Advances in orthodontic anchorage with the use of mini-implant techniques

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RESEARCH

IN BRIEF

- Informs that orthodontic mini-implants (OMIs) provide reliable anchorage in all three dimensions (antero-posterior, transverse and vertical).
- Reports that OMIs are well accepted and tolerated by both adult and adolescent patients, with minimal morbidity.
- Highlights that optimum use of OMIs requires an understanding of orthodontic biomechanics, particularly in terms of the effects of altered traction positions.

Orthodontic mini-implants (OMIs) represent a new form of anchorage provision and appear to provide a variety of benefits for both anchorage-demanding and complex orthodontic cases. This paper reports the latest perspectives on OMIs in terms of the emerging clinical evidence base coupled with their varied clinical applications.

INTRODUCTION

Every type of tooth movement, irrespective of the (fixed or removable) orthodontic appliance involved, generates an equal and opposite reactive force, as first described by Newton's third law of motion. Anchorage (reinforcement) comprises a myriad of clinical approaches to reduce the negative effects of this reactive force, which manifests clinically as anchorage loss. Mesial movement of the first molar teeth, during active retraction of the anterior teeth, is a classic example of such unwanted anchorage loss. Unfortunately, all types of conventional intra-oral anchorage reinforcement are associated with anchorage loss. Throughout the twentieth century headgear was regarded as the 'gold standard' for anchorage reinforcement, principally because it was the only source of anchorage not dependent on the dentition. Headgear, however, is often associated with compliance problems, in that insufficient wear by the patient results in anchorage loss.[1] In addition, its application is limited to resisting mesial movement of the maxillary molars and, to a lesser extent, vertical control of these teeth.

Fortunately, the start of the twenty-first century has seen the emergence of a new form of orthodontic anchorage, utilising orthodontic mini-implants (OMIs), also known as mini-screw implants and

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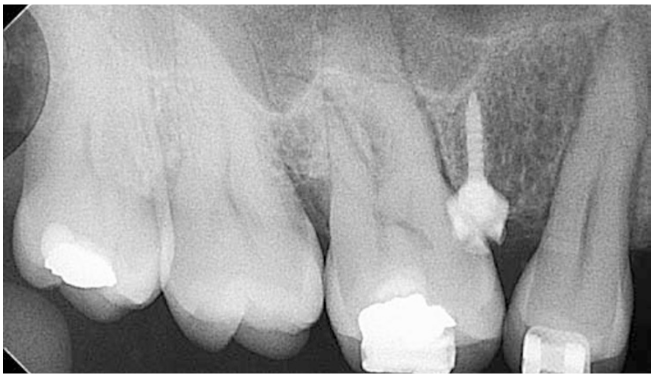


Fig. 1 Radiograph showing an OMI inserted in a buccal alveolar site between the upper right second premolar and first molar teeth. These roots were diverged with initial fixed appliance treatment to increase the interproximal space before insertion

temporary anchorage devices (TADs). These are modified bone screws with typical body (endosseous) dimensions of 1.5–2 mm diameter and 6–10 mm length. Their surfaces are polished and smooth compared to tooth implants. Hence they rely on mechanical retention within the alveolar and palatal bones, especially their cortical layers, rather than osseointegration (Fig. 1). OMIs are inserted using a small amount (0.1–0.2 ml) of local anaesthetic, often using a self-drilling screwdriver technique (without the need for formal pilot hole preparation). They can be immediately loaded for anchorage supplementation and remain *in situ* for variable time spans ranging from a few months to several years. They are then removed with a simple unscrewing action, without the need for local anaesthesia.

The initial attraction of orthodontic mini-implants was the possibility of them providing reliable anchorage, independent of the dentition and requiring no more patient compliance than standard fixed appliance treatment. More recently it has been recognised that OMIs provide anchorage in all three dimensions and consequently their use has expanded the range of malocclusions which can be managed orthodontically; for example, severe Class II, anterior open bite and hypodontia cases.[2] Furthermore, it has also become apparent that mini-implant anchorage, through advanced biomechanical control, can enhance the effects of orthodontic appliances in terms of their control of tooth movements and hence clinical outcomes, for example, the effective torque (inclination) control of upper incisor positions.[3–5]

This paper aims to provide dentists with insight into the nature of advanced orthodontic anchorage in the twenty-first century, by describing some of the applications of orthodontic mini-implants, balanced with a description of some of the latest research on how this form of orthodontic anchorage compares to conventional techniques.

LITERATURE REVIEW ON ORTHODONTIC SKELETAL ANCHORAGE

Almost 5,000 papers have been written on this subject since the very first orthodontic paper described the use of maxillofacial bone screws for orthodontic anchorage in 1983.[6] The majority of these have been either case reports on clinical and technique

Fig. 2 Intra-oral photograph of a mini-implant and powerarm combination for en masse bodily retraction of the six upper incisor and canine teeth. The OMI was inserted mesial to the upper first molar tooth and an elastomeric module attached for direct traction to a 'wavy' powerarm

innovations; or biological science research on OMI-bone interactions, factors affecting success rates (stability under loading) and iatrogenic risks.[2] While much of the biological research is robust and explains the bone-implant interface, it is unfortunate that very few of the clinical papers would stand up to serious scientific scrutiny. A Cochrane review[7] published in 2007 identified only one randomised controlled trial that the reviewers considered was of Cochrane quality. This paper reported a clinical comparison of orthodontic palatal implants and headgear. These palatal implants were similar to dental implants, not orthodontic mini-implants, especially in requiring an osseointegration phase before loading. They provided indirect anchorage of the maxillary molar teeth via a transpalatal arch. This study demonstrated that this palatal anchorage was as effective as headgear when treating maximum anchorage cases.[8] The authors concluded that for certainty of intra-oral anchorage in a maximum anchorage case, clinicians should consider the palate as a site for implant placement, and particularly consider these osseointegrated implants if only maxillary molar stabilisation is required.

Subsequently, a systematic review in 2009 identified only 21 papers of scientific value from 3,364 abstracts on orthodontic implants and mini-implants.[9] The authors concluded that the OMI papers had poor methodology and related clinical studies were just in their infancy. A second systematic review[10] calculated an overall failure rate of OMIs of 13.5% (95% CI 11.5–15.8) and provisionally concluded there was no evidence on the influence of patient age, sex, the insertion site (buccal or palatal) or the thread morphology. They also suggested that there were no differences between self-drilling and pre-drilled (pilot hole) insertions, immediate loading versus delayed loading, and that the type of soft tissue at the insertion site was immaterial. Root contact, however,

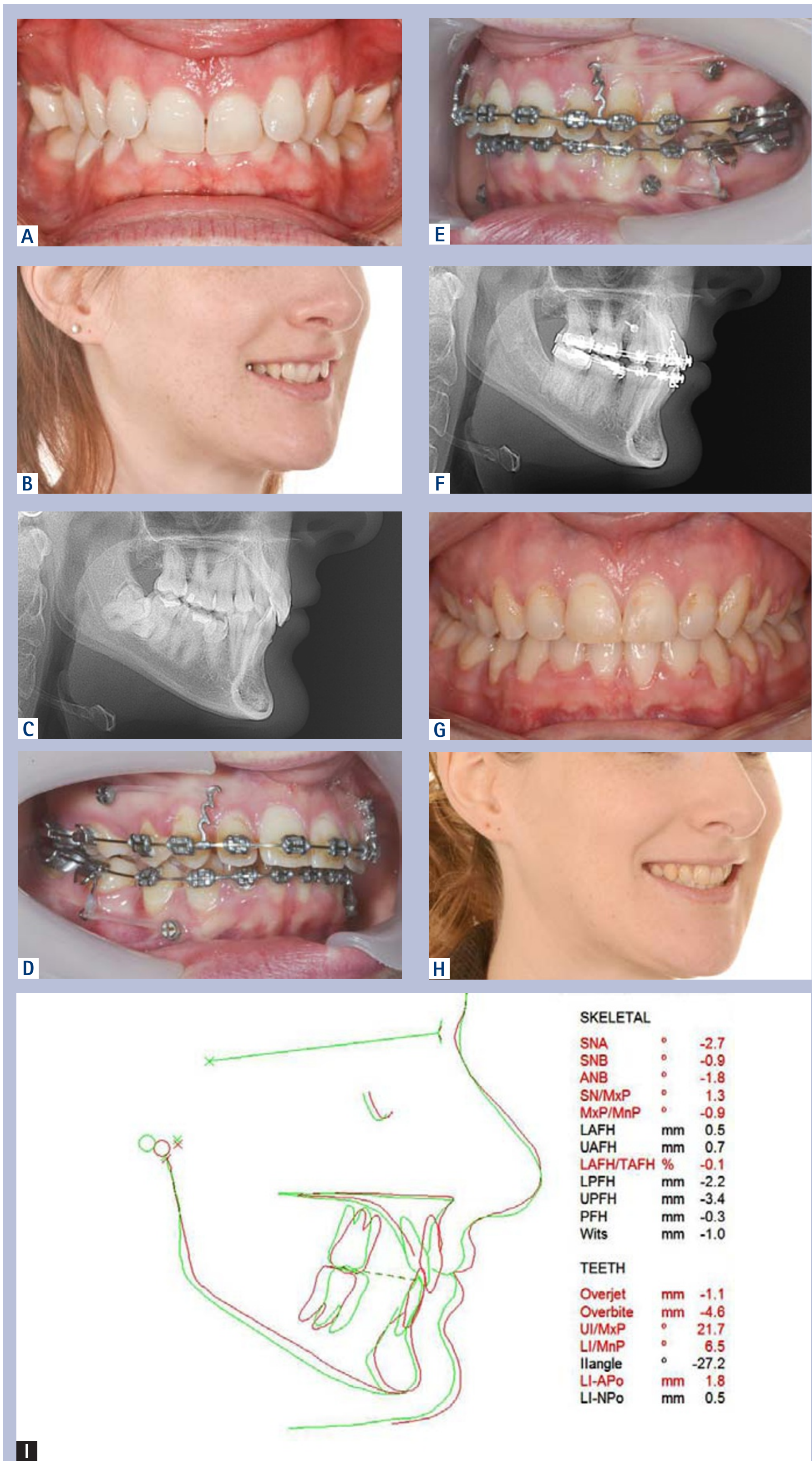


Fig. 3 (a,b) Pre-treatment photographs and (c) lateral cephalogram of an adult patient who presented with a traumatic Class II division two malocclusion and partially impacted lower second premolars. Orthognathic surgery had provisionally been planned and all second premolars removed accordingly. The patient then requested non-surgical treatment. This would conventionally be very difficult so four OMIs and powerarms were added (d,e) for controlled retraction of the upper incisors and protraction of the lower molars. A late-treatment lateral cephalogram (f) shows favourable inclination of the upper incisors due to substantial palatal movement of their roots. At debond a Class I occlusion had been achieved with a normal overbite (g,h), and both aesthetic display and inclination of the maxillary incisors. The cephalometric superimposition (i) illustrates the substantial palatal root movement (torque) of the upper incisors and lower molar mesialisation, without anchorage losses

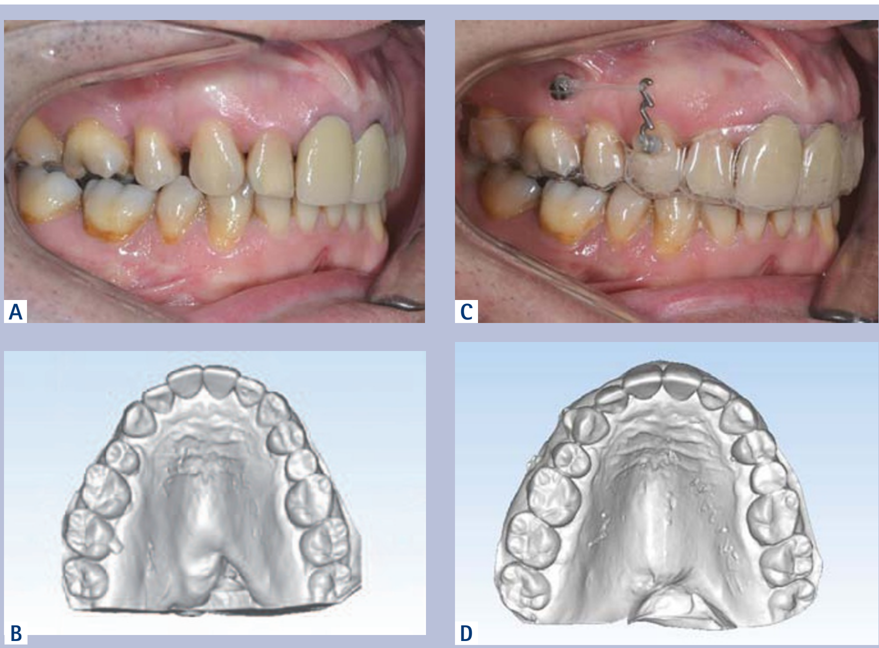
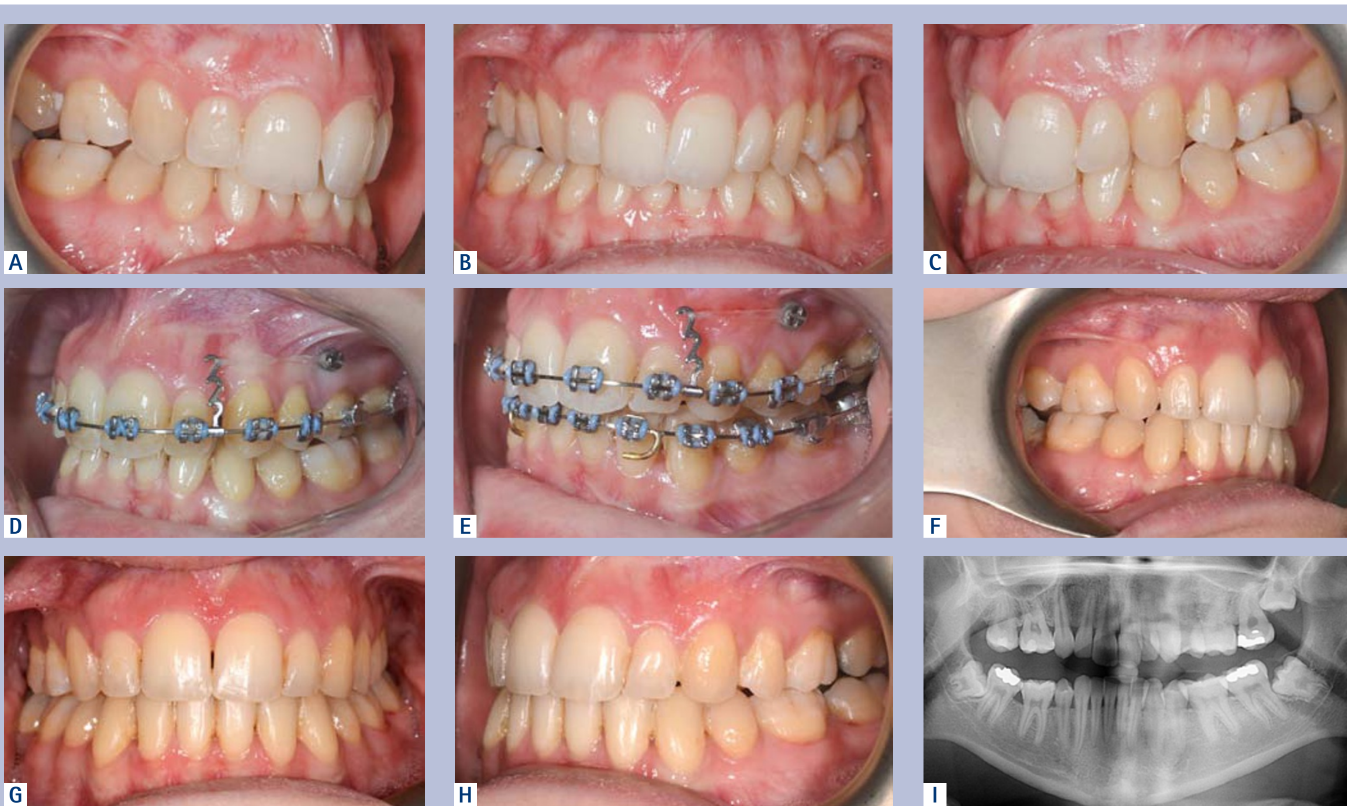


Fig. 4 An adult patient where (a,b) the right maxillary canine was to be retracted into the adjacent residual premolar space to facilitate aligner correction of the incisor irregularity. A buccal OMI (c) was used for single tooth retraction using a powerarm bonded onto the canine crown. This provided bodily retraction of the canine (d) which could not be achieved with aligners alone

resulted in a greater number of failures. This information is valuable for both orthodontists and patients when the use of OMIs is being considered and when obtaining fully informed consent. However, the authors of this systematic review also concluded that further high quality studies need to be carried out.

It was against this background, of a general lack of comparative scientific evidence on the clinical use of mini-implant anchorage, that one of the authors (JS) instigated a UK-based randomised controlled trial on OMIs.[11] This study involved the use of headgear, a transpalatal arch and orthodontic mini-implants in maximum anchorage cases requiring relief of crowding and incisor retraction in the maxillary arch. The authors concluded that OMI anchorage now provides a safe, minimally invasive, anchorage technique that has proved to be much more versatile and reliable for maximum anchorage reinforcement than conventional anchorage supplementation, and without the need for as much patient cooperation. In effect, these findings support the contention that



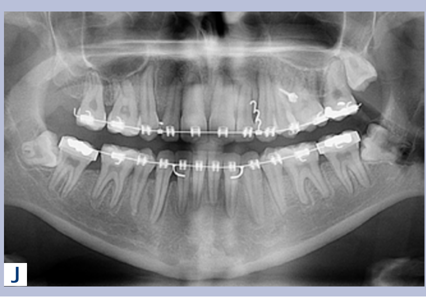


Fig. 5 (a–c) Pre-treatment photographs of an adult patient with a Class II division two malocclusion. Multiple premolars were absent, including both right maxillary premolars with an associated shift of the upper centreline to the right side. The patient requested centreline correction without re-opening of premolar spaces. (d) An OMI was inserted mesial to the upper left first molar, to provide distalisation of all left maxillary teeth and hence space for centreline correction, via the powerarm (e). Debond views (f–h) showing Class I left canine relationship, although slight lower centreline displacement is still evident. (i,j) Pre- and mid-treatment panoramic radiographs show how the upper incisor, left canine and second molar roots have moved towards the left side and distally relative to the midpalatal suture, and both anterior and posterior sinus walls, respectively

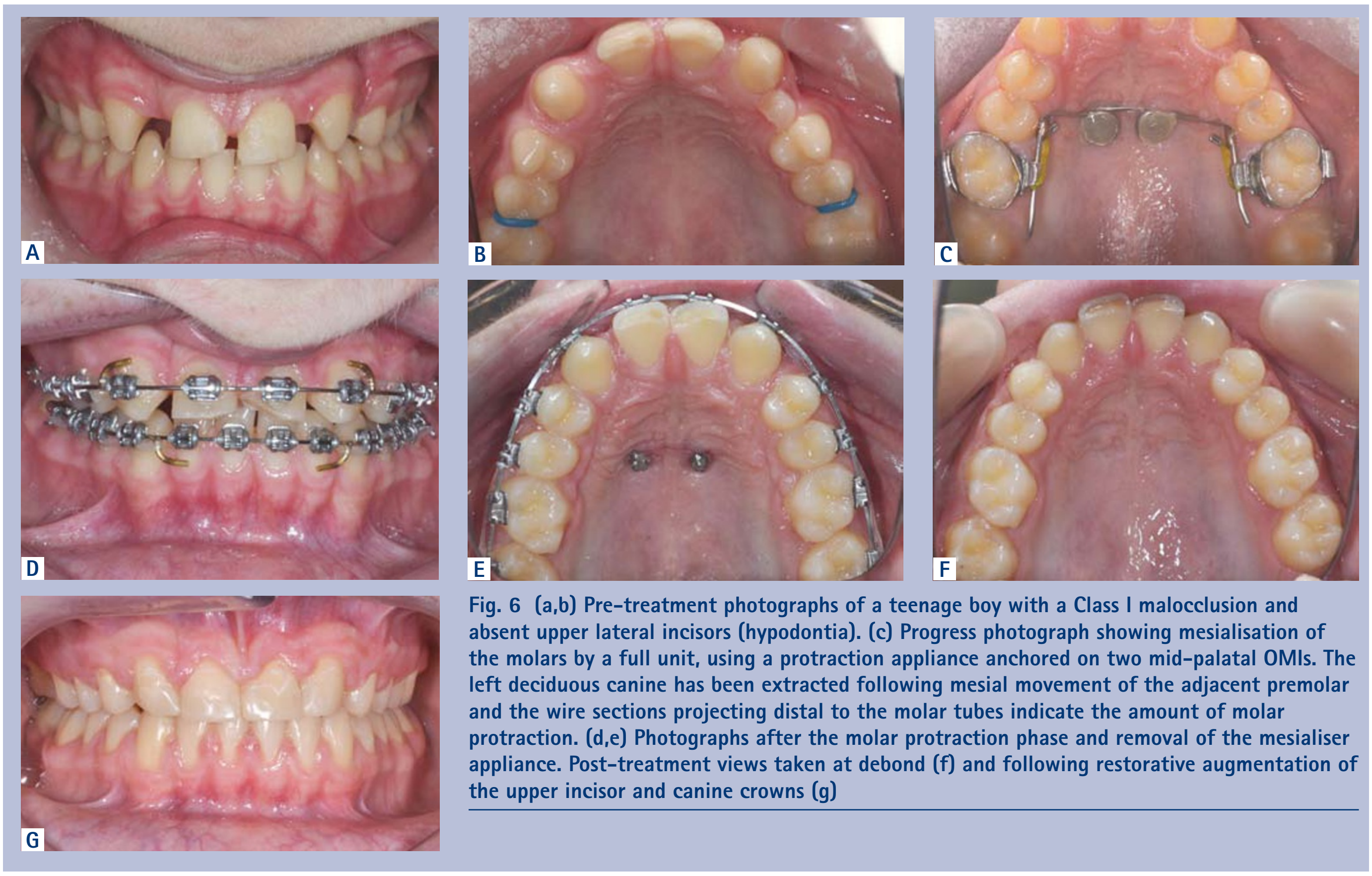


Fig. 6 (a,b) Pre-treatment photographs of a teenage boy with a Class I malocclusion and absent upper lateral incisors (hypodontia). (c) Progress photograph showing mesialisation of the molars by a full unit, using a protraction appliance anchored on two mid-palatal OMIs. The left deciduous canine has been extracted following mesial movement of the adjacent premolar and the wire sections projecting distal to the molar tubes indicate the amount of molar protraction. (d,e) Photographs after the molar protraction phase and removal of the mesialiser appliance. Post-treatment views taken at debond (f) and following restorative augmentation of the upper incisor and canine crowns (g)

OMI, and not headgear, now represents the gold standard for orthodontic anchorage. Hence, as this new field evolves in both clinical and research terms, the evidence is now emerging from high quality studies that mini-implant anchorage is at least as effective as conventional techniques and that it is preferred by patients to the existing alternative approaches. Further scientific studies will add to this evidence base and as OMI techniques develop further we may see a complete move away from headgear and other forms of anchorage supplementation as the use of OMIs becomes commonplace for anchorage demanding applications.

CLINICAL APPLICATIONS

Aside from orthodontic mini-implants providing reliable anchorage and receiving a high level of patient acceptance,[11–13] it is now possible to control anchorage, and hence tooth movements, in three dimensions. Therefore, OMI usage should be considered in each of the three planes of space:

- antero-posterior
- transverse
- vertical.

At the mention of orthodontic anchorage reinforcement, most of us automatically think of maxillary molar stabilisation using headgear or a banded transpalatal arch. It is therefore appropriate to begin with a description of this common antero-posterior application in terms of the details of both skeletal anchorage reinforcement and enhanced biomechanical control. Direct anchorage is typically achieved from a mini-implant inserted in a buccal site, through attached mucosa, and between the first molar and second premolar roots. Traction is applied from the head of the OMI either directly to a tooth (bracket) or via a powerarm (an elongated hook attached to either the archwire or a tooth) (Fig. 2). This combination provides both stable anchorage (that is, the avoidance of mesial movement of the adjacent molars since no traction is applied to these teeth) and enhanced control of incisor teeth movements. The powerarm provides better torque control as the incisors are less prone to retroclination (lingual tipping of their crowns) during their retraction.[3–5] This ensures that the planned antero-posterior tooth movements and an optimal aesthetic result may be achieved, even in adult 'camouflage' patients (Fig. 3). It is even possible to use this mini-implant and powerarm combination along with orthodontic aligners (clear plastic tooth positioners), when there would otherwise be very limited control of bodily tooth movement (Fig. 4). In the coming years, this 'fusion' orthodontic approach, which combines the benefits of different appliances, may increase the range of malocclusion traits treatable with aligners, especially in terms of controlled space closure.

Antero-posterior mini-implant anchorage also facilitates molar distalisation, without the risk of anchorage loss. Premolar and incisor tooth advancement occurs with all forms of 'non-compliance' distaliser designs unless they are bone-anchored.[14] Alveolar insertion sites provide limited scope for molar distalisation because of the risk of contact between the (moving) tooth roots and the adjacent OMI (Fig. 5). More than half a unit of maxillary molar distalisation changes are best achieved with mini-implants inserted in the mid-palate area, although this is more technically demanding in terms of distaliser appliance design and fabrication.

Similarly, mid-palatal anchorage may be used for molar protraction, where the posterior teeth need to be moved mesially to close spaces due to hypodontia or premature tooth losses (Fig. 6). Such molar protraction can obviate the need for long-term restorative pontic provision and it should be considered as a treatment alternative and discussed when obtaining informed consent where there is sufficient alveolar bone for orthodontic space closure.[15]

Many patients present with a large centreline shift, due to the unilateral absence of teeth (Fig. 5) or underlying transverse skeletal asymmetry. This requires anchorage reinforcement on the side that the centreline is to be moved towards. Conventional anchorage, with appliances such as a transpalatal/lingual arch or headgear, connects the

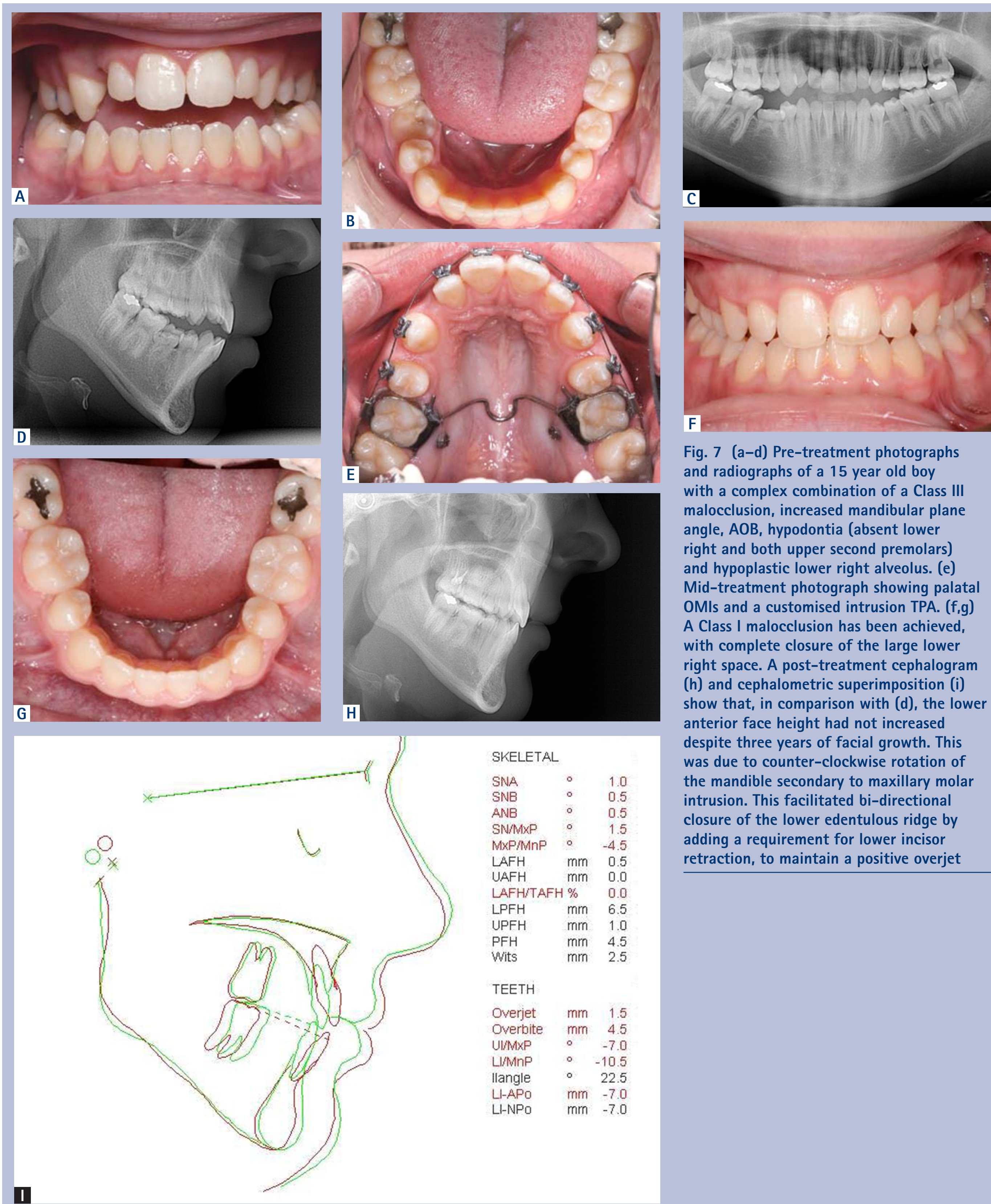


Fig. 7 (a–d) Pre-treatment photographs and radiographs of a 15 year old boy with a complex combination of a Class III malocclusion, increased mandibular plane angle, AOB, hypodontia (absent lower right and both upper second premolars) and hypoplastic lower right alveolus. (e) Mid-treatment photograph showing palatal OMIs and a customised intrusion TPA. (f,g) A Class I malocclusion has been achieved, with complete closure of the large lower right space. A post-treatment cephalogram (h) and cephalometric superimposition (i) show that, in comparison with (d), the lower anterior face height had not increased despite three years of facial growth. This was due to counter-clockwise rotation of the mandible secondary to maxillary molar intrusion. This facilitated bi-directional closure of the lower edentulous ridge by adding a requirement for lower incisor retraction, to maintain a positive overjet

anchor teeth on both sides of the maxillary arch. However, this connection on the non-anchorage side is at best unwarranted and frequently acts as a hindrance to tooth movements on this side. Unilateral anchorage is also beneficial for correction of vertical asymmetry where the patient has an occlusal plane cant, that is, the occlusal plane is tilted (relative to the face) with one side at a lower vertical level that the other side. Fortunately, it is now possible to correct centreline shifts and many vertical occlusal plane cants using mini-implant anchorage. In particular, the OMIs are only inserted in the specific quadrants where additional anchorage is required, freeing the tooth movements on the contralateral side (Fig. 5).

Finally, skeletal anchorage promises to cause a paradigm shift in the management of patients with vertical growth discrepancies particularly anterior open bite (AOB). Conventional treatment approaches involve either premolar or molar extractions (with subsequent retraction and potentially unstable extrusion of the incisor teeth) or orthognathic surgery (in the form of a maxillary impaction osteotomy). The ability to provide vertical anchorage now enables orthodontists to offer such patients a viable, minimally invasive treatment alternative.[2,16] This frequently means that AOB patients may be treated on a non-extraction basis or that effective vertical control may be achieved during the treatment of other orthodontic problems, such as hypodontia (Fig. 7). It is recognised however that long-term research results are needed to support the widespread application this new technique, especially since AOB correction is classically one of the most prone malocclusion traits to relapse.

CONCLUSIONS

With the advent of mini-implant anchorage, we now have a safe, minimally invasive, clinical anchorage technique that has proved to be much more versatile and reliable for maximum anchorage reinforcement than conventional anchorage supplementation, and without the need for as much patient cooperation. As this new field evolves in both clinical and research terms, the evidence is emerging gradually, from high quality studies, that OMI anchorage is at least as effective as conventional techniques and it is preferred by patients to the alternative approaches available. Further scientific studies will add to this evidence base and as OMI techniques develop further we may see a complete move away from headgear and other forms of anchorage supplementation as the use of OMIs becomes commonplace for anchorage demanding applications.

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