ORIGINAL ARTICLE

Do miniscrews remain stationary under orthodontic forces?

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Miniscrews have been used in recent years for anchorage in orthodontic treatment. However, it is not clear whether the miniscrews are absolutely stationary or move when force is applied. Sixteen adult patients with miniscrews (diameter = 2 mm, length = 17 mm) as the maxillary anchorage were included in this study. Miniscrews were inserted on the maxillary zygomatic buttress as a direct anchorage for en masse anterior retraction. Nickel-titanium closed-coil springs were placed for the retraction 2 weeks after insertion of the miniscrews. Cephalometric radiographs were taken immediately before force application (T1) and 9 months later (T2). The cephalometric tracings at T1 and T2 were superimposed for the overall best fit on the structures of the maxilla, cranial base, and cranial vault to determine any movement of the miniscrews. The miniscrews were also evaluated clinically for their mobility (0: no movement, 1: ≤0.5 mm, 2: 0.5−1.0 mm, 3: >1.0 mm). The mobility of all miniscrews was 0 at T1 and T2. On average, the miniscrews tipped forward significantly, by 0.4 mm at the screw head. The miniscrews were extruded and tipped forward (−1.0 to 1.5 mm) in 7 of the 16 patients. Miniscrews are a stable anchorage but do not remain absolutely stationary throughout orthodontic loading. They might move according to the orthodontic loading in some patients. To prevent miniscrews hitting any vital organs because of displacement, it is recommended that they be placed in a non–tooth-bearing area that has no foramen, major nerves, or blood vessel pathways, or in a tooth-bearing area allowing 2 mm of safety clearance between the miniscrew and dental root. (Am J Orthod Dentofacial Orthop 2004;126:42-7)

The growing demand for orthodontic treatment methods that require minimal compliance and provide maximal anchorage control, particularly by adults, has led to the expansion of implant technology in orthodontics.[1] Endosseous implants and onplants have been used as direct or indirect orthodontic anchorage for different clinical purposes. They have been used in mandibular retromolar or edentulous areas for direct anchorage for molar protraction or uprighting[2-5] and in the palate as an indirect anchorage for canine or anterior teeth retraction or molar distalization.[6-8]

Although endosseous implants and onplants have been used successfully for orthodontic anchorage, their clinical applications are still limited in edentulous or retromolar areas because of their size and complicated fixture designs. Other disadvantages include a long waiting period (2 to 6 months) for bone healing and osseointegration,[2,3,6] comprehensive clinical and laboratory work, difficult removal after treatment, and high cost. Miniplates[9,10] and miniscrews[11-15] have recently been introduced as simpler alternatives to endosseous implants and onplants in orthodontics. Their advantages include smaller size, greater number of implant sites and indications, simpler surgical placement and orthodontic connection, shorter (or even no) waiting period, no need for laboratory work, easier removal after treatment, and lower cost.

Endosseous implants and palatal onplants are thought to provide absolute or rigid anchorage.[2,3,6] They integrate with the surrounding bone and thus remain absolutely stationary under orthodontic loading.[16-18] For the miniscrews, it is suggested that a waiting period for bone healing and osseointegration before loading is unnecessary because the primary stability (mechanical retention) of the miniscrews is sufficient to sustain a regular orthodontic loading.[11,19,20] However, the behavior of miniscrews under orthodontic loading is not clear clinically; do they remain absolutely stationary like endosseous implants or move according to the orthodontic loading? The answer could affect their use as orthodontic anchorage. The purpose of this clinical cephalometric study was to

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Submitted, April 2003; revised and accepted, June 2003.
0889-5406/$30.00

doi:10.1016/j.ajodo.2003.06.018

Fig 1. Miniscrews and screwdriver used in study.

answer this question and report the behavior of miniscrews under orthodontic loading.

MATERIAL AND METHODS

Sixteen consecutive women who had miniscrews as anchorage for the en masse retraction of anterior teeth were included. Their ages ranged from 22 to 29 years old. All patients gave informed consent for both the traditional and the miniscrew anchorage methodologies, surgical techniques, and the possibilities of failure, irritation, or local inflammation during orthodontic treatment.

The miniscrew was 2 mm in diameter and 17 mm in length (Leibinger, Tuttlingen, Germany) (Fig 1). The implant site was the zygomatic buttress of the maxilla (Fig 2,*A*). The zygomatic buttress of the maxilla is a pillar of cortical bone running along the zygomatic process of the maxilla and the zygoma. It is usually located above the maxillary first molar in an adult or between the maxillary second premolar and the first molar in a younger patient. It is palpable clinically as a ridge running upward along the curvature between the alveolar process and the zygomatic process of the maxilla. The thickest area of the zygomatic buttress of the maxilla is above the junction (turning point) between the alveolar process and the zygomatic process of the maxilla. Cortical bone thickness is approximately 3 to 4 mm, and cancellous bone thickness is approximately 4 to 5 mm (Fig 2, *B*). However, its thickness varies on the pneumatization of the maxillary sinus.

The miniscrews were inserted under local anesthesia. A 4-mm vertical incision was made with a #15 surgical blade at the mucogingival junction above the maxillary second premolar and first molar. A mucoperiosteal flap was elevated to expose the zygomatic process of the maxilla. After the turning point of the zygomatic process of maxilla was located, a 1.5-mm spiral drill was used to drill a pilot hole under normal saline-solution irrigation. The drilling speed was kept at 500 to 800 rpm. The pilot hole was irrigated thoroughly with normal saline solution. The miniscrew was then driven into the pilot hole with a screwdriver (Fig 3). The head of the miniscrew remained outside the mucogingival junction so that a nickel-titanium (Ni-Ti) coil spring could be attached. The wound was thoroughly irrigated with normal saline solution before closure with a stitch of suture. The surgical procedures were performed on both sides, and 32 miniscrews were placed. One week of antibiotics and 2% chlorhexidine mouth rinse were prescribed, and the patients were instructed to maintain oral hygiene. The miniscrews were left for 2 weeks (waiting period) for adequate wound healing before loading.

The appliances for en masse anterior retraction were a .016 × .022-in stainless steel basal archwires with incisor lingual root torque, 2 lever arms (.016 × .022-in stainless steel) for intrusion of the anterior teeth, and 4 Ni-Ti coil springs for en masses retraction (Fig 4). On each side, the lever arm was inserted into the auxiliary tube on the first molar and hooked on the basal archwire for intrusion of the anterior teeth. Two Ni-Ti coil springs were used on each side. One Ni-Ti coil spring with a force of 150 g was attached between the miniscrew and the canine, and another with a force of 250 g was attached between the miniscrew and the hook on the basal archwire between the lateral incisor and the canine. The patients were seen at 1-month intervals.

Lateral cephalometric radiographs were taken 2 weeks after placement of the miniscrews (T1) and 9 months after placement of the en masse anterior retraction (T2). All T1 and T2 lateral cephalometric radiographs were traced with a 0.3-mm pencil. The images of the right- and left-side miniscrews were averaged to eliminate errors from head posture differences during x-rays. The landmark *screw tail* was defined as the midpoint between the pointed tips of the right and left miniscrews; the landmark *screw head* was defined as the midpoint between the blunt ends (the end that fits onto the screwdriver) of the right and left miniscrews; and the landmark *screw body* was defined as the midpoint between screw tail and screw head (Fig 5).

The cephalometric tracings of T1 and T2 were superimposed for an average best fit among the anatomic structures of the maxilla, cranial base, and cranial vault.[21-24] They were registered on sella and oriented on the anterior cranial base to obtain an anatomic best fit on the maxilla, with the outline of the cranial vault

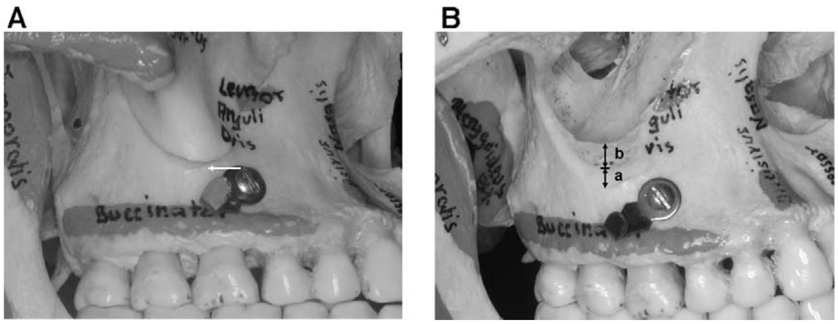

Fig 2. A, Implant site: zygomatic buttress of maxilla (*arrow*). **B**, Part of zygomatic process of maxilla is removed to reveal thickness of cortical bone (a) and cancellous bone (b).

used for final confirmation.[24] A horizontal reference line through the sella was then constructed anteriorly 7° to the sella-nasion line, and a perpendicular line through sella was constructed as the vertical reference line. The vertical and horizontal changes from T1 to T2 at screw tail, screw body, and screw head were measured and analyzed by paired *t* test ($P < .05$). Eight cases were randomly selected, traced, superimposed and measured again 2 months later for error analysis ($P < .1$).[25]

The miniscrews were also evaluated clinically for their horizontal mobility[26] at T1 and T2. The horizontal leg of an L-shaped .018 × .025-in stainless-steel wire was inserted into the mesial opening of the auxiliary tube on the maxillary first molar, and its vertical leg was adjusted to rest on the distal aspect of the screw head. The vertical leg was used as the reference for measuring miniscrew mobility. The screw head was connected to an orthodontic tension gauge (Tomy, Tokyo, Japan) with a ligature wire. The orthodontic tension gauge was then pulled mesially by applying 400 g of force, and the horizontal distance between the vertical leg and the screw head was recorded with a sliding caliper. The scale for horizontal mobility was as follows: 0: no movement, 1: ≤0.5 mm, 2: 0.5−1.0 mm, 3: >1.0 mm.

RESULTS

All patients tolerated the miniscrews well throughout the 9 months of treatment. Error analysis showed that there was no significant difference between the first and second measurements on the vertical and horizontal changes of the screw tail, the screw body, and the screw head (Table I). The random errors of the vertical and horizontal measurements ranged from 0.0 to 0.3 mm (Table I). All 32 miniscrews remained stable clinically (scale: 0) at T1 and T2.

On average, the miniscrews were tipped forward significantly at the screw head (Table II). The tipping and extrusion at the screw tail and the screw body were not significant. In 9 of the16 patients, the miniscrews were not displaced in any direction (0.0 mm) at the screw head, the screw body, and the screw tail. In the remaining 7 patients, the miniscrews were displaced during treatment (Table III) (Fig 6). At the screw tail, the miniscrews were extruded and tipped from −1.0 mm backward to 1.0 mm forward. At the screw body, the miniscrews were extruded and tipped forward from 0.0 to 1.0 mm. At the screw head, the miniscrews were extruded and tipped forward from 0.5 to 1.5 mm.

Fig 3. Miniscrew is driven into zygomatic buttress by screwdriver.

DISCUSSION

This study showed that miniscrews are a stable anchorage for orthodontic tooth movement. The miniscrews remained stationary under orthodontic loading in 9 of the 16 patients. Although the screw head was tipped forward significantly, 0.4 mm on average, the displacement would be clinically insignificant.

However, the miniscrews were extruded and tipped forward in the direction of orthodontic loading in 7 of the 16 patients. The tipping and extrusion ranged from −1.0 to 1.5 mm, which was much greater than the random errors in vertical and horizontal measurements (0.0 to 0.3 mm). Thus, the miniscrews remained clini-

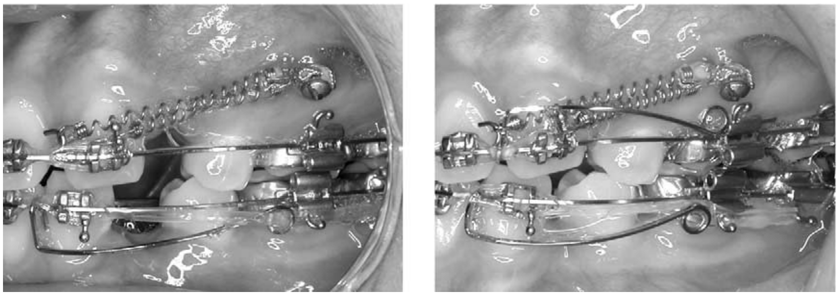

Fig 4. Appliances for en masse anterior retraction. **A**, During en masse anterior retraction. **B**, At end of en masse anterior retraction.

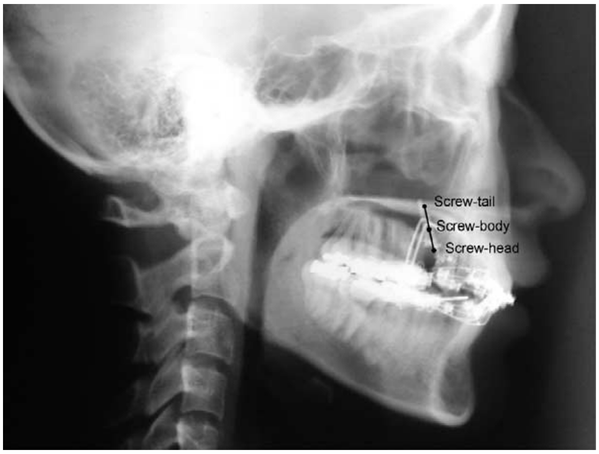

Fig 5. Cephalometric landmarks of screw head, screw body, and screw tail.

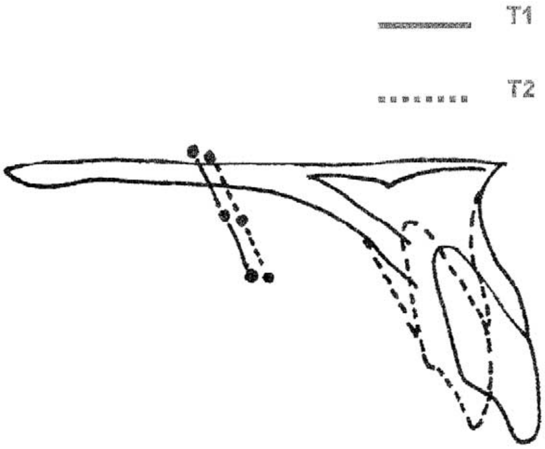

Fig 6. Displacement of miniscrew of patient 5 at T1-T2.

Table I. Analysis of method errors

	Difference between first and second measurements (mm)			
	Mean	*SD*	t *value*	*Random error*
Screw tail				
Horizontal	0.0	0.0		0.0
Vertical	0.1	0.4	1.0 (ns)	0.3
Screw body				
Horizontal	0.0	0.2	0.5 (ns)	0.1
Vertical	0.1	0.2	1.5 (ns)	0.1
Screw head				
Horizontal	0.0	0.2	0.8 (ns)	0.1
Vertical	0.1	0.2	1.0 (ns)	0.1

SD, standard deviation; *ns,* nonsignificant, paired *t* test, $P < .1$.
Random error[25]: $\sqrt{(SD)^2/2}$.

Table II. Average movement (mm) of miniscrews at T1-T2

	T1-T2 (mean ± SD)	*Paired* t *test*
Screw tail		
Horizontal	−0.1 ± 0.5	ns
Vertical	0.2 ± 0.4	ns
Screw body		
Horizontal	0.1 ± 0.3	ns
Vertical	0.2 ± 0.3	ns
Screw head		
Horizontal	0.4 ± 0.5	*
Vertical	0.1 ± 0.2	ns

Positive value: forward or downward movement; negative value: backward or upward movement.
*$P < .05$.

cally stable but not absolutely stationary under orthodontic loading. The miniscrews were not an absolute anchorage, like an endosseous implant. The displacement could be attributed to several factors, such as fixture size, orthodontic force magnitude, depth of the miniscrew inside the implant site, bone quality and quantity at the implant site, and waiting period. Among these factors, the waiting period might play a determining role in displacement.

For the endosseous implants or palatal onplants, a

Table III. List of 7 patients whose miniscrews moved at T1-T2 (mm)

Patient no.	*Screw tail (horizontal, vertical)*	*Screw body (horizontal, vertical)*	*Screw head (horizontal, vertical)*
1	(0.0, 0.5)	(0.5, 0.0)	(0.5, 0.0)
2	(−0.5, 0.0)	(0.0, 0.0)	(0.5, 0.0)
3	(−0.5, 0.0)	(0.0, 0.0)	(0.5, 0.0)
4	(−0.5, 0.5)	(0.0, 0.5)	(0.5, 0.5)
5	(1.0, 1.0)	(1.0, 1.0)	(1.5, 0.5)
6	(0.0, 1.0)	(0.5, 0.5)	(1.0, 0.0)
7	(−1.0, 0.5)	(0.0, 0.5)	(1.0, 0.5)

Positive value: forward or downward movement; negative value: backward or upward movement.

waiting period of 2 to 6 months[2,3,27-31] is necessary for complete peri-implant osseointegration so that the endosseous implant or palatal onplant can remain stationary throughout force application.[16-18] Nevertheless, an osseointegrated endosseous implant at a site of very low bone quality might be subject to movement during the first few days of loading and then settle into a fixed position after a few weeks.[32] This is because of the microfracture or microcrack of the peri-implant microcalli and strong bone remodeling and resorption on the tension and compression sides.[32] This could possibly explain the miniscrew displacement in this study if the miniscrews were osseointegrated.

Conversely, it has been suggested that a waiting period is not necessary for miniscrews because their primary stability (mechanical retention) is sufficient to sustain normal orthodontic loading, and this would not compromise the clinical stability of the miniscrews.[11,19,20] The waiting period was 2 weeks in this study. Apparently, 2 weeks was long enough for soft tissue healing but not long enough for osseointegration. It has been shown histologically that, when the load was placed prematurely, a layer of fibrous tissue would interpose at the bone-implant contacts.[33] Although there was no histologic evidence in this study, we hypothesize that the miniscrews were not osseointegrated and that a layer of fibrous tissue was interposed between the miniscrews and the surrounding bone. This layer of fibrous tissue allowed the miniscrew to be extruded and tipped in the direction of orthodontic loading, just like a tooth against the periodontal ligament. The fibrous tissue was compressed, and then the threads of the miniscrew mechanically locked into the surrounding bone. This hypothesis explains why some miniscrews in this study were displaced and still had no mobility clinically.

Another explanation is that the interposed soft tissue was a layer of inflammatory infiltrate caused by bone overheating during drilling; this has been correlated with complete loosening and failure of an endosseous implant.[34,35] However, no miniscrews in this study loosened or failed during the treatment. Further studies are needed to determine the exact tissue reaction at the peri-miniscrew contact surface.

The fixture size of the miniscrews in this study was 2.0 mm in diameter, and the orthodontic force magnitude was 400 g; these were larger and greater than those used in other clinical reports and studies on miniscrews.[11-15] However, a larger implant fixture and a smaller orthodontic force does not guarantee the retention of an endosseous implant inside the implant site. It was reported in an experimental study in rabbits that 1 of 16 endosseous implants (4.0 mm in diameter) was displaced 0.5 mm under 150 g of orthodontic force over 8 weeks when the implants were loaded prematurely 2 weeks after the insertion.[33] Again, the premature load or length of the waiting period seems to be more critical to displacement.

The question to be answered is this: does it really matter whether miniscrews move when loaded? Miniscrews are used as temporary fixtures for orthodontic tooth movement and will be removed at the end of treatment. It seems that miniscrews, as temporary fixtures, do not have to remain absolutely stationary under orthodontic loading, as long as the treatment effects are achieved. Nevertheless, the displacement of miniscrews would be a serious matter when the displacement harms adjacent vital organs, such as dental roots, nerves, and blood vessels. This is a very important, yet overlooked, possibility. Therefore, miniscrews should not be placed at a site adjacent to any vital organ. A suitable implant site for miniscrews could be in a non–tooth-bearing area that has no foramen or pathway for any major nerves and blood vessels. When miniscrews are placed in a tooth-bearing area, a clearance of 2.0 mm between the miniscrew and the dental root is recommended for safety, based on the finding of this study that displacement was −1.0 mm to 1.5 mm.

CONCLUSIONS

Miniscrews are a stable anchorage for orthodontic tooth movement but do not remain absolutely stationary like an endosseous implant throughout orthodontic loading. They might move according to the orthodontic loading in some patients. To prevent hitting any vital organs because of miniscrew displacement, it is recommended that miniscrews be placed in a non–tooth-bearing area that has no foramen, major nerves, or blood vessel pathways, or in a tooth-bearing area allowing a 2-mm safety clearance between the miniscrew and dental root.

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