*405 males; 435 females, age 16 ± 5 years*) received buccal shelf screw placements that were performed by the same orthodontist (*Dr. C.C.*) using standardized procedures between 2009 and 2012 at the Beethoven Orthodontic Center, Taiwan.[1,46]

Patients were informed about the possibilities of inflammation around and loosening of the miniscrews. A total of 1680 miniscrews (*2 x 12mm, stainless steel, Newton's A, Taiwan, Fig.1*) were placed on buccal shelves (*Fig. 2-3*) without flap elevation under

Fig. 2:
Between 1st and 2nd molars a larger buccal shelf bone volume is present.

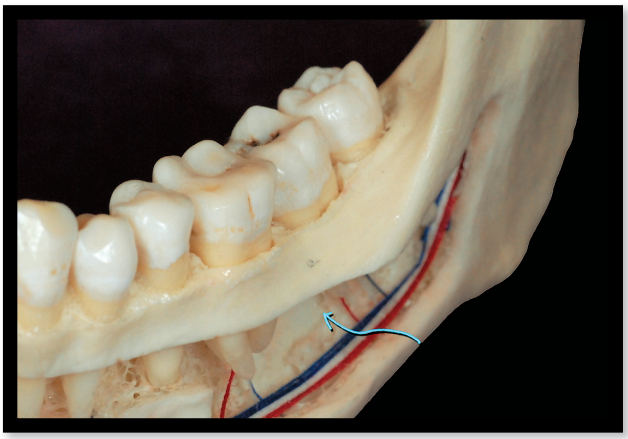

Fig. 3: There is a safe zone between the 1st and 2nd molar roots.

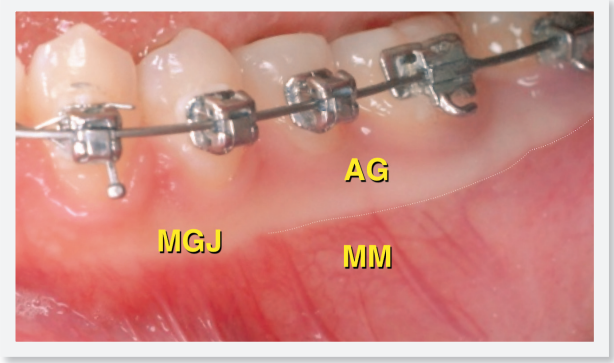

Fig. 4:
The mucogingival junction (MGJ) seperates the attached gingiva (AG) and the movable mucosa (MM).

local anesthesia; 1286 miniscrews were in movable mucosa and 394 mini-screws penetrated attached gingiva (*Fig. 4*). All miniscrews were placed as parallel as possible to the lower 1st and 2nd molar roots (*extra-alveolar approach*). The placement procedures are described as follows. Use a dental explorer to make a dent through the soft tissue, periosteum and on the cortical bone of buccal shelf outside the 1st and 2nd molar roots . Then, an orthodontic bone screw (*2 x 12mm stainless steel, Newton's A, Taiwan*) further penetrates this dent and is screwed in an upright direction parallel to the long axis of the lower 1st and 2nd molar roots (*Fig. 5-6*).

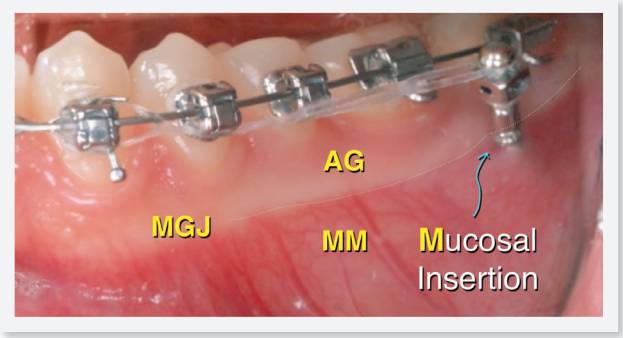

Fig. 5:
Mucosal insertion refers to the position that the buccal shelf screw is inserted in the movable mucosa.

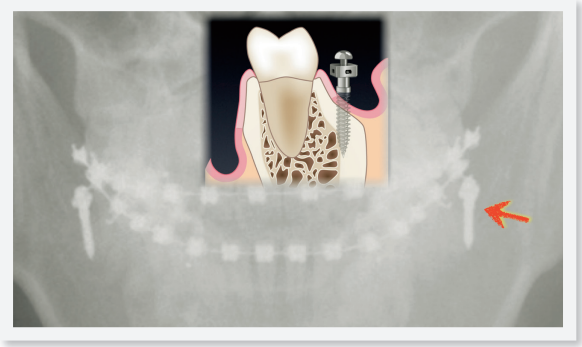

Fig. 6:
The extra-alveolar approach on buccal shelves refers to the position of screws which have been placed parallel to the lower 1st and 2nd molar roots as shown in this X-ray.

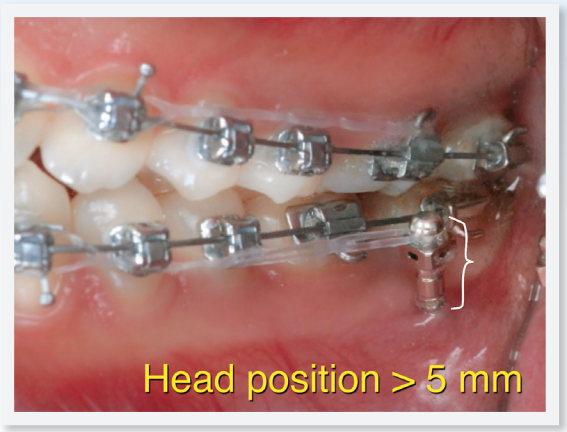

Fig. 7:
In the extra-alveolar approach on buccal shelves, all screw heads was at least 5mm above the soft tissue, in order to prevent the soft tissue overgrowth.

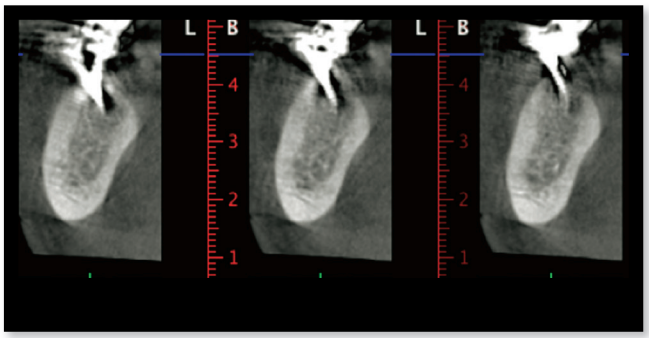

Fig. 8:
In the extra-alveolar approach on buccal shelves, on average, there is 5mm of bone engagement as shown in this CBCT.

No pilot drill is needed. Screw heads, at the insertion point, are at least [46-49] 5mm above the soft tissue (*Fig. 7*). On average, there is 5mm of bone engagement (*Fig. 8*).[50] All miniscrews are immediately loaded by using elastomeric modules (*power chains*), with a force ranging from 8oz. to 14oz based on the patient's age, to connect the canine hook and screw head. Elastomeric chains generally lose 50% to 70 % of their initial force during the first day of load application,[51,52] therefore, in order to maintain the

constant force level, pre-stretching [53] of all power chains should be performed to drain the initial force before attaching to the miniscrews. All screws were placed by the same placement protocol[1,2] and the patients were instructed to keep the screw heads clean at all times to prevent inflammation. The power chains were replaced every four weeks. The stability of the buccal shelf screws was tested up to four months after placement.

RESULTS

121 mini-screws out of the 1680 placements failed during the course of the study. Failure was defined as loose screws that were exfoliated or removed by the clinician within 4 months of screw placement. The average failure time for these 121 failed mini-screws was 3.3 months. The overall failure rate was 7.2% for the entire sample (*n=1680*). In the movable mucosa (*MM*) group, 94 out of 1286 (*7.31%*) failed; 27 out of 394 (*6.85%*) failed in the attached gingiva (*AG*) group (*Fig. 9*). A Chi-square test showed there was no statistical significance of the failure rates between miniscrews inserted through MM compared to AG ($p > .05$).

There was a significant correlation between the failure rate and the following variables: Age, left or right hand site, and individual bone quality.

Notably, the average age for these 121 failed screw patients was 14 ± 3 years (*Fig. 10*) which is considered

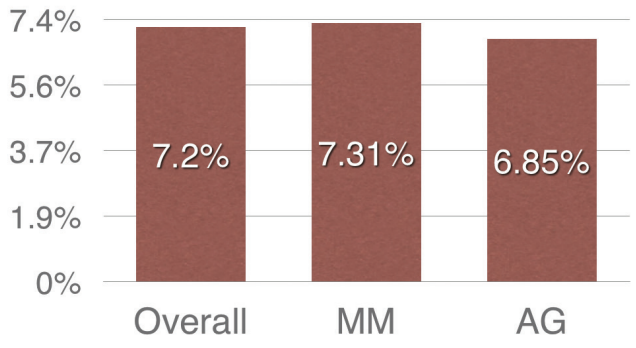

Fig. 9:

The overall failure rate was 7.2% for the entire sample (n=1680). In the movable mucosa (MM) group, 94 out of 1286 (7.31%) failed; 27 out of 394 (6.85%) failed in the attached gingiva (AG) group.

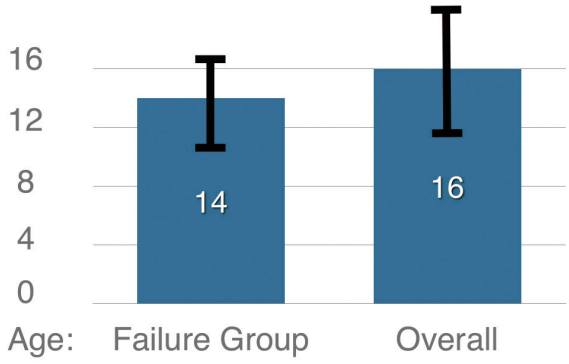

Fig.10:

Notably, the average age for these 121 failed screw patients was 14±3 years which is considered lower than the overall average age (16±5 years).

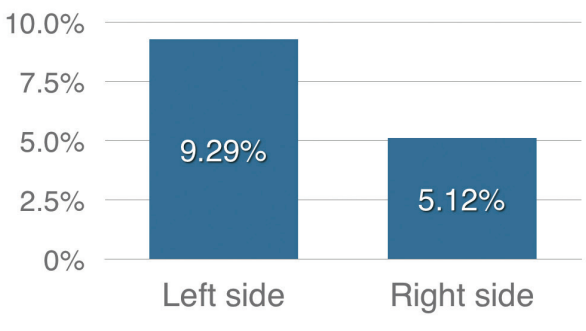

Fig.11 :

A Chi-square test showed statistical significance of the failure rates between left (9.29%) and right (5.12%) hand sites (p<.001) This significant difference indicates the techical sensitivity for placing on the left hand site, as opposed to the right hand site, where it is much easier to insert the screw.

lower than the overall average age (*16 ± 5 years*). This data indicates that younger patients have higher failure rates. This result may be due to the immature cortical bone in younger patients which could not sustain the mechanical locking.

Among these 121 failed screws, 78 screws came from left buccal shelves; 43 screws from right buccal shelves (*Fig. 11*). A Chi-square test showed statistical significance of the failure rates between left (*9.29%*) and right (*5.12%*) hand sites ($p<.001$) This significant difference indicates the techical sensitivity for placing on the left hand site, as opposed to the right hand site, where it is much easier to insert the screw.

When comparing the failure rate from one side vs both sides, an interesting fact was found. The 121 failed screws came from 105 patients of which 89 patients had single screw failure and the other 16 patients lost screws on both sides. This data indicates that when a patient has a loose screw on one side the chance for screw failure on the other side will dramatically increase. This implies that indiviual bone quality might play a significant role in screw retention.

DISCUSSION

Regarding different insertion sites of miniscrew placement, most studies showed higher failure rate in the mandible (*19.3%*) than in the maxilla (*12%*). The overall failures of the mini-screw in the mandible were 1.5 times more than those of the maxilla. The higher mini-screw failure rates observed for those inserted in the mandible can be attributed to (*1*) the greater bone density of the mandible that can lead to higher insertion torque value, possibly harmful to miniscrew success; (*2*) bone overheating during insertion; (*3*) less cortical bone formed around the miniscrew inserted in the mandible; and (*4*) a narrower vestibule compared with the maxilla that prevents the patient from cleaning the area throughly. All studies used the inter-radicular insertion approach which placed the screws between the roots. In addition, mini-screw placed between the mandibular second premolars and first molars had significantly higher failure rates compared with miniscrew placed between the first and second premolars.[24,54,55]

The disadvantage of the inter-radicular insertion approach could be improved by using the extra-alveolar insertion approach. Our group had designed and practiced this extra-alveolar insertion approach for ten years. In previous studies, there has been no evaluation of clinicians' skills as a factor influencing success rates. Therefore, in order to exclude this variable, prior to this study the operator (*Dr. C.C.*) followed this placement protocol[1, 46] for six years and performed over 3000 buccal shelf screw placements. This extensive practice should have reduced the operation errors and the clinical bias in decision-making for the selection of the insertion site. The operator's learning curve, which was determined by evaluation of the success rate of miniscrews placed by the operator (*Dr. C.C.*) over four periods each consisting of 12 months, was investigated prior to this study.

In this extra-alveolar insertion protocol, buccal shelf miniscrews can be placed in either the movable mucosa or attached gingiva. In terms of stability,

there was a high success rate for both groups (~93%). This is clinically valuable information because bone buccal to the roots of the teeth is more accessible by penetrating the movable mucosa apical to the mucogingival junction. Also many patients have a minimal width of attached gingiva buccal to the molars. Thus in this retrospective study, the majority of the buccal shelf miniscrews (*1286/1680*) were placed through movable mucosa. Due to the elevated position of the screw head, mucosal insertion does not jeopardize the health of the soft tissue. For extra-alveolar screw placement, insertion through the movable mucosa is often a preferred procedure for buccal shelf mini-screws, because it can access more bone volume, is an easier surgical procedure, and is usually more comfortable for the patient. It is important for clinicians to realize that these advantages can be achieved without sacrificing screw stability.

Many studies have found no significant differences between failure rate and age.[11,16,17,21] However, in this study, younger patients had a higher failure rate. This might be attributed to a difference in bone density because bone calcification is not fully complete in adolescents. However, immature bone is not necessary to be the contra-indication for screw placement. One could change the insertion angle to increase the solid cortical bone engagement. With this upright position, the screw tip could catch more solid bone and enhance the mechanincal locking.[56] For sure, we normally reduce the amount of loading moment for younger patients.

The significant difference in failure rates between the left side (*9.29%*) and the right side (*5.12%*) indicates the technical sensitivity for placing on the left hand site, as opposed to the right hand site, which is much easier to insert the screw. The maneuver of screw insertion on the left hand side is more difficult for right-hand operator. This 9.29% failure rate on the left side is significant higher than 5.12% on the right side. Nevertheless, it also indicates that there is a big room for improvement on the left hand side.

There were 16 patients who had screw failure on both sides. It implies that individual bone quality might play a significant role in screw retention. The bone density of cortical bone could be identified in the beginning before placing the screw. When encountering this type of soft bone, it would be a good idea to inform the patients right away about the possibility to re-insert the screw. Furthermore, when a screw fails on one side, it is also a good idea to inform patients about the possibilty of failure on the other side.

CONCLUSIONS

The overall failure rate of buccal shelf screw placement was 7.2% under an initial loading of 8 to 14oz per mini-screw based on the patients' age. The buccal shelf area is appropriate for mini-screw placement, and these buccal shelf screws serve as an ideal orthodontic anchorage to move the lower dentition back in an en mass pattern. Factors that influenced the clinical success of mini-screws on buccal shelves were the patient's age, the bone quality, and the operator's skills. Insertion points in various soft tissue zones do not affect the success rate because the screw heads are upright and away from soft tissue in this particular extra-alveolar screw placement.

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