DOI: 10.2478/aoj-2006-0014

Use of miniscrews as temporary anchorage devices in orthodontic practice. I - Introduction

George Anka
Tama-shi, Tokyo, Japan

Aim: To describe the use of miniscrews as temporary anchorage devices to facilitate mesial, distal and vertical orthodontic tooth movement.
Method: The development of miniscrews and the direct and indirect application of forces from these devices are described. Case reports will be given in a second paper.
(Aust Orthod J 2006;22: 131–139)

Received for publication: June 2005
Accepted: August 2006

Introduction

The term 'temporary anchorage device' (TAD) can refer to different types of screws, plates and onplants used for temporary skeletal anchorage to facilitate orthodontic tooth movement.[1] The first device used for temporary skeletal anchorage was introduced by Gainsfort and Higley in 1945.[2] Some 20 years later Linkow used a blade-type device to retract the anterior teeth.[3] These early TADs were followed by a vitallium screw to aid intrusion of the anterior teeth,[4] a posterior implant[5] and the introduction of onplants.[6] Subsequently, Kanomi[7] introduced a 1.2 mm mini-implant, the first of the so-called mini-implants, and Sugawara[8] the miniplate skeletal anchorage device (SAS). In addition to these early workers other clinicians and researchers have contributed to the development of TADs such as miniscrews.

Strategically placed miniscrews are used to provide temporary intra-oral anchorage to distalise the upper canines, to retract the upper anterior teeth *en masse* and/or to facilitate tooth movement in all directions. Miniscrews are small, easily placed and less invasive devices than plate-type implants, onplants and dental implants. One of the great advantages of using TADs is that teeth in the same arch can be moved in opposite directions, for example, the molars on one side may be moved distally while the contralateral molars are moved mesially. This combination of movements is difficult to carry out using traditional orthodontic mechanics.

In this article I will introduce and describe some of the principles governing the use of miniscrews as temporary anchorage devices to facilitate mesial, distal and vertical orthodontic tooth movement. Case reports will be given in a second article.

Force classification

When miniscrews were first used to provide intra-oral anchorage they were inserted in the buccal plate of the upper alveolar process and the upper canines were retracted along an archwire.[7] This is an example of a 'direct' force: the force module is attached directly to the tooth or teeth being moved and the miniscrew (Figure 1a). The next development was to retract the upper anterior teeth *en masse* with an orthodontic elastic or a coil spring stretched between a miniscrew and a buccal arm/hook attached to the archwire.[9] This is an 'indirect' force (Figure 1b). With further experience a transpalatal bar was used with miniscrews to prevent unwanted bucco-palatal tipping.[9] Miniscrews were also placed in other sites, such as the palatal cortical plate of the alveolar process, on the same side as a tooth/teeth being moved or on the contralateral side to the tooth/teeth being moved.

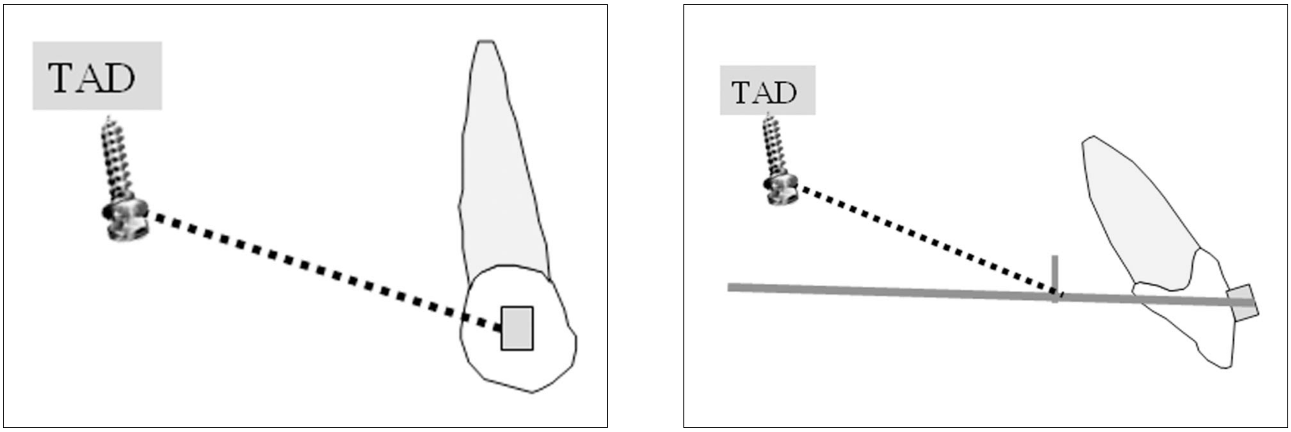


Figure 1. Force classification.
a. Direct force.

b. Indirect force.

Figure 2. Insertion of a miniscrew.
a. Insertion.

b. Torque lever.

There are two advantages in using an indirect force:

a. The point of attachment of the force can be varied to facilitate the planned tooth movement. For example, a tooth can be moved bodily if the end of the arm or hook is adjusted so that the retraction force passes through or close to the centre of resistance of the tooth.

b. The length of an extension arm can be adjusted (or a new arm added) to provide a suitable working distance for an elastic/closed coil spring.

Insertion of miniscrews

TADs can be placed with an adjustable torque driver or an electric handpiece with rotational and torque limits (Figure 2). The ideal torque value at the end of implantation is between 15 N cm and 20 N cm. It should not be less than 10 N cm otherwise the miniscrew will not be able to resist immediate loading. We have found that if the torque value at the end of implantation is less than 5 N cm, which is a common finding in young patients, the failure rate will be high. Sites with dense bone, where the final torque value can be above 20 N cm, should be pre-drilled to avoid fracturing the miniscrew. Two to three weeks after placement the force on a miniscrew can be increased to 4 N, and about a month later it can be increased to 6 N if the intention is to distalise the upper molars.[10,11]

The quality and the thickness of the cortical bone will determine if immediate loading is possible and the magnitude of force that can be used. We prefer to place a force of approximately 2 N immediately following insertion of a miniscrew. Others consider that

Figure 3. Maxillary sites.
a. A palatal miniscrew between the first premolar and the first molar. The composite additions on the central incisors were used to assist bite opening.

b. A buccal miniscrew inserted between the upper second premolar and first molar.

immediate loading is not necessary to prevent a miniscrew loosening.[10,11] The initial force should not exceed the capacity of the newly-inserted miniscrew to resist it.

Between 3 and 4 N of continuous force can used with miniscrews of 1.6 mm x 8 mm without distorting or loosening the screw, and about 5 N per side can be used with 2 mm x 8 mm miniscrews placed palatally in the maxillary alveolar process. For *en masse* movement a unilateral force of about 4 N (or a bilateral force of 8 N) can be used.[12,13] These are general guidelines and the optimum force will depend on the patient's age, gender and skeletal type (*e.g.* brachyfacial or dolicofacial).

We have discovered that the cortical bone in patients under 15 years of age will not support a miniscrew. Therefore, we prefer to delay placement of miniscrews until the second premolars have erupted fully.[14] If the cortical bone at this age is not dense enough to support a miniscrew, treatment should be delayed further until the second molars have erupted fully or limited tooth movement undertaken.

Sites for miniscrews

In an unpublished study of 850 miniscrews we inserted over a five year period, 40 per cent of the maxillary miniscrews were placed in the alveolar process palatally, 14 per cent were placed in the alveolar process buccally and 6 per cent in other maxillary sites, such as the midpalate (Figure 3). In adolescents, however, the midpalate is the least suitable site for a miniscrew because the midpalatal suture is not completely fused. As a result there is a high failure rate of miniscrews placed in this site.

In the mandible 30 per cent of the miniscrews were placed in the buccal cortical plate of the alveolar process between the first molar and second premolar, approximately 5–8 mm from the cervical margins and at the mucogingival junction. Of the remainder 10 per cent were placed in other buccal sites such as the external oblique ridge, and a further 10 per cent were placed in the lingual alveolar process distal to the lower second molars.

If there is insufficient space for a miniscrew between the roots of adjacent teeth the roots should be separated before the miniscrew is placed. As a rule miniscrews are inserted 30–45 degrees to the bone surface in cortical bone: in this position they avoid the root apices (Figure 3b). In some cases the angle of insertion of a miniscrew must be varied to suit the anatomy of the area, to avoid damaging a root at the time of implantation or to avoid moving a root into a miniscrew during treatment. Final placement of a miniscrew will depend to some extent on the direction of planned tooth movement.

If there is insufficient bone, or if the bone is of poor quality or if 'firm' anchorage is required then the miniscrew should be inserted transcortically, that is penetrating the buccal and lingual cortical plates. This is referred to as 'bicortical' anchorage, and is often used in the lower premolar and anterior regions.[1,15] When inserting a miniscrew for bicortical anchorage light anaesthesia should be used on the penetration side and the opposite side left anaesthetised so that

Figure 4. A buccal miniscrew inserted between the lower first and second molars.

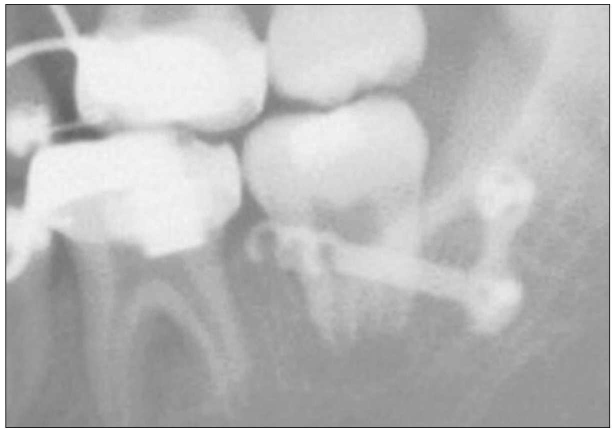


Figure 5. Radiograph of a miniplate TAD.

the clinician can detect when the miniscrew enters the opposite cortical plate.

Maxillary sites

The majority of maxillary miniscrews are placed in the alveolar process palatally between the first molar and the first or second premolar and 5–10 mm from the cervical margins. In this site there is ample bone between the single palatal root of the first molar and the root of the second premolar (Figure 3a).

Miniscrews are also placed in the buccal surface of the maxilla, utilising virtually all inter-dental root spaces with the exception of the space between the upper central incisors. A miniscrew in the latter area is uncomfortable because of the labial frenum. Miniscrews are frequently placed buccally between the roots of the maxillary premolars and molars (Figure 3b). Placement of a miniscrew between the posterior teeth is ideal for most anchorage purposes, but it will limit distal movement of the posterior teeth if it occupies either an interdental or an inter-radicular space. If distal movement is planned the miniscrew should be positioned in the border of the zygomatico-alveolar crest. As the mucosa in this area is loosely attached to the underlying bone an indirect force from a hook/wire around the neck of the miniscrew will be necessary. A hook in this area is often difficult to adjust and prevention of infection can be demanding.

Any foreign object in the palate will act as a stimulus for the tongue to play with and, as a result, midpalatal miniscrews are often loosened. The area behind the upper incisors, which contains the incisive foramen and thick palatal rugae and is contacted by the tongue during speech and swallowing, should be avoided if at all possible. Miniscrews placed in the posterior alveolar area of the palate generally cause the least irritation. However, care should be exercised when placing a miniscrew in this area because of the blood vessels and nerves emerging from the palatine foramen. The position of the foramen is variable and accidental damage to the blood vessels and nerves in this area can result in bleeding and numbness.

Other maxillary sites to be avoided are the upper anterior (labial) region and the maxillary tuberosity region. Miniscrews placed in the anterior region may interfere with the action of the lips and cause discomfort, and the presence of the third molar will limit use of the tuberosity site unless the third molar has been extracted. A miniscrew in a third molar site is favourably placed for retraction, but it will not provide good anchorage if the cortical bone is thin. Furthermore, a long miniscrew can injure the arteries and nerves in this area.

Mandibular sites

In the mandible the preferred site for a miniscrew is in the buccal cortical plate of the alveolar process between the first molar and second premolar. Miniscrews can be placed between the lower first and second molars (Figure 4). The lingual site should be avoided as miniscrews placed in this situation may irritate the tongue and be a source of discomfort to the patient. A lingual mandibular torus

Figure 6. Palatal arch.
a. Soldered hooks.

b. Clip-on hooks.

can be a good site for placement of a flat-head miniscrew, but patients should be warned beforehand that miniscrews in this site are sometimes uncomfortable.

Small diameter miniscrews (1.2–1.4 mm) are preferred in the anterior mandible because the interdental spaces are narrow.[16,17] This site should be avoided if possible as miniscrews placed in this area can irritate the labial mucous membrane, particularly if there is an active mentalis muscle.

Miniscrews inserted bicortically provide strong anchorage in the anterior region of the mandible. In other mandibular sites miniscrews can be placed monocortically. The alveolar cortical bone is thicker in the lower canine and the premolar areas than the cortical bone in the anterior region, but it is thinner than the cortical bone further posteriorly. The mental foramen, located below and between the first and second premolars, is not usually of concern unless a plate-type TAD is planned. The crest of the external oblique ridge has thick cortical bone and provides excellent anchorage (Figure 5).

Distal movement

Distal movement of the upper buccal segment is frequently undertaken in orthodontics. Many orthodontists still use extra-oral traction, acrylic palatal buttons or intra-arch devices, such as the Pendulum appliance and Distal Jet appliance, to provide the anchorage to enable the upper molars to be distalised. These methods rely on patient compliance and often result in anchorage loss and distally tipped molars. Miniscrews rely less on patient compliance and can provide an instant supply of anchorage and a predictable treatment outcome. There is, however, an important difference: extra-oral traction can affect a large area of the maxilla and the adjacent bones whereas molar distalisation with the aid of a miniscrew tends to have a local effect.[18]

When both upper molars are to be distalised without distal tipping and/or flaring a rigid palatal arch of 0.36 mm stainless steel wire with soldered or clip-on hooks should be used (Figure 6). The hooks for elastics are usually placed between the canine and first premolar. The palatal arch should be expanded slightly before cementation as the molars will move onto a wider part of the maxilla during treatment. Miniscrews are placed palatally between the upper second premolars and the first molars. In this position elastics can be easily stretched between the hooks on the palatal arch and the miniscrews. This design can also be used to intrude and extrude teeth at the same time. Clinically, the upper molars can be distalised about 5–6 mm.

When unilateral distalisation is desired the palatal or lingual arch can be sectioned and the wire bent into an extended arm with a hook for an elastic and a wire guard to protect a newly implanted miniscrew from being dislodged by the patient or their toothbrush (Figure 7). The wire guard can be removed after several months. The extended arms can be bilateral or unilateral. Unwanted molar rotations can be prevented by increasing the degree of offset or with a compensating molar offset bend if a standard

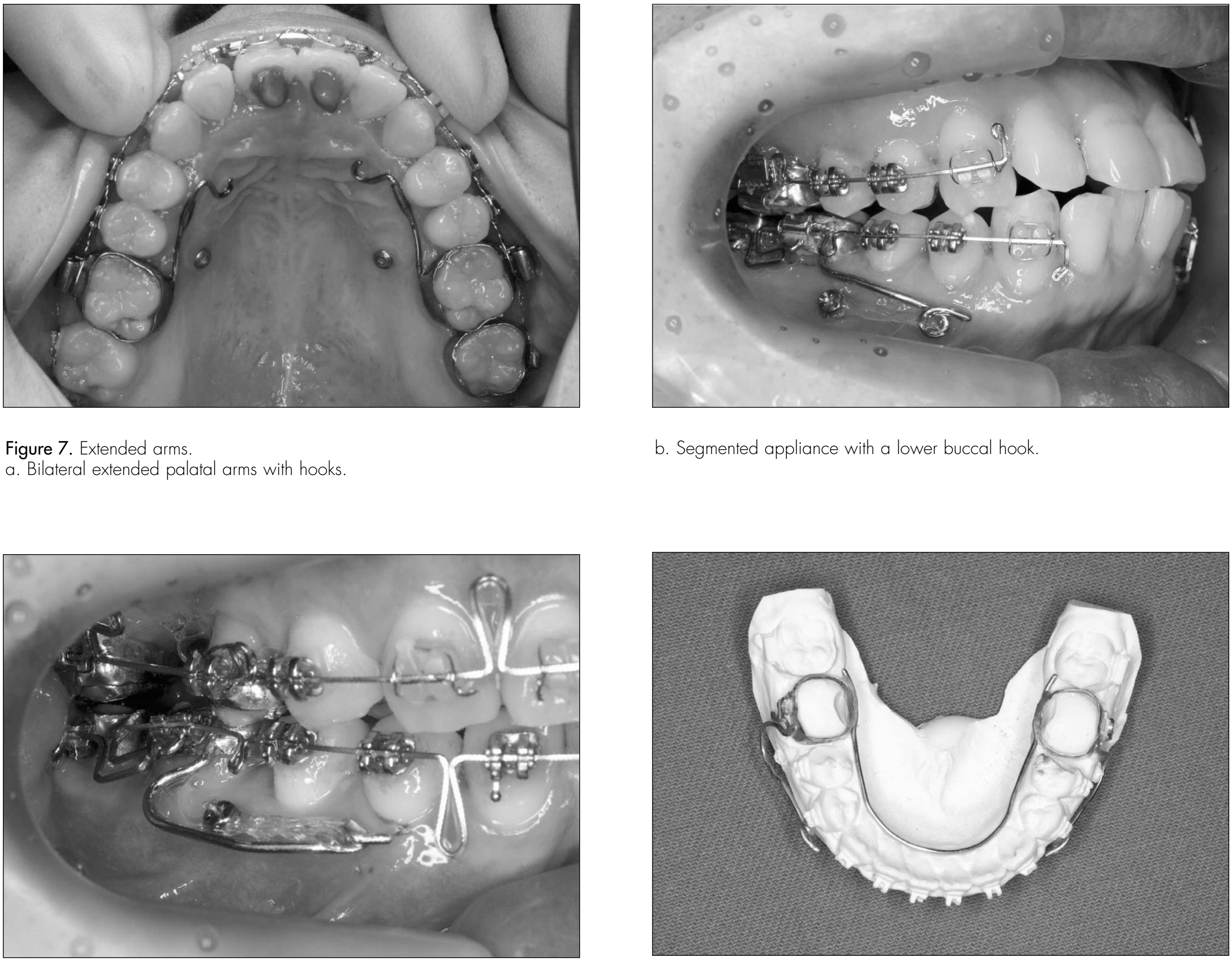


Figure 7. Extended arms.
a. Bilateral extended palatal arms with hooks.

b. Segmented appliance with a lower buccal hook.

c. Lower buccal extended arm.

d. Appliance prior to cementation.

edgewise tube is used. A heavy stainless steel wire (close to full size) is invariably necessary to maintain the form of the arch.

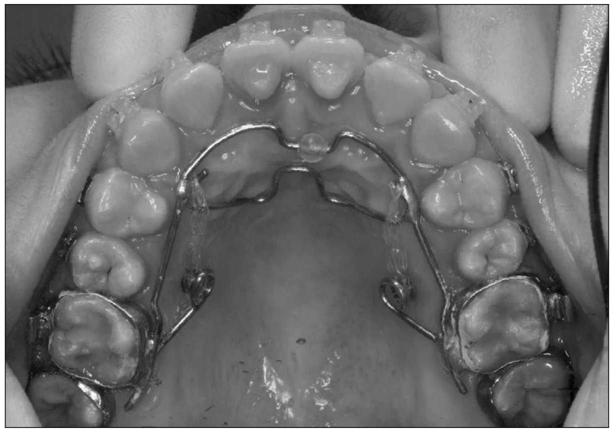
In the mandible distal movement of the lower molars is limited by the ascending ramus of the mandible and the investing soft tissues. Essentially, the method of distalisation used in the upper arch can be adapted to the lower arch: it is then known as a 'lingual arch with extended buccal arms' (Figure 7d). Unilateral distalisation of a lower molar can also be achieved with the aid of a single extended arm.

The lower molars or the entire lower arch can be distalised if the anchorage value of the miniscrews is sufficient.[19] During distalisation of lower molars the lower archwire should have a distal tip-up bend between the first and second molars to prevent the second molar from being tipped downward and creating a posterior open bite. Distal movement of a second molar appears to slow as the roots approximate the cortical bone forming the mylohyoid ridge. Distalisation should be stopped if the second molars become embedded in the soft tissues overlying the ascending ramus and a gingival pocket on the distal of the second molar develops. This area is difficult to keep clean. This phenomenon is more likely to occur in a young patient than in an adult. The lower third molars should be extracted before distalisation is started. In some cases it may be preferable to extract the lower second molars rather than the third molars; then only one molar on each side will need to be distalised.

Mesial movement

When upper or lower molars are moved mesially to a

Figure 7.
e. Buccal hook with wire guard.



f. Palatal hooks with wire guards.

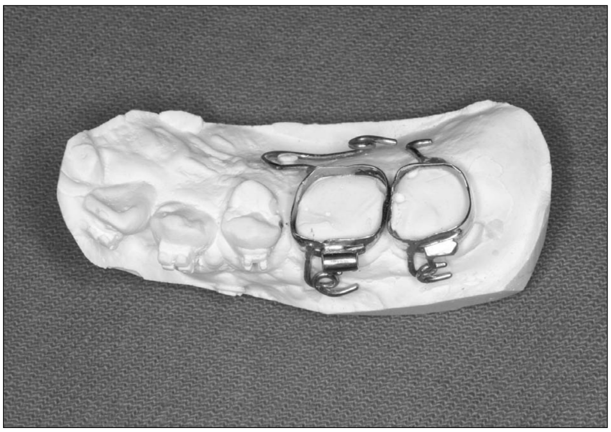
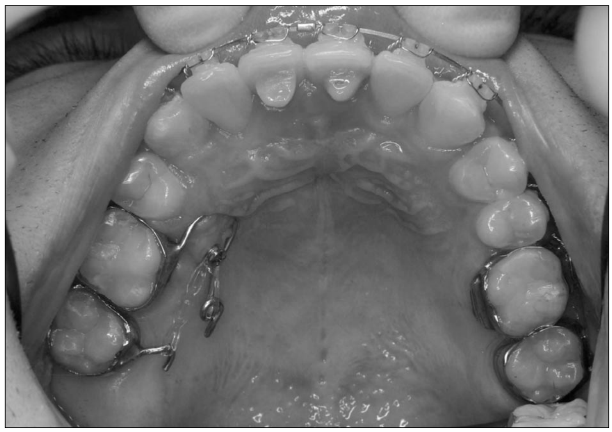


Figure 8. Mesial movement.
a. Buccal and palatal hooks for unilateral mesial movement.



b. Mesial movement with a single palatal miniscrew.

narrower part of the alveolar process tooth movement slows, presumably because the roots have impacted against the dense buccal cortical bone or impacted on dense bone left by the trailing root.[20] This phenomenon is particularly noticeable in the mandible. If bodily movement is desired the force should be positioned as close as possible to the centre of resistance of the tooth/teeth being moved.

A lingual arch can be used to prevent tipping during mesial movement. If unilateral mesial movement is desired and unwanted rotations are to be avoided miniscrews can be placed in the labial and lingual cortical plates (Figure 8). Although two miniscrews (one per side) will provide greater rotational control than a single miniscrew, lingual miniscrews in the mandible are uncomfortable. As a rule we use buccal miniscrews only. In the upper arch molar bands with hooks, palatal miniscrews between the second premolar and first molar and buccal miniscrews between the canines and the premolars can be used.

Intrusion

Changes to the vertical dimension may involve intrusion of the posterior teeth in an anterior open bite case or intrusion of the upper anterior segment in a case with a 'gummy' smile and tilted occlusal plane. Intrusion of the upper molars allows the mandible to auto-rotate and close an anterior open bite. In our experience the lower molars can be intruded to a lesser extent than the upper molars. We consider the depth of the palatal vault and width of the upper arch are important considerations when intruding upper

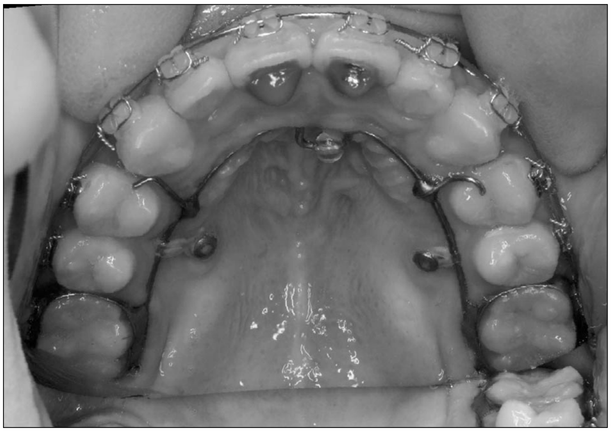


Figure 9. Intrusion using elastomeric chains from palatal miniscrews to a palatal arch.

Figure 10. Extrusion using a buccal cantilever spring.

molars. We have found intrusion is generally possible in cases with a deep palatal vault and a constricted upper arch, but it is difficult, if not impossible, in cases with a shallow palatal vault. Some relapse following intrusion can be expected: Sugawara and coworkers who used SAS implants reported that 30 per cent of the open bite correction relapsed.[21]

An anterior open bite is easier to treat and the outcome more predictable if a palatal arch is used. In the cases where molar intrusion is the main aim direct ties to the palatal/lingual arch are necessary (Figure 9). We aim to correct an open bite by changing the vertical height of the posterior alveolar process. Miniscrews should be placed as far as possible from the cervical margins so that the elastics have a long working distance and an effective vertical vector. Intrusion carried out slowly will not usually affect the crown heights. If the gingivae cover the crowns or gingival pockets develop, a gingivectomy, followed by a one to two week rest period for the tissue to heal should be carried out. Intrusion can be resumed after a week or two. In severe cases a corticotomy may assist intrusion. There is high probability of a severe root resorption if a heavy intrusive force is used. Miniscrews placed midpalatally provide an excellent working distance and good force control, but this site should be avoided if possible because midpalatal miniscrews are often uncomfortable.

Extrusion

In Class II deep bite cases we often use a utility archwire in the lower arch to level and intrude the lower anterior teeth and use the reciprocal effect to extrude the lower molars. At the present time we do not have any data on the stability of extruded molar segment(s), but we have noticed that extruded teeth are prone to relapse. An effective and simple method of extrusion, devised by Park Young-Cheol (personal communication) is shown in Figure 10.

Summary

The direct and indirect application of a force, and the application of miniscrews as temporary anchorage devices have been described. Miniscrews can provide the anchorage necessary to move either the dental arch as a whole or segments of teeth in directions not easily accomplished with conventional methods.

Acknowledgments

To the scientists and clinicians who have dedicated their time and efforts to developing temporary anchorage devices.

Corresponding author

Dr George Anka
Ozenji Nishi 3-37-1
Asou-ku
Kawasaki
Japan 215 0017
Tel: (+42) 337 2525
Fax: (+42) 339 0918
Email: Anka465@sweet.ocn.ne.jp

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