CLINICAL SECTION

Skeletal anchorage systems in orthodontics: absolute anchorage. A dream or reality?

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This article examines the concept of orthodontic anchorage and focuses on ways skeletally derived anchorage is gained. A brief history of the different skeletal anchorage systems to date is given. The article gives an emphasis on the use of one particular skeletal anchorage technique—the micro-implant—to assist with orthodontic anchorage and active tooth movement. Advantages and disadvantages of this new technique are discussed. An illustration of the use of micro-implants is given with reference to a case where they have been used in a novel manner to provide distal movement of maxillary molars.

Key words: Orthodontics, skeletal anchorage, micro-implant, mini-implant, distal movement

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Introduction

Newton's third law of motion states 'each action has an equal and opposite reaction'. This is particularly relevant to orthodontics where such 'action' is favourable tooth movement, and the equal and opposite reaction is often an unwanted tooth movement. Anchorage is defined as the resistance to such unwanted tooth movement. To illustrate this further, consider the situation where an increased overjet is reduced by retraction of the maxillary incisors and canines. In this case, the maxillary molars will tend to move forwards as the maxillary anterior segment is retracted, as dictated by Newton's third law (Figure 1).

Not all malocclusions will have the same anchorage demands and it is up to the skill of the orthodontist to manage all the available anchorage sources to bring about full correction of the malocclusion. Anchorage may be gained:

- extra-orally using headgear or a facemask;
- intra-orally from teeth, bone, soft tissue and appliance mechanotherapy.

Occipital headgear supplements posterior anchorage by using the bones of the posterior skull to resist the unwanted tooth movement, thus preventing or reducing the forward movement of the maxillary posterior dentition. Similarly, facemasks use the bones of the face and chin to supplement anterior anchorage by resisting the backwards movement of the maxillary anterior dentition as the buccal segments are protracted. However, the use of such extra-oral appliances is not without problems. Poor compliance and ocular damage has been reported in the literature.[1] Intra-oral methods of anchorage control are numerous, but the majority result in a degree of anchorage loss. Absolute anchorage is a concept implying no movement of the anchorage unit, which may be required in the treatment of a maximum anchorage case (Figure 2).

If the anchor point (anchorage unit) in the force system is situated directly within bone, then the reactionary forces that always occur will theoretically result in no unwanted tooth movement (Figure 3). Skeletal anchorage is a technique utilizing some form of bony anchor in an attempt to provide absolute anchorage.

Sources of skeletal anchorage

- Endosseous implants
- Zygomatic wires

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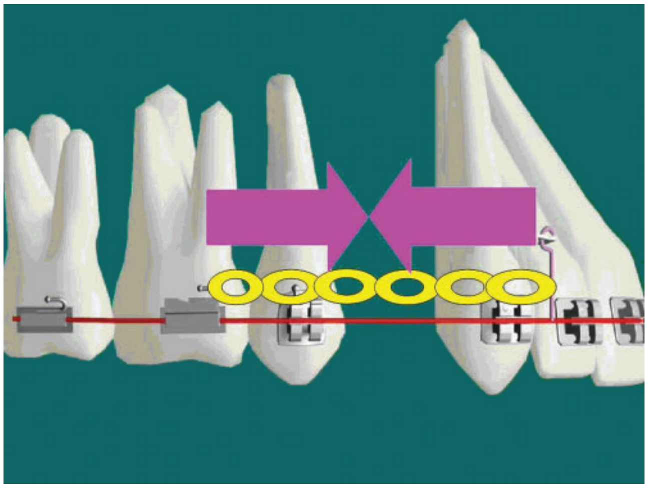


Figure 1 Demonstration of reciprocal anchorage

- Mid-palatal implants
- Onplants
- Mini bone plates
- Micro-implants

If intra-oral skeletal anchorage can be exploited by using the bones of the maxilla, zygoma or mandible to prevent unwanted tooth movement, then the need for headgear or facemasks may be much reduced.

History

Gainsforth and Higley[2] first reported using Vitallium metal bone screws, as a potential source of intra-oral anchorage, in dogs in 1945. Unfortunately, subsequent force application resulted in loss of the screws. Beder and Ploger[3] reported that titanium caused no adverse tissue response in bone and Brånemark demonstrated that titanium implants were stable over five years having osseointegrated to bone under light microscopic view.[4] Following this, Linkow[5] reported on the successful use of mandibular blade-vent implants to provide anchorage, which re-ignited the interest in the use of implants to gain orthodontic anchorage. Roberts *et al.*[6] described the use of standard titanium endosseous implants against which the molars were protracted. However, the use of endosseous implants in a growing individual is contraindicated. Interdisciplinary planning, with restorative colleagues, is required to ensure that the implant is placed in the correct position to be restored following the orthodontic treatment.

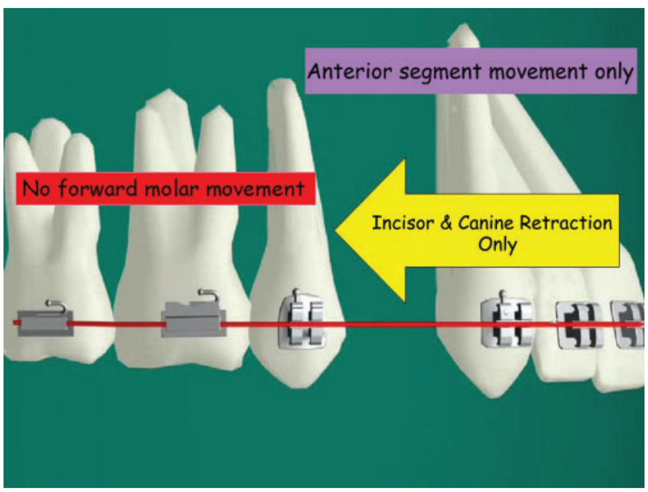


Figure 2 Maximum anchorage Class II division 1 case. All the premolar space is required for overjet reduction

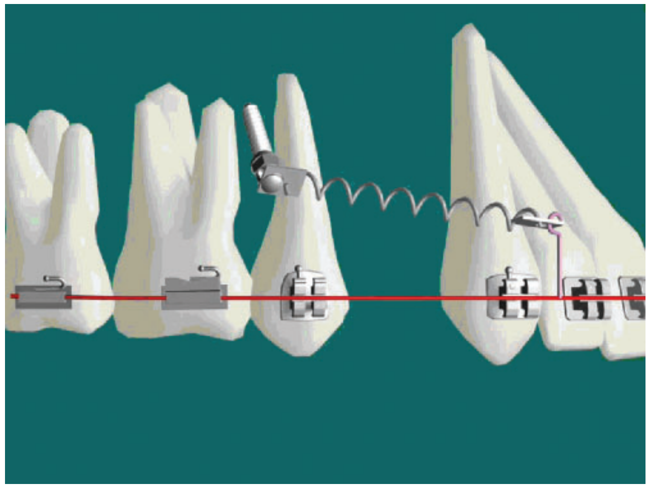
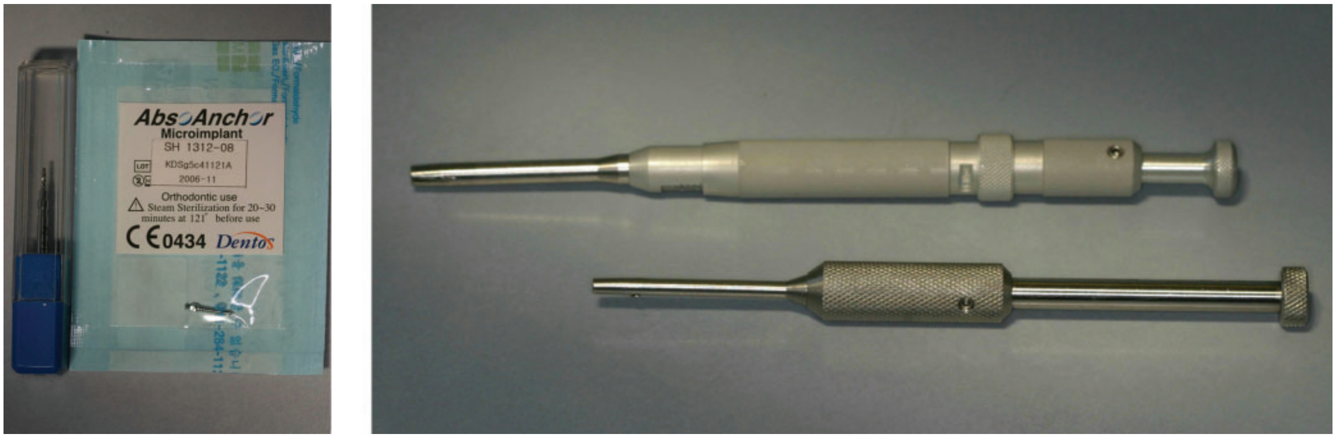


Figure 3 Demonstration of skeletal anchorage using a micro-implant for overjet reduction

Melsen[7] originally reported on a case series of ten patients without posterior teeth, who had stainless steel ligature wires placed into the maxillary antral wall to provide posterior maxillary anchorage. Coil springs were attached from the wires to the anterior teeth to retract the maxillary incisor teeth successfully.

Triaca[8] first described the mid-palatal area as being suitable for a short implant. Wehrbein[9] described the Orthosystem mid-palatal implant, developed by Straumann. Such a system requires placement of a short cylindrical implant into the anterior palatal vault followed by a latent period of 12 weeks, to facilitate true osseointegration, before the implant is loaded.[10] Fabrication of a surgical stent to aid implant placement away from the anterior teeth roots is recommended with this system.[11]

Onplants were developed by Nobel Biocare and consist of an implant disc, which is placed on the palate via a surgically created sub-periosteal tunnel. Following a period of osseointegration, further surgery allows an



(a) (b)

Figure 4 (a,b) One manufacturer's micro-implant system, showing micro-implant, pilot drill and screwdriver(s) available for micro-implant placement

attachment to be made from the Onplant to the teeth to provide indirect skeletal anchorage. Block and Hoffman[12] investigated the technique and reported favourable results. However, no commercial product is available.

Jenner and Fitzpatrick[13] first reported on the use of a mandibular mini-plate (such as those used to stabilize a mandibular fracture) to provide posterior horizontal mandibular anchorage to achieve distal movement of the mandibular dentition. Sugawara *et al.*[14] reported on nine cases with an anterior open bite (AOB) who were treated with mandibular bone plates to provide posterior vertical mandibular anchorage to intrude the mandibular molars. Counter-clockwise rotation of the mandible occurred following intrusion, thus allowing the AOB to be corrected. Sherwood[15] independently reported on the intrusion of maxillary molars that resulted in a similar counter-clockwise mandibular rotation and correction of the AOB.

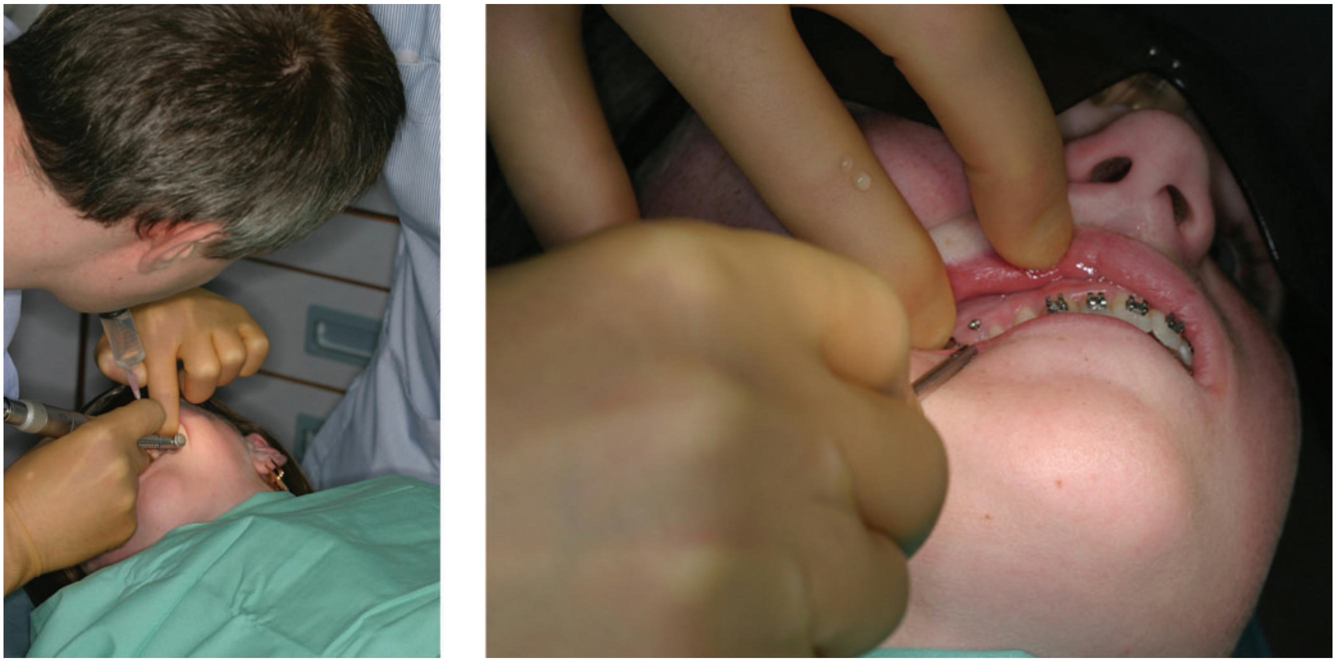
Correction of an AOB in this way by true molar intrusion, as opposed to unstable incisor extrusion, may obviate the need for surgery for patients with a mild AOB. Treatment of AOB, in the non-growing patient, has traditionally been with orthognathic surgery. Such surgery has classically involved, at least, a unipart or multi-segmented LeFort I maxillary osteotomy with differential posterior impaction. However, if orthodontic intrusion of the molar teeth remains stable, then orthognathic surgery may be avoided for patients with a mild AOB and skeletal Class I or II profiles. Randomized controlled trials will ultimately be required to test the technique further and to assess the validity of reported claims.[13–15]

Creekmore and Eklund[16] reported the use of a single Vitallium bone screw placed into the anterior nasal spine to procline maxillary incisors. Kanomi[17] described the use of four 1.2 mm diameter by 6 mm length mini bone screws and coined the term 'mini-implant'. Importantly, he theorized on the many uses of such mini-implants and the anatomical sites where they could be used. Presently, the term 'temporary anchorage devices' has been coined for such devices, to distinguish them from standard endosseous implants, which are regarded as a permanent fixture.

Melsen and Costa[18] investigated the histological tissue reaction around the immediately loaded Aarhus micro-implant. They concluded that the degree of osseointegration occurring around the micro-implants varied from 10 to 58% and was time-dependent. They concluded that immediate loading of micro-implants was effective. Park and co-workers[19–21] have reported on many cases treated with the micro-implant technique to highlight their experience to date.

Miyawaki *et al.*[22] investigated factors associated with micro-implant success. They found that micro-implants of less than 1 mm in diameter, those associated with ongoing inflammation or those placed in patients with a high mandibular planes angle were associated with a poorer prognosis. There are now many different companies manufacturing micro-implants (Figure 4). Prabhu and Cousley[23] have recently reported on the current options available for skeletal anchorage including various micro-implant systems commercially available.

The fundamental techniques of micro-implant insertion are similar. The micro-implant is inserted either after first preparing a pilot hole to facilitate its insertion (Figure 5) or it is placed directly without prior preparation of a pilot hole. The technique used is dependant upon the individual manufacturer's recommendation.



(a) (b)

Figure 5 (a,b) Micro-implant placement using a pilot drilling technique

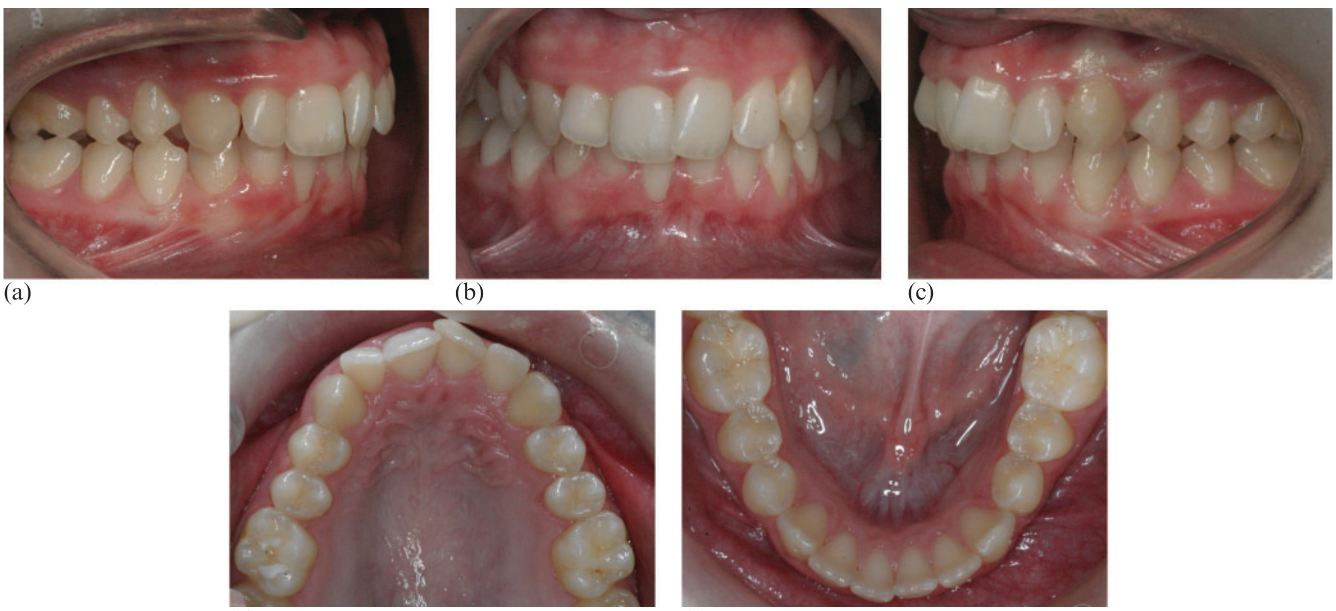
Possible advantages of micro-implants

- Acceptable to patients compared with the alternatives, e.g. headgear or facemask
- Eliminate risk of ocular damage associated with headgear use
- Relative ease of insertion
- Ease of removal
- Temporary
- Versatile placement, with buccal and palatal placement possible
- Cheap

Disadvantages

Potential for:

- root damage during micro-implant insertion;



(a) (b) (c) (d) (e)

Figure 6 (a–e) Pre-treatment intra-oral photographs

- infection;
- micro-implant failure.

In addition:

- an initial learning curve exists for the operator;
- there is only low level of scientific evidence available at present (at case series level);
- micro-implants do not reduce the need for patient compliance.

Root damage may occur while placing the micro-implant. Herman and Cope[24] suggest that when using the 'Imtec micro-implant' there is little risk of root perforation if a drill is used only to pierce the cortical bone followed by placement of the micro-implant directly into the bone (self-drilling technique). Contrary to this view, Kyung suggests, with the 'Abso-Anchor micro-implant' to use a pilot drilling technique. This technique uses a drill with a speed less than 300 rpm to prepare a full length pilot hole first—this is confusingly called the self-tapping technique. Kyung suggests this is safer than the self-drilling technique and reduces the chance of root perforation. No scientific evidence exists to refute such differing claims. Asscherickx *et al.*[25] reported on three instances of accidental root damage occurring following mini-screw insertion using histological examination in dogs. They demonstrated almost complete repair of the damaged periodontal structure (cementum, ligament and bone) at a minimum of 12 weeks following removal of the mini-screws and which was complete at 18 weeks. However, such regenerative capacity may be related to the amount of root damage. The authors stressed that more work is required in this important area and concluded that larger-scale studies are required before any definitive conclusions can be drawn following root damage. Factors relating to micro-implant failure have been previously discussed. It is important that the micro-implant is stable once inserted to allow immediate loading.[18] Osseointegration is not the goal when using micro-implants, although this may occur to a small degree.[26] This incomplete osseo-integration of the micro-implants facilitates removal.

Movements possible with micro-implants: within three planes of space

- Distal molar movement
- Mesial molar movement
- Incisor intrusion (deep bite cases)
- Molar intrusion (anterior open bite cases)
- Crossbite or scissor bite correction

(a)

(b)

Figure 7 (a,b) Pre-treatment OPG and lateral cephalogram

A case to illustrate distal molar movement

RM, a 13-year-old girl, presented with a mild Class II division 1 malocclusion on a mild skeletal II base with mildly reduced vertical facial proportions. The malocclusion was complicated by a ¾-unit Class II canine and molar relationship bilaterally, together with mild upper and lower arch crowding (Figure 6). A pre-treatment OPG and lateral cephalogram were taken (Figure 7) and analysed (Figure 8). One option for treatment would have necessitated a non-extraction approach with distal movement of the upper buccal segments to correct the Class II buccal segments.

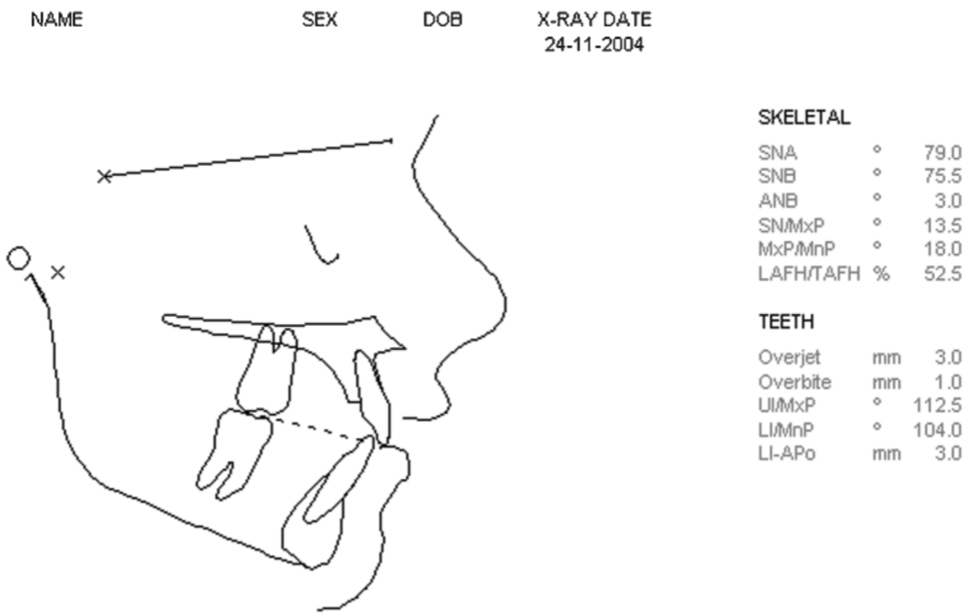


Figure 8 Pre-treatment cephalometric analysis

However, the patient was unwilling to wear the headgear that would be necessary to distalize the upper buccal segments, but was keen to attempt distal movement with micro-implants. The risks and benefits of alternatives to this treatment were stressed. RM and her parents were informed that the micro-implant technique was a recent development and that there was a relative paucity of scientific evidence to support the technique fully. Following this discussion, written informed consent was obtained.

Distal molar movement achieved with micro-screws

The micro-implants were inserted between the maxillary first molar and second premolar bilaterally under very shallow local anaesthesia. This is important because should the micro-implants enter the periodontal ligament space, due to placement error, pain may still be felt by the patient. Topical anaesthesia alone has also been suggested. Such shallow anaesthesia and any subsequent pain will alert the clinician that the micro-implant may be entering the ligament—the micro-implant may then be redirected away from the ligament and root surface. Profound anaesthesia will remove such sensibility. Periapical radiographs were taken after the insertion of the micro-implants, which demonstrated their position away from the roots (Figure 9).

Nickel titanium coil springs were then attached from the micro-implants to a sliding jig on the archwire to impart a continuous distalizing force to the maxillary first molar (Figure 10). Intra-arch distal movement of

(a) (b)

Figure 9 (a,b) Periapical radiographs showing clearance of the roots by the micro-implants following insertion

(a) (b) (c)

Figure 10 (a–c) Commencement of molar distalization force using sliding ball hook (jig)

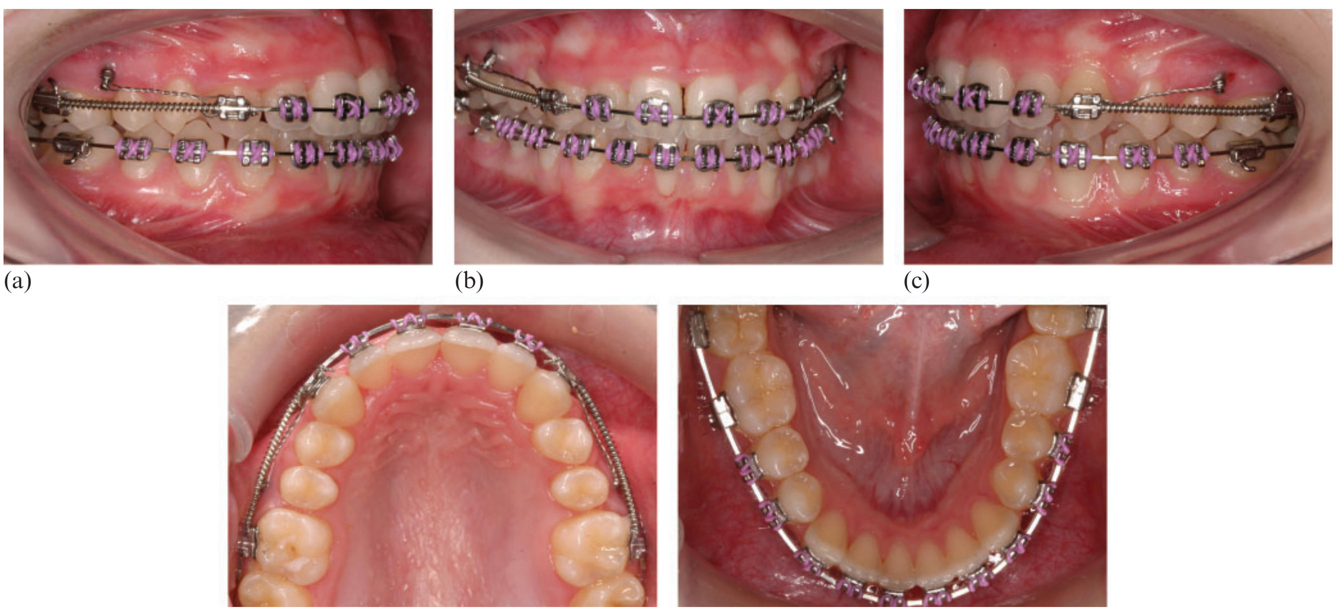
the upper buccal segments took only 2.5 months to correct molar and premolar relationships to Class I. Once this had been achieved, correction of the canine relationship could then be completed.

Molar and premolar correction now achieved

Once distalization had begun, the sliding jig was replaced with a nickel titanium coil spring directly on the archwire. This had the advantage of applying a pure distal force without any vertical force vector. Forward movement of the canines (anchorage loss) was prevented by tying a taught steel ligature from the micro-implants to the canines (Figure 11).

Case near end of treatment

The method of molar distalization shown involved first distalizing the buccal segments then followed by removal of the buccal micro-implants. No anaesthesia was required for removal of the micro-implants. The over-corrected molar relationship was held with a micro-implant supported transpalatal arch (TPA). The TPA was cemented and then followed by immediate placement of two palatal micro-implants situated anterior to the TPA, and in direct contact with it, to attempt to gain additional anchorage value for the TPA (Figure 12). This was then followed by separate anterior retraction in order to limit the load to the micro-implants (as the clinical response of the micro-implants to loading was not fully known). However, group distal movement of the whole maxillary dentition has been reported and may be more time-efficient.[20] The case is shown at the end of space closure (Figure 13). A lateral cephalogram was subsequently taken and analysed (Figure 14). Superimposition of the pre-treatment and near-end lateral cephalograms shows that correction of the malocclusion has been achieved by a combination of distal movement of the upper buccal segments and a degree of favourable mandibular growth (Figure 15). The case is shown following debond (Figure 16).



(a) (b) (c)

(d) (e)

Figure 11 (a–e) Following distal molar and premolar movement, Class I molar relationship now present. Space has now opened up in upper arch with no increase in overjet

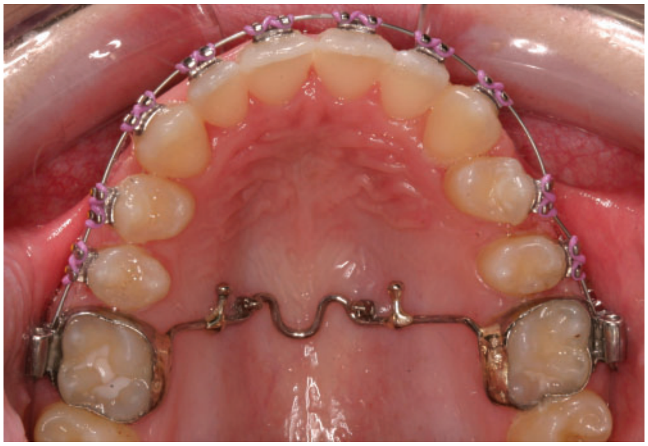
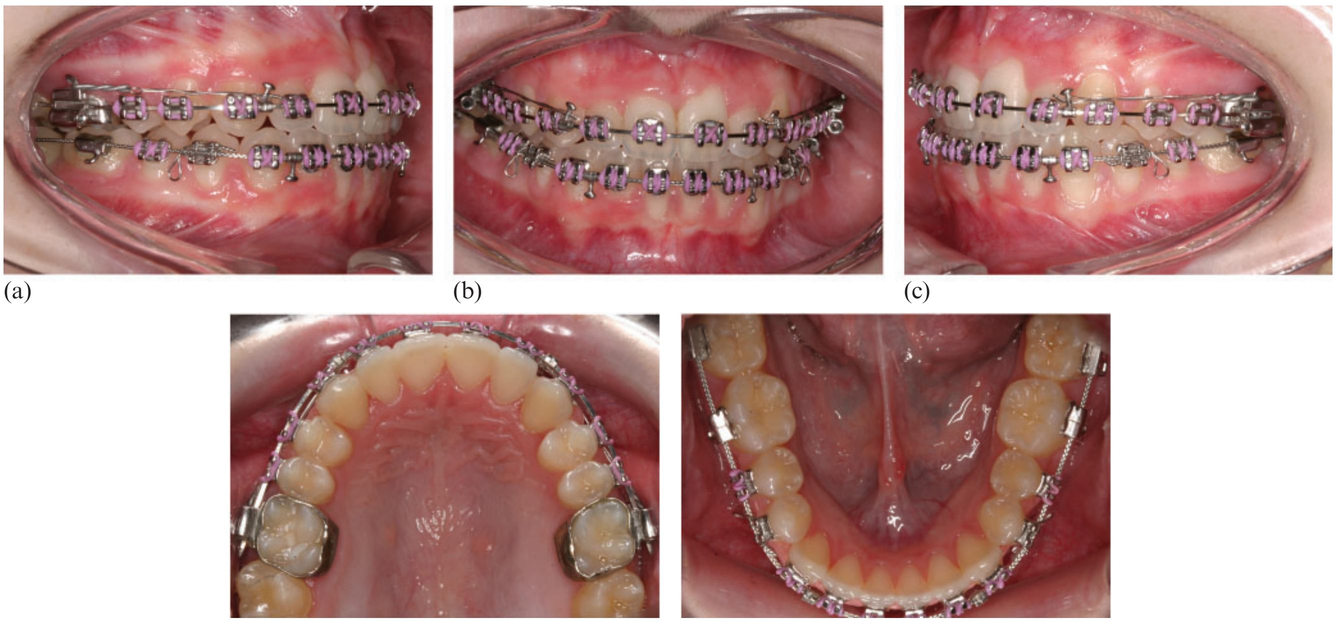


Figure 12 Palatal micro-implants placed anterior to the TPA and in contact with it to support molar correction

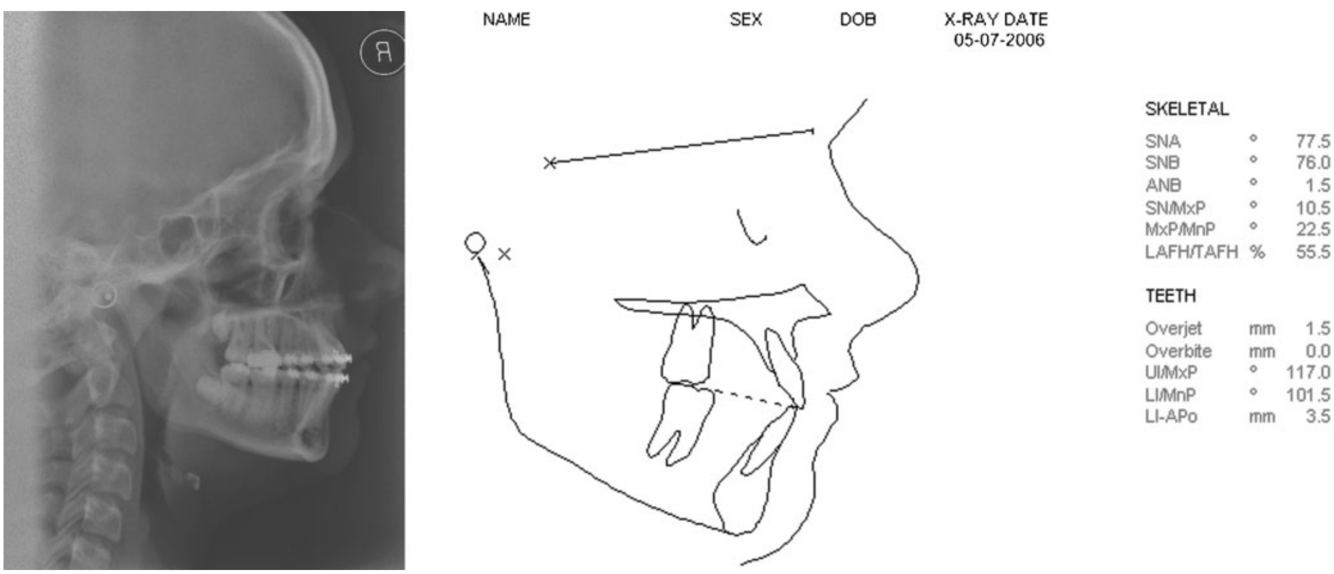
Conclusion

Skeletal anchorage devices are a newly available addition to the specialist orthodontist's armamentarium and are now becoming a reality. At present, there is no high-level scientific evidence available to support their use. However, clinical case reports and series suggest that they have a value in managing patients who have challenging anchorage demands. They are an invasive technique and, hence, are not without potential surgical problems. The risks and benefits in each particular case need to be assessed so that their use can be justified and valid informed consent gained. With the anticipation of randomized controlled trials to assess relative effectiveness and efficiency of such devices, compared with the alternatives, we will be able to assess the validity of this



(a) (b) (c) (d) (e)

Figure 13 (a–e) Completion of space closure



(a) (b)

Figure 14 (a,b) Near-end-treatment lateral cephalogram and analysis

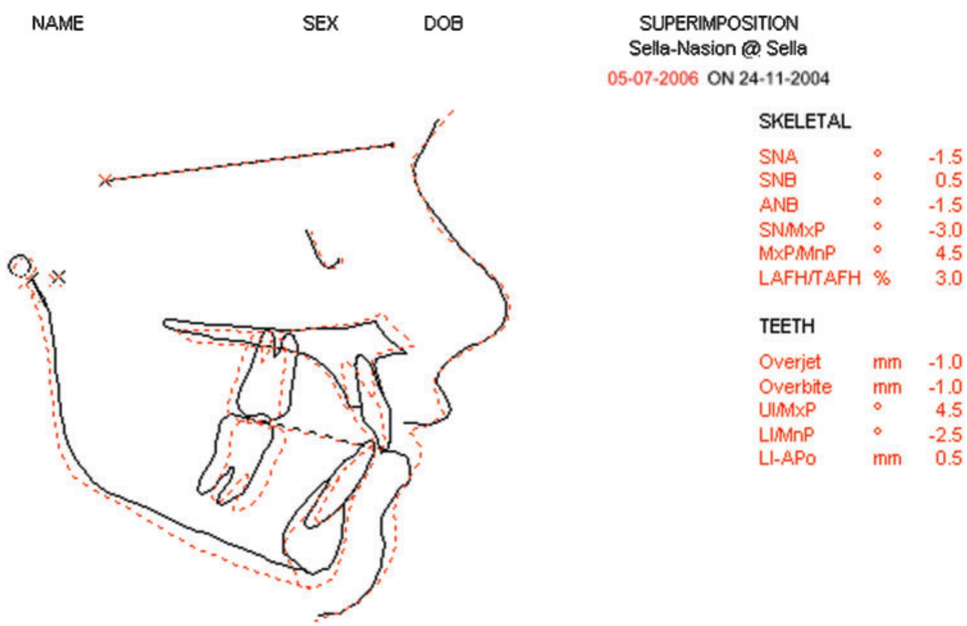
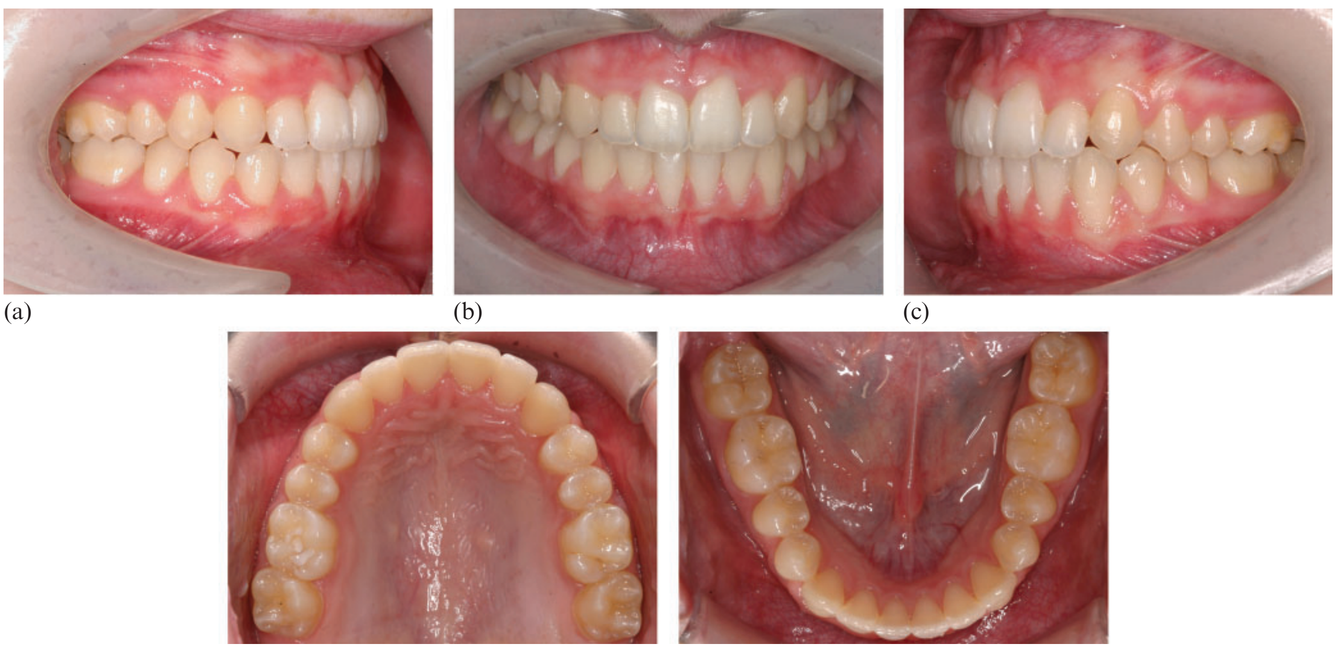


Figure 15 Superimposition of pre-treatment and near-end treatment lateral cephalograms. Changes with treatment are shown in red. Class II molar correction has been achieved by distal movement of the upper buccal segment plus a degree of favourable mandibular growth



(a) (b) (c)

(d) (e)

Figure 16 (a–e) End of active treatment

technique further and objectively evaluate the evidence before fully endorsing the technique.

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References

1. Booth-Mason S, Birnie D. Penetrating eye injury from orthodontic headgear—a case report. *Eur J Orthod* 1988; **10**: 111–14.
2. Gainsforth BL, Higley LB. A study of orthodontic anchorage possibilities of basal bone. *Am J Orthod Oral Surg* 1945; **31**: 406–17.

3. Beder OW, Ploger WJ. Intraoral titanium implants. *Oral Surg Oral Med Oral Path* 1959; **12**: 787–99.
4. Branemark PI, Adell R, Breine U, Hansson BO, Lindstrom J, Ohlsson A,. Intra-osseous anchorage of dental prostheses. I. Experimental studies. *Scand J Plast Reconstr Surg* 1969; **2**: 81–100.
5. Linkow LI. The endosseous blade implant and its use in orthodontics. *Int J Orthod* 1969; **18**: 149–54.
6. Roberts WE, Marshall KJ, Mozsary PG. Rigid endosseous implant utilized as anchorage to protract molars and close an atrophic extraction site. *Angle Orthod* 1990; **60**: 135–52.
7. Melsen B, Petersen JK, Costa A. Zygoma ligatures: an alternative form of maxillary anchorage. *J Clin Orthod* 1998; **32**: 154–58.
8. Triaca A, Antonini M, Wintermantel E. Ein neues Titan-Flaschrauben-Implantat zur orthodontischen Verankerung am anterioren Gaumen. *Inf Orthod Kieferorthop* 1992; **24**: 251–57.
9. Wehrbein H, Glatzmaier J, Mundwiller U, Diedrich P. The Orthosystem—a new implant system for orthodontic anchorage in the palate. *J Orofac Orthop* 1996; **57**: 142–53.
10. Cousley R. Critical aspects in the use of orthodontic palatal implants. *Am J Orthod Dentofacial Orthop* 2005; **127**: 723–29.
11. Cousley R.R. Parberry D.J. Combined cephalometric and stent planning for palatal implants. *J Orthod* 2005; **32**: 20–5
12. Block MS, Hoffman DR. A new device for absolute anchorage for orthodontics. *Am J Orthod Dentofacial Orthop* 1995; **107**: 251–58.
13. Jenner JD, Fitzpatrick BN. Skeletal anchorage utilising bone plates. *Aust Orthod J* 1985; **9**: 231–33.
14. Sugawara J, Baik UB, Umemori M, Nagasaka H, Kawamua H, Mitani H. Treatment and posttreatment dentoalveolar changes following intrusion of mandibular molars with application of a skeletal anchorage system (SAS) for open bite correction. *Int J Adult Orthodon Orthognath Surg* 2002; **17**: 243–53.
15. Sherwood KH, Burch JG, Thompson WJ. Closing anterior open bites by intruding molars with titanium miniplate anchorage. *Am J Orthod Dentofacial Orthop* 2002; **122**: 593–600.
16. Creekmore TD, Eklund MK. The possibility of skeletal anchorage. *J Clin Orthod* 1983; **17**: 266–69.
17. Kanomi R. Mini-implant for orthodontic anchorage. *J Clin Orthod* 1997; **31**: 763–67.
18. Melsen B, Costa A. Immediate loading of implants used for orthodontic anchorage. *Clin Orthod Res* 2000; **3**: 23–28.
19. Park HS, Kwon TG, Kwon OW. Treatment of open bite with microscrew implant anchorage. *Am J Orthod Dentofacial Orthop* 2004; **126**: 627–36.
20. Park HS, Lee SK, Kwon OW. Group distal movement of teeth using microscrew implant anchorage. *Angle Orthod* 2005; **75**: 602–09.
21. Park HS, Kwon TG. Sliding mechanics with microscrew implant anchorage. *Angle Orthod* 2004; **74**: 703–10.
22. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. *Am J Orthod Dentofacial Orthop* 2003; **124**: 373–78.
23. Prabhu J, Cousley R.R. Bone anchorage devices in orthodontics. *J Orthod* 2006; **33**: 288–307.
24. Herman R, Cope J.B. Miniscrew implants: Imtec Mini Ortho Implants. *Semin Orthod* 2005; **11**: 32–39.
25. Asscherickx K, Vannet BV, Wehrbein H, Sabzevar MM. Root repair after injury from mini-screw. *Clin Oral Implants Res* 2005; **16**: 575–78.
26. Deguchi T, Takano-Yamamoto T, Kanomi R, Hartsfield JK, Roberts WE, Garetto LP. The use of small titanium screws for orthodontic anchorage. *J Dent Res* 2003; **82**: 377–81.