Might skeletal anchorage be applied to orthodontic tooth movement and orthopedic jaw movement?” With this question in 1983, Creekmore and Eklund were the first orthodontists to suggest in print that a small metal screw could withstand a constant force of sufficient magnitude and duration to reposition an entire anterior maxillary dentition without becoming loose, painful, infected, or pathologic.¹ Their case opened an entirely new area for managing orthodontic anchorage, but may have been too progressive and too invasive for its time.

Toward the end of the 1980s, a number of clinicians focused on the use of standard dental implants as temporary anchorage for orthodontic tooth movement and then as permanent abutments for tooth replacement.²-⁵ The major advantage of these implants is that they make it possible to move multiple teeth without loss of anchorage. They can be placed in areas where natural anchorage or conventional orthodontic appliances are impractical, including the edentulous spaces in the alveolus of either arch, the palate, the zygomatic process, the retromolar regions, and the ramus. Disadvantages of dental implants are the need for an invasive surgical procedure, the limitations on placement sites imposed by the implants’ 10mm length, the time required for osseointegration prior to force application, and cost. In addition, they are not recommended for female patients younger than 16 or males younger than 18.

More recently, new onplants, miniplates, and palatal implants have been developed specifically for use in orthodontics.⁶-⁸ The miniplates have been advocated as anchorage for molar intrusion⁷;⁹-¹¹ palatal implants have been used for space closure, and most effectively for distalization of maxillary molars.⁵,⁷ Because these new devices still have many of the same limitations as standard dental implants, however, most orthodontists have now turned to miniscrews.¹²⁻¹⁷ Repeating the experience of Creekmore, they have found that small screws, like those used for rigid fixation in maxillofacial surgery, work well for orthodontic anchorage.¹⁴,¹⁵ The size of the screws has been reduced even further in the last few years.¹⁶,¹⁷

The material generally used for miniscrews is medical grade 4 or 5 titanium, although stain-
less steel has been proposed as an alternative. Recent histological studies in animals have shown that the osseointegration of titanium mini-
screws is less than half that of conventional den-
tal implants.\textsuperscript{7,18,19} There was no significant differ-
ence in the bone surrounding the miniscrew sites
whether the miniscrews were loaded or unloaded
with force.\textsuperscript{9,18,20} The presence of more compact
bone in the mandible may account for some dif-
fferences in miniscrew performance found be-
tween the maxillary and mandibular arches.\textsuperscript{7,18-21}

Incomplete osseointegration represents a
distinct advantage in orthodontic applications,
allowing for effective anchorage with easy inser-
tion and removal. The miniscrew material and the
specific design of the self-tapping portion are still
important, however, in determining resistance to
breakage. Even though orthodontic forces are not
normally great enough to break the screws, the
rotational forces associated with placement and
removal can cause miniscrew failure, especially
if the bone consistency is high or a partial inte-
gration has occurred. Differences among various
miniscrew head designs have also been noted
with regard to soft-tissue healing.

This article illustrates the clinical applica-
tions of a new titanium miniscrew designed for
orthodontic anchorage.

Miniscrew Design

The conical screws used in the Miniscrew
Anchorage System\textsuperscript{*} (MAS), made of medical
grade 5 titanium, are available in three sizes (Fig.
1). Type A has a diameter of 1.3mm at the top of
the neck and 1.1mm at the tip. Type B is 1.5mm
in diameter at the neck and 1.3mm at the tip.
Both types are 11mm long. Type C, which is
9mm long, has a diameter of 1.5mm at the neck
and 1.3mm at the tip.

The screw head consists of two fused
spheres (the upper 2.2mm in diameter, the lower
2mm), with an internal hexagon for insertion of
the placement screwdriver. A .6mm horizontal
slot at the junction of the two spheres allows for
the attachment of elastics, chains, coil springs,
ligature wires, or auxiliary hooks.

Mechanical Testing

Two methods were chosen to test these
screws mechanically, representing two potential
modes of failure during insertion and removal:
torsional strength and bending strength. The tests
were conducted in the Department of Mechanical
Engineering at the University of Genoa, Italy, by
seating the screws in a tapped brass block at a
thread depth of 6mm. For torsion-to-failure test-
ing, a dial torque wrench with a recording device
was turned in a clockwise direction, perpendicu-
lar to the long axis of the screw. For bending-to-
failure testing, a dial bending arm with a recording
device was used to deform the screw along its
long axis in a clockwise direction. Six screws
were used for each test.

\textsuperscript{*Micerium, S.p.a., Via Marconi 83, 16030 Avegno, Italy; www.
micerium.it.}
The mean resistance to breakage in torsion was 48.7Ncm for the 1.5mm-diameter miniscrew and 37.4Ncm for the 1.3mm-diameter miniscrew. The mean resistance to breakage in flexion was 120.4N for the 1.5mm-diameter miniscrew and 91.7N for the 1.3mm-diameter miniscrew.

These results suggest that the MAS screws can resist a force much greater than that of any orthodontic application. It is possible, however, to apply a torsional force of more than 40Ncm during insertion or removal and thus to break the screw. To limit this torsional force, the clinician should use a small screwdriver and hold it by the fingertips. If the self-tapping screw encounters extreme resistance during insertion, additional pilot drilling may be required. At the time of removal, if the screw seems to be osseointegrated, a minor surgical procedure may be needed to remove it completely.

Placement Sites

Miniscrews are used in place of traditional appliances such as headgear and lingual arches in cases where absolute anchorage is necessary. From a biomechanical standpoint, miniscrews allow more bodily tooth movement during space closure by placing the force vectors closer to the center of resistance of the teeth.

The sites most often utilized for MAS insertion in the maxilla include:
- Interradicular spaces, both buccal and lingual
- Extraction spaces
- Inferior surface of the anterior nasal spine

In the mandible, the most common mini-screw placement sites are:
- Interradicular spaces, both buccal and lingual
- Lateral to the mentalis symphosis
- Extraction spaces

In our experience, the most useful locations are the interradicular spaces, either buccal or lingual, between the second premolars and first molars in both arches, or the buccal space between the upper lateral incisor and canine.

Surgical Procedure

A surgical guide can be made from a rectangular wire segment to help identify the miniscrew location on the intraoral x-ray (Fig. 2A). The self-tapping screw often requires no preparation of the medullary bone. If the bone is too dense, however, a bur (.9mm for Type A, 1.1mm for Type B) should be used to drill a pilot hole through the gingival and cortical bone under local anesthesia. We recommend placing a stop on the bur to limit the depth of insertion to 2-3mm, but it is critical that the depth be 2mm shorter than the miniscrew. The axial inclination of the bur must be the same as the desired inclination of the miniscrew.

Special attention is required during screw placement to reduce the chance of injury to delicate anatomic structures such as vessels, nerves, and dental roots. A metallic marker, which can be attached to a vacuum-formed retainer or directly to the brackets, can be used to show the position of the miniscrew relative to the roots on the pre- and post-placement panoramic or periapical radiographs (Fig. 2B). To date, we have not seen
any trauma to anatomic structures during screw placement. Vessels and nerves are easily avoided by proper interpretation of the x-ray images. The roots are more difficult to identify, but damage can be eliminated by limiting any pilot drilling to the cortical plate of the alveolar bone (2-3mm). If a self-tapping screw encounters a root during insertion, it will stop, and can then be redirected by the clinician.

A manual screwdriver is used to insert the miniscrew, preferably between the free and attached gingiva. When properly placed, the screw head will protrude through the soft tissue. Once the initial stability of the miniscrew has been confirmed, an orthodontic force of 50-250g can be applied immediately. The head of the miniscrew has been designed to prevent compression of the mucosa, but if this occurs after placement of a chain or nickel titanium coil spring, we suggest using Monkey Hooks** instead.

Post-operative antibiotics or analgesics are usually not needed. To the best of our knowledge, no post-surgical complications have been reported in the literature. Once the orthodontic anchorage is no longer required, the screw can be easily removed with the manual screwdriver, usually without local anesthesia. The mucosa generally heals within a few days, and new bone fills in the placement site.

**Closure of Extraction Spaces**

Loss of posterior anchorage during extraction space closure can exacerbate the curve of Spee and deepen the bite. Miniscrews provide reliable skeletal anchorage for anterior retraction in either arch, whether a single tooth at a time or en masse.

Maxillary miniscrews are usually placed between the roots of the first and second premolars, where the large interradicular space typically allows easy insertion without root interference. The screw heads can be situated at or above the mucogingival line, depending on the desired

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line of action. If both intrusive and distalizing forces are needed, the miniscrew should be positioned above the mucogingival line (Fig. 3). If the primary movement is to be a distalizing vector, however, the miniscrew should be placed at the mucogingival line (Fig. 4). The higher the screw is placed in the maxilla, the more perpendicular to the bone it must be to avoid damage to the maxillary sinus (Fig. 5). If the alveolar process is prominent, an auxiliary such as a Monkey Hook can be used to keep the chain or coil spring away from the soft tissue, thus avoiding discomfort and gingival irritation (Figs. 3, 4).

In the mandibular arch, miniscrews can be useful in patients where maximum anchorage is needed, such as bialveolar protrusion and Class
II cases. We do not recommend placing miniscrews between the roots of the lower first and second premolars, however, because of the proximity of the mentalis foramen.

Symmetrical Incisor Intrusion

Many patients present with moderate-to-severe deep bites requiring pure intrusion of the anterior teeth to level the occlusal plane. Unless the deep bite is so extreme that absolute anchorage is needed, it may be inadvisable to place miniscrews simultaneously in both arches in young patients. In these cases, miniscrews can be used to reinforce conventional orthodontic mechanics. One of our most common treatment methods involves the use of biteplanes bonded to the lingual surfaces of two or all four upper incisors.22

To provide anchorage during incisor intrusion, miniscrews can be placed between the upper lateral incisors and canines (Fig. 6). The insertion should not be performed until after leveling and alignment, however, so that the maximum amount of interradicular space will be available. To avoid tipping the upper incisors buccally during intrusion, the ends of the archwire should be cinched back.

Correction of a Canted Occlusal Plane

A canted occlusal plane is often considered impossible to level with traditional orthodontic treatment. Miniscrews, on the other hand, provide skeletal anchorage for intrusion of the appropriate teeth on the canted side (Fig. 7). The screws can be inserted between the upper lateral incisors and canines, the upper canines and premolars, or the lower lateral incisors and canines. To avoid interference with the teeth to be intruded, it is important to center the miniscrews between their roots (Fig. 8).

Alignment of Dental Midlines

When an entire arch needs to be moved laterally to correct the posterior malocclusion, the dental midlines are usually aligned with intermaxillary elastics, requiring considerable patient compliance. Vertical forces may be contraindicated in some cases, or the intermaxillary elastics may decompensate the arches from a frontal perspective, causing the bite to open. In these more complex cases of midline deviation, miniscrews may be a useful alternative. A screw can be placed either lingually or buccally so that the head stands out at the crown margins (Fig. 9).
Thus, the line of force is directed more occlusally, with an enhanced horizontal vector.

**Extrusion of Impacted Canines**

Various procedures have been suggested to prevent anchorage loss and avoid canting of the occlusal plane while an impacted canine is pulled down into occlusion. Some authors have recommended inserting auxiliaries such as Kilroy Springs** on the main archwire. Others have proposed using superelastic overlay archwires.24

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Fig. 9 A. Patient requiring lateral movement of entire maxillary arch to correct posterior malocclusion. B. Miniscrew placed in existing space between upper right canine and first premolar. C. Elastomeric chain attached between screw and archwire, directing force more occlusally and horizontally. D. After alignment of dental midlines.
In both systems, the teeth must be leveled and aligned before they can be combined into an anchorage unit.

Miniscrews can be used instead when heavy forces are required to bring an impacted canine into occlusion, without relying on the rest of the teeth for anchorage (Fig. 10). Treatment time may be shortened—in fact, there is no need to bond the entire arch during canine extrusion—and there are no undesirable side effects on the other teeth. Whether the canine is impacted palatally or lingually, the miniscrew can be placed to provide the most appropriate force vector; it can even be removed and relocated as the canine is extruded. Auxiliaries can be used to make the miniscrew mechanics even more versatile.

**Fig. 10** A. Patient with palatally impacted maxillary right canine. B. Miniscrew placed as anchorage for appropriate force vector without involving other teeth. C. After uprighting and partial extrusion using only miniscrew, case completed with maxillary fixed appliance. D. Final results, showing root parallelism.
Opinions have differed regarding the efficacy of orthodontic intrusion of posterior teeth. Although miniscrews can be a reliable source of anchorage, it is difficult to place them precisely in the narrow space between the roots of the first and second molars without interfering with the roots. In some cases, more than one screw might even be needed to withstand a relatively high intrusion force. Therefore, we suggest limiting the use of miniscrews to situations where simple intrusion of one or two molars is needed and where placement will be unproblematic (Figs. 11,12). In open-bite cases requiring bilateral intrusion of the posterior segments, miniscrews are not an ideal solution.

Molar Distalization

Fixed and removable maxillary molar distalization devices for the correction of Class II
malocclusions without the need for special patient compliance have become increasingly popular over the past decade. These appliances range from fixed devices that are activated by the orthodontist to open-coil springs, but most utilize some form of palatal coverage to provide anchorage and prevent incisor flaring. Nevertheless, studies of molar distalization have shown a considerable amount of anterior anchorage loss.

The ideal site for skeletal anchorage would be the palate, but this requires a surgical procedure to place the implant and another to remove it. In our experience, screws less than 2mm in diameter are unstable when used for palatal anchorage and routinely fail.
Clinical Applications of the Miniscrew Anchorage System

Fig. 14 A. During molar distalization, compression of Distal Jet’s coil spring moves activation lock distally, away from miniscrew (blue). B. Loss of anchorage can be prevented by bonding light-cured composite (yellow) between screw head and lock.

Fig. 15 A. Patient with asymmetrical Class II malocclusion treated with Distal Jet, with miniscrews placed mesial to activation locks to block mesial movement. B. After molar distalization and removal of Distal Jet, miniscrew repositioned just mesial to distalized molar to stabilize it while the remaining teeth are moved distally.
The MAS + Distal Jet** may be a solution. After the Distal Jet appliance has been placed and activated, palatal miniscrews are inserted between the roots of the first and second premolars, mesial to the activation locks attached to the anterior rests (Fig. 13A-C). The miniscrews block mesial movement of the appliance during distalization, thus preventing loss of anterior anchorage. Further compression of the Distal Jet’s coil springs will move the locks distally, away from the miniscrews (Fig. 14); during this phase, anchorage loss can be prevented by bonding light-cured composite between the screw heads and the locks (Fig. 13D). After molar distalization, the Distal Jet is converted to a passive retainer, and brackets are bonded to the teeth for completion of the Class II correction (Fig. 13E-G). Another option is to remove the miniscrew after molar distalization and replace it just mesial to the distalized molar, where it will stabilize the molar while the remaining teeth are moved posteriorly (Fig. 15).

The MAS + Distal Jet should not be used in the mixed dentition, because the palatal screw may interfere with developing permanent teeth.

**Molar Mesialization**

Molars are often moved mesially in orthodontic treatment to close extraction spaces or edentulous spaces. Molar mesialization is not a simple movement and can lead to problems such as loss of anterior anchorage and molar tipping. Furthermore, if there is a knife-edge alveolar ridge in the space to be closed, alveolar bone may be lost.

A miniscrew placed mesial to the space, at a height that will produce a force vector approximating the center of resistance of the molar, can be a valuable source of anchorage. If the screw is inserted after the initial leveling and alignment have been completed, a full-size archwire can be used to prevent mesial crown tipping of the molar during space closure. Because mesial movement is usually slow, especially in the mandibular arch, no more than 2-3mm of molar mesialization should be attempted (Fig. 16).

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Intermaxillary Anchorage

Miniscrews are a convenient source of anchorage in both extraction and nonextraction therapy when intermaxillary forces are applied with Class II elastics or anterior repositioning appliances. Many undesirable side effects can be produced by such mechanics, including bite opening and excessive proclination and protrusion of the lower incisors. One possible solution is to place a miniscrew between the roots of the lower first and second molars or the second premolar and first molar. The location between the second premolar and first molar (as close as possible to the first molar) is generally preferable, because the screw must be inserted perpendicular to the alveolar process, which can be difficult in more posterior regions where access is limited. In addition, the interradicular space between the second premolar and first molar is wider than
the space between the first and second molars. Placement of the miniscrew mesial to the first molar may also prevent mesial movement of the entire lower arch, although care must be taken to avoid contact with the molar roots.

In Class III treatment, when the maxillary arch needs to be advanced, miniscrews can be placed between the roots of the lower canines and first premolars for elastic attachment (Fig. 17). If the mandibular arch needs to be repositioned distally, the miniscrews can be placed between the roots of the upper first and second molars or second premolars and first molars.

Upper Third Molar Alignment

Miniscrews can also be useful in cases with multiple missing teeth where conventional orthodontic mechanics are difficult to apply. For example, an upper third molar can be uprighted with a fixed sectional wire, utilizing a palatal miniscrew for skeletal anchorage to limit unwanted extrusion of the molar (Fig. 18).

Discussion

Miniscrews are already widely used in Europe and Asia, but there is still some skepticism in the United States, where many orthodontists consider them too invasive to be part of their daily practice routines. One concern is whether placement of a miniscrew should be performed by the orthodontist or the oral surgeon. Most American orthodontists refer out any procedure that is not strictly orthodontic to be performed by the orthodontist or the oral surgeon. Most American orthodontists refer out any procedure that is not strictly orthodontic, such as oral hygiene or extraction of permanent teeth, even if it is part of the orthodontic treatment plan. In our opinion, however, placement of a miniscrew is not simply a surgical procedure, but requires specific planning based on orthodontic considerations such as force vectors and the types of anchorage and tooth movement required. Sometimes the screw needs to be relocated to a better position during treatment, which may become complicated if the patient has to be referred to a specialist.

Histological studies have confirmed that titanium screws are biocompatible and are easily removed because of their incomplete osseointegration. What is still unknown is whether differences in size, shape (conical or cylindrical), head design, pilot drilling, and physical properties can influence the likelihood of successful treatment or minimize potential complications such as breakage at the neck during the application of orthodontic forces. One potential problem is the trend toward reduced diameters of self-tapping screws. We believe this could lead to a dangerous reduction in their mechanical resistance, and therefore consider testing to breakage in torsion and flexion to be a fundamental step before the clinical application of any new miniscrews.

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Conclusion

Although more research is needed into many aspects of miniscrew application, the cases presented in this article and elsewhere in the literature clearly demonstrate the versatility and technical advantages of skeletal anchorage. In our opinion, orthodontic treatment using a skeletal anchorage system is not only more effective, but offers a variety of treatment alternatives in challenging cases where traditional mechanics cannot be used. Advantages of miniscrews over other forms of anchorage include:

• Optimal use of traction forces, regardless of the number or positions of the teeth
• Applicability at any stage of development, including interceptive therapy
• Shorter treatment time, with no need to prepare dental anchorage
• Independence of patient cooperation
• Patient comfort
• Low cost

Of course, there are potential complications common to all implant procedures, including:

• Damage to anatomic structures such as nerves, vessels, and roots
• Loss of a screw during placement or loading
- Breakage of a screw within the bone during insertion or removal
- Inflammation around implant sites

With the MAS, we have experienced none of these problems except for the loss of three screws during force loading. Breakage may be more likely with screws of smaller diameter. Furthermore, the MAS offers several advantages compared to more invasive osseointegrated systems:
- Increased selection of insertion sites
- Ease of insertion and removal
- Ability to withstand immediate loading
- Applicability in growing patients
- Low cost

REFERENCES