Richard Cousley

The Orthodontic Mini-implant Clinical Handbook

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WILEY Blackwell

This edition first published 2013

Wiley-Blackwell is an imprint of John Wiley & Sons, formed by the merger of Wiley's global Scientific, Technical and Medical business with Blackwell Publishing.

Registered office: John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial offices: 9600 Garsington Road, Oxford, OX4 2DQ, UK

The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

2121 State Avenue, Ames, Iowa 50014-8300, USA

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Library of Congress Cataloging-in-Publication Data

Cousley, Richard R. J.

The orthodontic mini-implant clinical handbook / Richard R.J. Cousley.

p. ; cm.

Includes bibliographical references and index.

ISBN 978-1-118-27599-3 (hardback : alk. paper)

I. Title.

[DNLM: 1. Orthodontic Anchorage Procedures. 2. Dental Implantation. 3. Dental Implants. 4. Miniaturization. WU 400]

617.6'93–dc23

2012044640

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover images courtesy of Richard Cousley

Cover design by Andrew Magee

Preface

If I have seen further than others, it is by standing upon the shoulders of giants.

Sir Isaac Newton (1642–1727)

Most of this book has been written only five miles from Woolsthorpe Manor, the location of both Sir Isaac Newton's birth and the orchard where the fabled apple's fall to the ground signified his theory of gravity. Like Sir Isaac, I wish to acknowledge that my achievements (albeit on a much simpler level) have only been possible because of the huge intellectual and practical advances of mini-implant researchers in countries as diverse as Korea, Japan, Denmark, Germany, the USA, Brazil and Turkey. These pioneers have ensured that 21st century orthodontics benefits from a powerful and versatile new adjunct: the orthodontic mini-implant (also known as mini-screw, mini-screw implant, micro-implant or temporary anchorage device [TAD]). For the first time, orthodontists are able to reliably control anchorage and tooth movements in all three dimensions. Consequently, orthodontic mini-implants have begun to change clinical practice around the world and their use is widely regarded as representing a paradigm shift in clinical orthodontics. They provide independent, stable, low compliance anchorage in routine cases, and for complex cases their use significantly expands the range of problems which can be effectively treated by orthodontics. Furthermore, observations of novel clinical effects have begun to confirm or alter long held views on orthodontic biomechanics and dentoalveolar remodelling.

Despite such wide ranging innovations, many 'grass-root' orthodontists have yet to embrace this new technique of anchorage reinforcement: why is this? Is it because of high cost, surgical invasiveness, poor patient acceptance, limited clinical applications, or a lack of published research? Fortunately the answer to all of these concerns is a resounding ‘no’. Whilst it is relatively early for many prospective clinical trials to have been conducted and published, large numbers of biological science and clinical research papers already provide a sound evidence base. In particular, the mini-implant, not headgear, now represents the gold standard for anchorage. Equally, many orthodontists have found mini-implants to be minimally invasive, safe, reliable, well tolerated, cost effective and highly useful in multiple clinical scenarios. Instead, the slow adoption of this new technology by some clinicians appears to be due to a combination of unfounded safety worries (especially regarding damage to the roots), clinical inertia, scepticism and even apathy. In reality, it is easier to try out (and conduct research trials on) a new type of orthodontic bracket than it is to adopt a fundamentally new clinical technique. I had elements of this mindset when mini-implants first became available in the UK in 2003. However, my own clinical experience and numerous detailed contributions to the worldwide literature (summarised in Chapter Two) have since convinced me that mini-implants will cause fundamental and irreversible changes in orthodontic practice in terms of both routine anchorage reinforcement and wide-ranging, even face-changing, clinical applications.

This book aims to provide orthodontists with the essential theoretical and clinical mini-implant information to enable them to easily introduce skeletal anchorage into their clinical practice in a wide variety of common clinical scenarios (especially in conjunction with straight wire appliances). It is also intended as a reference for dental and surgical colleagues who may receive requests to insert orthodontic mini-implants. This handbook is not intended to replace larger mini-implant textbooks, which readers may find useful for further background details and examples of unusual clinical scenarios. General principles are covered in the initial chapters then subsequent chapters focus on a step-by-step approach (with clinical tips and, where necessary, laboratory descriptions) to guide the novice through the most common clinical uses for orthodontic mini-implants. Whilst this entails a degree of repetition, the over-arching concept is that the essential clinical information for each scenario is easily available in one area of text. Notably the techniques described are not intended to represent the only ways of using mini-implants, but rather the culmination of my learning curve and accumulated knowledge such that new orthodontists may feel confident in using mini-implants from the outset.

The clinical chapters in this handbook have a ‘cookbook’ feel, although this has both positive and negative connotations in the era of evidence based medicine. I strongly believe that clinicians should have a sound understanding of the principles and basis for techniques such as mini-implant usage. However, the experience of providing mini-implant courses has taught me that colleagues with limited experience or confidence with mini-implants have a justifiable need for basic clinical guidelines based on the best available practice and evidence. Consequently this book is structured so that readers may easily follow the main steps for a specific clinical scenario whilst learning the key benefits of mini-implant anchorage. I hope that both you and your patients benefit accordingly.

Richard R.J. Cousley

1

Mini-implant Principles and Potential Complications

The origins of orthodontic bone anchorage

Orthodontic-specific skeletal fixtures were developed from two distinct sources:

- restorative implants
- maxillofacial surgical plating kits.[1]

Orthodontic implants were first produced in the 1990s by modification of dental implant designs, making them shorter (e.g. 4–6 mm length) and wider (e.g. 3 mm diameter). However, they retained the crucial requirement for osseointegration, i.e. a direct structural and functional union of bone with the implant surface causing clinical anklyosis of the fixture. In contrast, mini-plates and mini-implants (mini-screws) are derived from bone fixation technology, and primarily rely on mechanical retention rather than osseointegration. In effect, modification of the maxillofacial bone plate design, adding a transmucosal neck and intra-oral head, resulted in the mini-plate; whilst adaption of the fixation screw design produced the mini-implant. Since the start of this millennium a wide variety of customised orthodontic mini-implants have been produced and these are now used in the vast majority of orthodontic bone anchorage applications. Orthodontic implants are no longer in standard use and the invasive nature of mini-plates appears to limit their use to orthopaedic traction (e.g. Class III) cases.

Using the right terminology

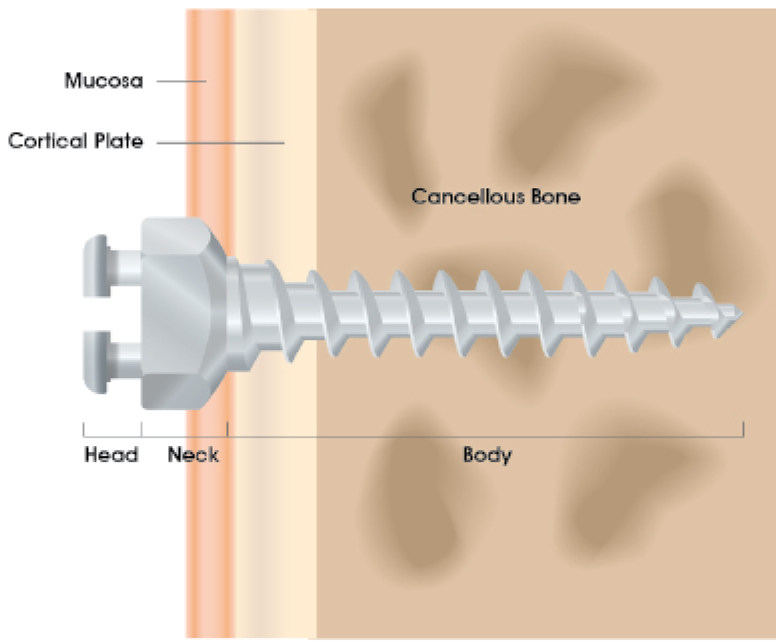
Unfortunately a misleading array of terms has been used for bone anchorage devices and their applications in both journals and the commercial literature. Essentially it is best to encompass all types of fixtures which provide skeletal anchorage under the umbrella terms: Bone Anchorage Devices (BADs) or Temporary Anchorage Devices (TADs), although the latter term does not indicate the essential role of bone in this anchorage. This book covers only one of the three types of BADs: mini-implants. Whilst the terms mini-implant and mini-screw are used interchangeably in the literature, it is erroneous to use the terms micro-screws or micro-implants since these fixtures are small (mini) and not *micro*scopic. I prefer the term mini-implant since it conveys the small size and implantable nature of these temporary fixtures.

Second, there appears to be much misunderstanding over whether mini-implants osseointegrate. Most mini-implants are made from either titanium or titanium alloy and histological studies show variable levels of bone–implant contact (BIC).[2,3] However, it is misleading to refer to this as osseointegration. Rather, clinical usage and percussion indicate that mini-implants are mechanically retained (like bone fixation screws) rather than forming a clinically discernible ankylotic union with the bone (which occurs with restorative implants secondary to the initial BIC phase). Hence, mini-implants can be immediately loaded and easily unscrew, usually without anaesthetic, at any time after insertion. This may be because of their relatively smooth surface and possibly because the surface contact is more a physical phenomenon than a biochemical one.

Principal design features

Most mini-implants have three constituent parts: the head, neck and body (Fig. 1.1), and are fabricated from a titanium alloy such as surgical grade five (Ti-6Al-4V). The head is the platform which connects to orthodontic appliances or elastic traction. The neck is the part that traverses the mucosa. The body is the endosseous section with threads around a core and a tapered tip. Mini-implants were initially available only in self-tapping (non-drilling) forms whereby a full depth pilot hole had to be drilled before mini-implant insertion. However, many self-drilling screws are now available. These have a tapered body shape with sharp tips and threads, and are inserted in a corkscrew-like manner. Full depth pre-drilling is avoided, although shallow perforation of the cortex is still advantageous where the cortex is thick or dense, e.g. the posterior mandible and palate.

Figure 1.1 Diagram showing the three principal sections of a mini-implant: the head superficial to the tissues, the neck traversing the mucosa, and the threaded body within the cortical and cancellous bone.



Clinical indications for mini-implants

Mini-implant usage may be broadly divided according to the case application and form of anchorage.

Routine cases

- Cases with high anchorage demands, e.g. retraction of prominent upper incisors or centreline correction (especially where unilateral anchorage only is required). Orthodontists new to mini-implant usage may find it easiest to introduce them into their clinical practice in such cases since the other aspects of the treatment are usually uncomplicated, enabling the orthodontist to readily recognise the anchorage effects and gain experience.
- Adults and older adolescents who wouldn’t comply well with other anchorage options, especially headgear.
- Where extrusive tooth movements would be unfavourable (risking an anterior openbite or vertical excess).

Complex cases

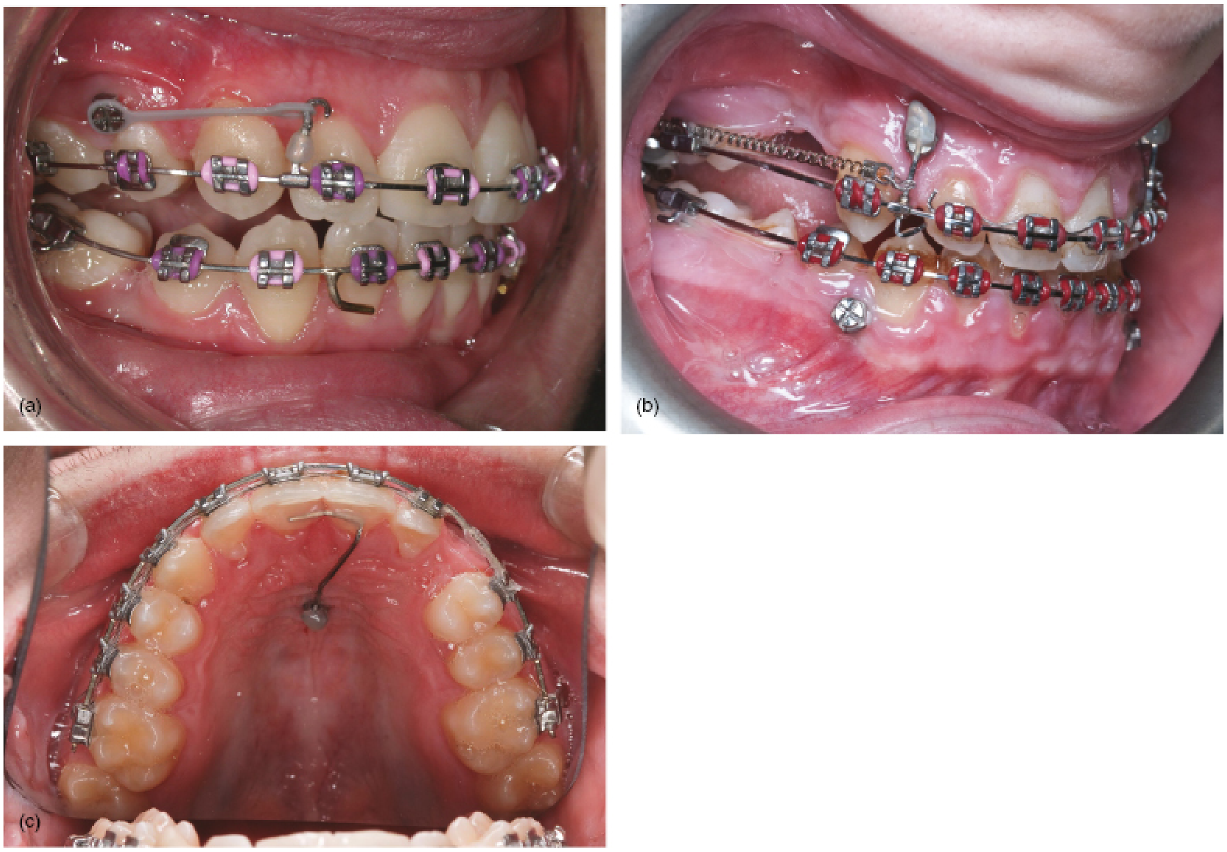
- Where conventional biomechanics would be limited, e.g. molar intrusion to correct an anterior openbite.
- Where conventional dental anchorage is limited by an inadequate number of anchor teeth (due to tooth loss or hypodontia) or periodontal support.

Direct and indirect anchorage

- Direct loading is when traction is applied from the mini-implant’s head to an appliance, typically with elastic chain or nickel titanium (NiTi) coil springs (Fig. 1.2a).

- Indirect loading involves using the mini-implant to reinforce anchor teeth, from which traction is applied (Figs 1.2b,c). Whilst indirect anchorage avoids some potential biomechanical side-effects (as discussed in Chapter Three) it risks insidious anchorage loss through flexing of the intermediary wire and undetected tipping or bodily translation of the mini-implant. Consequently, I prefer to use direct anchorage wherever possible and this will be elucidated in the clinical scenario chapters.

Figure 1.2 (a) Direct anchorage where this grey elastomeric attachment provides traction from the mini-implant head to a powerarm on the fixed appliance for en masse retraction of the anterior teeth. (b) The maxillary mini-implant provides indirect anchorage for molar protraction in this hypodontia case. Horizontal traction is applied, using a NiTi coil spring, connected to a vertical auxiliary wire, which in turn is joined to both the main archwire (using a cross-tube attachment) and the mini-implant head (where its position is secured by composite resin). (c) Indirect anchorage of the upper incisors during unilateral molar protraction, using an elastomeric chain on the fixed appliance. This involves a 0.019 × 0.025 stainless steel auxiliary wire from the mid-palatal mini-implant's head to the central incisors' palatal surfaces, secured to both with composite resin.



Potential mini-implant complications

A number of risks and side-effects have been observed with mini-implant clinical usage and in the research literature. Fortunately, these are reversible in most clinical situations, but it is important to consider them in an effort to maximise success and to provide informed patient consent.

Root/periodontal damage

Multiple clinical and animal studies have shown that traumatised root surfaces are repaired within 12 weeks by cellular cementum and periodontal regeneration (provided that there is no infection portal present).[4,5,6,7,8,9,10,11] Orthodontists can be reassured that there are no known reports of tooth anklyosis or loss arising from mini-implant usage. This may be because, in normal clinical usage, if a self-drilling mini-implant contacts a root then the insertion stalls and its tip is highly likely to blunt, preventing extensive penetration of the root tissues. Indeed, the patient is likely to complain of pain even before root contact. Therefore, any irreversible effect from mini-implant and tooth proximity is on the mini-implant: it fails (by becoming mobile) *not* the tooth.[12,13,14,15]

Mini-implant failure

- Primary failure occurs when a mini-implant is clinically mobile at the time of insertion. This is due to inadequate cortical bone support in terms of its thickness and density, or close mini-implant proximity to an adjacent tooth root.[12,16,17]
- Secondary failure refers to a situation where the mini-implant is initially stable but then exhibits mobility, usually after 1–2 months. This delayed instability is due to bone necrosis around the mini-implant threads, which may result from thermal bone damage (during pilot drilling), excessive insertion torque, excessively close proximity to a tooth root, traction overload, or a combination of these.

Perforation of nasal and maxillary sinus floors

There is no evidence that this is problematic in terms of either infection or creation of a fistula. Indeed, the consensus based on dental implant research is that a soft tissue lining forms over a perforating fixture's end. However, in order to maximise bone engagement and minimise patient discomfort it is generally recommended that maxillary alveolar insertion sites should be within 8 mm of the alveolar crest in dentate areas, and closer where maxillary molars are absent.

Damage to neurovascular tissues

Disruption of the inferior dental, mental or greater palatine nerves and blood vessels is highly unlikely given their relative distance from standard insertion sites. The nasopalatine nerve is closer to potential anterior palatal insertion sites, but this can be readily avoided if recommended mid-palatal insertion procedures are followed, e.g. mid-palatal insertion sites ought to be distal to the transverse level of the maxillary canines.

Mini-implant fracture

Fracture, especially of the tip section, may occur when a root is inadvertently contacted and/or the insertion angle is altered with the mini-implant partially inserted into the cortical plate. Fractures of the main portion of a mini-implant body, on either insertion or removal, appear to be a particular risk with mini-implants featuring a narrow diameter and cylindrical body design (Fig. 1.3),[18,19] or when excessive insertion torque occurs (e.g. in the posterior mandible with dense, thick cortical bone). In the rare event that removal of a fractured part is indicated then this involves creating access by raising a small mucoperiosteal flap, trephination of a narrow collar of bone around the mini-implant end, and then derotation of the fractured fragment using a weingarts or mosquitos-like instrument.

Figure 1.3 Intra-oral radiograph of the retained fractured part of a cylindrically shaped mini-implant situated mesial to the maxillary first molar.

Pain

There is often an expectation that high levels of pain will occur, but the opposite is true, such that some patients appear to feel virtually no discomfort during and after insertion.[20,21] The majority of patients appear to experience mild pressure-related pain at the time of insertion and up to 24 hours of low level pain thereafter. This is self-limiting, controlled by simple analgesics (e.g. paracetamol or ibuprofen) and comparable (but of shorter duration) to other orthodontic experiences, such as the effects of separators and aligning archwires.[22] The latter comparison is beneficial when it comes to explaining the likely pain experience to patients who already have a fixed appliance in situ. When it comes to mini-implant removal, local anaesthesia is usually not required and indeed patients find that the injection sensation is worse than the actual discomfort of explantation.[23]

Soft tissue problems

The labial or buccal mucosa adjacent to a mini-implant head may be traumatised especially if the mini-implant has a prominent profile, or sharp edges, or it is inserted in or near loose mucosa (Fig. 1.4). Peri-implant inflammation, analogous to gingivitis around the mini-implant neck, is usually superficial and self-limiting. It is more likely if the mini-implant is either over-inserted in attached gingiva or inserted in an area of mobile mucosa. If tissue hyperplasia fails to resolve with oral hygiene measures, and either interferes with use of the mini-implant or causes patient discomfort, then the mini-implant should be removed (Fig. 1.5). Fortunately, acute infections are rarely seen and are readily resolved by antibiotics or immediate explantation.

Figure 1.4 Labial ulceration caused by this mandibular mini-implant's insertion at the mucogingival junction and by the active movement of the adjacent labial sulcus.

Figure 1.5 (a) Hyperplasia of the palatal mucosa covering an over-inserted mini-implant in the palatal alveolar site between the left molars. (b) Normal tissue appearance after simple excision of the hyperplastic tissue and replacement of this mini-implant. Minor peri-implant hyperplasia is seen on the right side.

Mini-implant migration

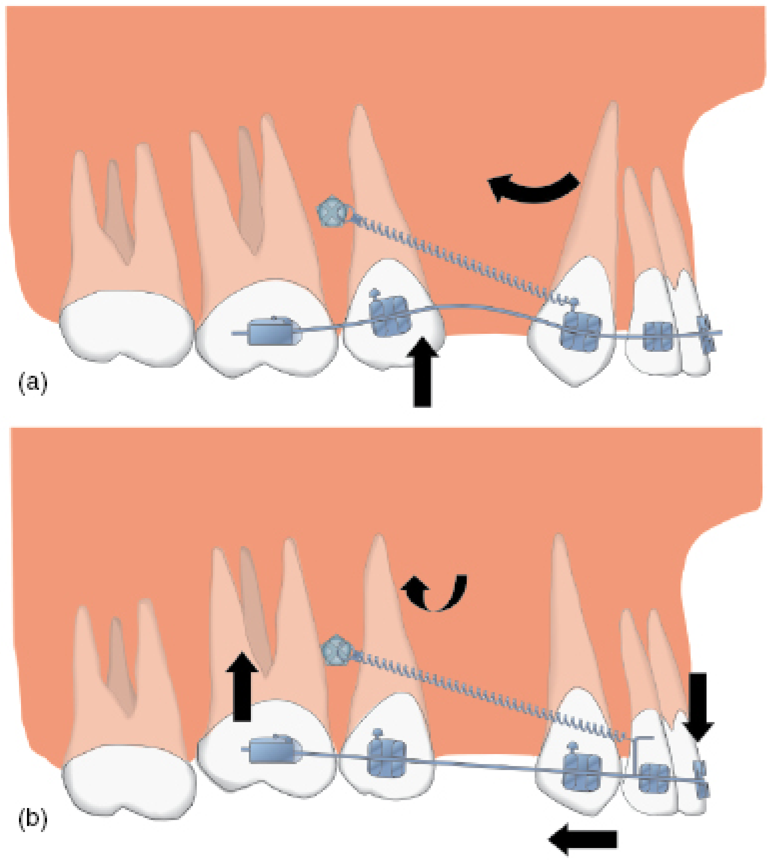
This depends on the head (and neck) to body ratio, on the degree of bone support, and the relative force level. In effect, both self-tapping and self-drilling mini-implants may tip and/or translate bodily in the direction of the applied force.[24,25, 26,27,28] This is problematic if it causes the mini-implant head to approximate an adjacent bracket or crown and cause soft tissue impingement or difficulty in utilising the mini-implant head.

On balance, the risk–benefit relationship for mini-implants appears to be highly favourable for patients with high or atypical anchorage requirements. This means that the consent process (discussed in Chapter Five) should focus on tangible limitations, such as mini-implant instability and pain, rather than on more theoretical risks of tissue damage.

Biomechanical side-effects

In many respects conventional fixed appliances often only exhibit subtle biomechanical side-effects such as frictional binding, tooth tipping and anchorage loss, because these effects are usually localised to single teeth or a group of several teeth. For example, traction applied at the coronal level (to a bracket) may result in tipping and poorly controlled bodily movement of that tooth. Since the adjunctive use of mini-implants provides more profound anchorage, active in all three dimensions and extrinsic to the fixed appliance, the side-effects may also be more strongly expressed and affect the entire arch (when continuous arch mechanics are utilised). Two clear examples of this occur when oblique traction is applied directly from a mini-implant to retract a canine, using traction applied to the canine bracket on either a flexible or rigid archwire. The oblique vector of traction encourages the canine to tip distally causing either a flexible archwire to exhibit a 'rollercoaster' bowing phenomenon (Fig. 1.6a), or a rigid archwire to rotate the entire arch (around its centre of rotation) causing a combination of molar intrusion and incisor extrusion (Fig. 1.6b).

Figure 1.6 Diagrams showing the vertical side-effects of an oblique vector of traction from a buccal mini-implant to the anterior teeth on (a) flexible and (b) rigid archwires. Distal tipping of the canine and a rollercoaster bowing of the archwire occurs in scenario (a), whilst predominantly molar intrusion occurs in (b).



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2

Maximising Mini-implant Success: Clinical Factors

A large number of research papers have been published in the orthodontic (and to a lesser extent in the surgical and dental implant) literature at an ever-increasing rate since the start of this millennium. This collective evidence provides a sound basis for mini-implant usage, although it may be difficult for orthodontists and dental colleagues to keep track of all this new information. Consequently, this chapter aims to collate and summarise the essential findings of the most relevant scientific and clinical research papers, in order that orthodontists may both understand and maximise their clinical usage of mini-implants.

Overall success rates

Mini-implant success is generally defined as the fixture remaining stable under continuous orthodontic loading for a minimum of 6 months, although many papers use a year as the minimum term. There is a consensus in the present literature that the success rate varies according to anatomical sites, e.g. 80 and 90% for the mandible and maxilla respectively.[1,2,3,4,5,6,7,8,9,10,11,12] This seems counter-intuitive since the mandible is generally regarded as the stronger jaw bone, but the reasons for this paradox will be explained here. Interestingly, mini-implants with minor mobility may still be graded as successful. This is evident clinically by slight rotational or lateral movement of the mini-implant on manipulation. This is painless and consequently asymptomatic for the patient. It is easily resolved by tightening the mini-implant, usually by one half to a full clockwise rotational (insertional) turn, provided that this does not submerge the head, and without the need for anaesthesia. When the mini-implant displays obvious lateral mobility with light digital pressure then this indicates failure and the mini-implant should be removed. Fortunately, most mini-implant failures become clinically evident within the first few months of insertion,[4,8,9] enabling early replacement or a modification to the treatment plan. Conversely, when a mini-implant feels firm after two months in situ then normal orthodontic forces may be applied with confidence.

Factors affecting mini-implant success

These are generally subdivided into three categories: patient, mini-implant and technique factors, and will be discussed accordingly.

Patient factors

Whilst mini-implant success appears to be unaffected by patient gender, the antero-posterior skeletal relationship, dental crowding, periodontal and temporomandibular status, several factors clearly affect stability. Their basis and clinical consequences are summarised below.

Cortical bone thickness and density

A combination of clinical, animal and artificial bone studies has demonstrated that the most important patient determinants of primary stability are the density and thickness of the maxillary and mandibular cortical plates. This helps to explain the variations seen in clinical studies of mini-implant success rates where both anatomical sites and individuals differ in terms of the cortical bone layer's quantity and quality.[13] The key facts to consider are:

- Cortical depth typically ranges from 1 to 2 mm and generally increases towards the apical aspect of the alveolus. In the maxillary alveolus cortical depth peaks both mesial and distal to the canines (the canine eminence) and the first molars, which partly accounts for the frequent use of these sites for anterior and posterior anchorage points, respectively. The maxillary alveolar cortex is thicker on the palatal than the buccal side, which contributes to the value of palatal alveolar insertions in anterior openbite correction (discussed in Chapter Nine), and the highest alveolar values for both jaws occur in mandibular molar sites.[14,15,16,17,18,19,20,21]
- An increase in either the cortical thickness or density leads to an increase in insertion torque (the resistance to rotational insertion).[22,23,24,25,26,27,28] Thickness and density are co-dependent factors with density appearing to be the more influential factor in terms of mini-implant primary stability.[24,25] The density of the underlying cancellous bone is much less relevant, except where the cortex is less than 1 mm thick, as occurs in some patients' maxillary sites, and provides inadequate stability on its own.[25]
- The ideal range of maximum insertion torque appears to be 5–15 Ncm for alveolar sites.[11,23,29,30,31,32,33] Maximum torque occurs during final seating of the mini-implant and is felt as an increase in resistance on turning a manual screwdriver, such that difficulty in digital rotation typically equates to the top of this torque

range. This is clinically valid without it being necessary to measure this in individual patients. In effect, low torque equates to poor *primary* stability (inadequate cortical support) and excessive torque results in *secondary* failure because microscopic bone stress leads to subclinical ischaemic necrosis around the mini-implant threads. This manifests clinically as the mini-implant screwing in with little resistance at the low end of the scale, and it being difficult to manually turn the screwdriver at the high end. Such excessive torque, especially in posterior mandibular sites, may be avoided by initial perforation of the cortical plate, as described later.

- Cortex depth and density are greater in the mandible than the maxilla.[34] In theory the mandible may provide greater primary stability, but the reported mandibular success rates are less than those for the maxilla because excessive insertion torque appears to cause high levels of peri-implant bone stress, resulting in secondary microscopic bone necrosis around the threads and hence mini-implant failure.[29]
- Cancellous bone, which has a similar density in both jaws,[34,35,36] has little effect on primary stability, except when the cortex is less than 1 mm (as seen in some maxillary sites). In the long-term cancellous bone may influence secondary stability in terms of stabilising the mini-implant body against migration and tipping.[26,28,37]

Interproximal space

The literature provides data on the *average* amount of interproximal space available for mini-implant insertion, but it is crucial to recognise that there is wide individual variation depending on the adjacent teeth’s root size, shape