The extent of movement and countermovement does, however, depend on the anchorage strength of the individual teeth, i.e., on the number and length of the roots, the root surface, and the structure of the surrounding bone.

Anchorage quality can be divided into three categories:
1. minimum anchorage;
2. medium anchorage; and
3. maximum anchorage.

These three categories can be described using the example of a conventional canine retraction after removal of a first premolar (Fig. 1).

In the case of minimal anchorage, the support is provided by the individual teeth. Figure 1a shows that a single premolar is not sufficient as an abutment to distalise a canine. The premolar is clearly mesialised in reaction to the application of force.

Figure 1b shows how two, equally strong, anchorage segments are formed. Action and reaction are comparable in this case; the result is reciprocal tooth movement.

In the case of maximum anchorage (Fig. 1c), the posterior group of teeth is secured and held stationary by using a miniscrew. The canine can be retracted by the complete force vector, as the reactive force is completely absorbed by the anchorage block formed.

Apart from anchorage quality, the basis, i.e., the type of anchorage location, plays a role:

Dental or desmodontal support:
- use of additional intra-oral devices (nance, palatal arch, lingual arch, lip bumper);
- modification of fixed appliance (buccal root torque, blocking);
- incorporation of the teeth of the other jaw (Class II or III elastic bands).

Extra-oral support:
- headgear; and
- face mask.

Enossal support:
- implants, miniscrews, etc.

This article only deals with anchorage in bony structures. The terms skeletal or cortical anchorage are used interchangeably in this case.

History and overview of skeletal anchorage
Bone anchorage has its roots in Gainsforth’s unsuccessful attempt to insert screws into the jawbone as load anchors in 1945. Many later experiments were unsuccessful and the method had become obsolete by the late 1970s.

From 1980 onward, various research groups (such as Creekmore, Roberts, and Turley2–7) took up the subject once more. Creekmore published the first, clinically successful patient treatment case.

There are now numerous options for cortical anchorage (Fig. 2), including (artificial or pathologically) ankylosed teeth on the basis of miniplates normally used in cranio-maxillo-facial surgery and the use of prosthetic implants.

In recent years, the requirements for cortical anchorage techniques have been defined in the literature. However, upon closer inspection, only orthopaedic mini-implants met these requirements favourably, in terms of:
- biocompatibility;
- small size;
- simplicity of insertion and use;
- primary stability;
- immediate load capacity;
- adequate resistance against orthodontic forces;
- usability with standard orthodontic appliances;
- independence of patient cooperation;
- clinically superior results in comparison with standard alternatives;
- ease of removal; and
- cost-effectiveness.

Fig. 1a-c: After removal of the first premolar, the canine is to be retracted; results for a) minimum, b) medium or reciprocal and c) maximum anchorage.

Fig. 2: Overview of the range of cortical anchorage options.

Figs. 3a, 3b: Clinical example of two typical miniscrew treatment applications: gap closure (3a) and straightening of tooth No. 7.

Figs. 4a, 4b: One-sided gap closure in the left lower jaw. Miniscrews prevented the expected reactive side effect of subsequent shifting of the middle line.

Figs. 5a–5h: Eight examples of the more than 700 different forms of miniscrews currently available: a) Ortho easy (FORESTADENT), b) Aarhus Mini Implant (Medicon), c) AbsoAnchor (Dentos), d) Dual-Top (Irel Medical), e) LOMAS (Mondial), f) Osas (Deurimed), g) Spider Screw (HDC) and h) tomas-pin SD (DENTALURUM).
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Mini-implants
Any form of skeletal anchorage, including miniscrews, is by definition an implant: “An implant is an artificial material implanted into the body, which is to remain there either permanently or for an extended period.”

More than 30 different terms for orthodontic screws are used in the international literature. The most common of these are mini-implant and miniscrew, while the terms minipin or pin are preferred when speaking to patients.

At present, there are more than 30 manufacturers of miniscrew systems (Fig. 5a–h). The number of screws per system ranges from two to 154 different types.

In order to assist practitioners in selecting such devices according to their practice’s needs, the most important decision-making criteria for choosing implant systems are discussed below.

Material
All miniscrews are made from pure titanium or from an alloy of titanium with aluminium or vanadium. The biocompatibility of such materials, the metal surface of which is in direct contact with the bone, has been firmly established.11–14

Osseointegration
Brånemark was the first to define the concept of osseointegration, which he described as “a direct functional and structural link between living bone tissue and the surface of a force-absorbing implant.”15–17

Several authors, such as Costa and Maino, view anchoring a miniscrew not as osseointegration, but as a skeletal resistance block.18,19 In the opinion of Cope and Bumann, miniscrews are anchored by mechanical stabilisation and not by osseointegration.20,21

Diameter of the miniscrew
The diameter of the miniscrews on the market varies between 1.2 and 2.5 mm. Diameter specifications of a screw normally refer to its outer diameter, i.e., the size of the shaft, including the thread.

For secure and primarily mechanical anchorage, a certain amount of bone is required around the screw. To date there have been no studies on the amount of bone actually required; the information available suggests 0.5 to 2 mm. At an interradicular level, the amount of space available prescribes the maximum diameter of the screw. Poggio et al.22, Schnelle et al.23, and Costa et al.24–25 provide some suggestions as to the vertical space required, i.e., the space between the enamel/cement interface and the mucogingival line. These investigations clearly indicate that the diameter of a mini-screw should not exceed 1.6 mm. It should be noted that the stability of a miniscrew in the bone depends on its diameter and not on its length.26–27

Length of the miniscrew
The length of the miniscrews on the market varies between 5 and 14 mm. Length specifications of a miniscrew usually refer to the shaft, i.e., the threaded section.

Like the diameter, the length of the screw selected depends on the amount of bone available. Depending on the region, the total thickness of the bone is between 4 and 16 mm.28

The length of a screw is of secondary importance to the diameter when it comes to secure anchorage, as mentioned above. Various studies have shown that it is the thickness of the cortical section that plays a more important role.29–31 As far as the distribution of force over the body of the screw is concerned, FEM analyses have shown that the load is applied only in the region of the cortical bone.29–31

When selecting the length of the screw, the depth of the gingiva must also be taken into account, with an average layer depth of 1.25 mm. Thus, the ratio between the length of the head (the part of the screw outside the bone) and the length of the threaded section (the part of the screw inside the bone) should be at least 1:1.

Poggio et al.22 recommend lengths of 6 to 8 mm. Costa24,25 suggests miniscrews with a length of between 6 and 10 mm. Based on these studies, it would appear that it’s not necessary to use longer screws. This has been confirmed by numerous clinical studies.

Easy identification of length and diameter through colour-coding of the screws can be accomplished by means of anodisation, using for example, Ortho easy (FORESTADENT).
A positive side effect of this is that the oxide layer formed results in firmer anchorage of the implant in the bone. A positive side effect of this is that the oxide layer formed results in firmer anchorage of the implant in the bone.34

Screw head
Some suppliers have a special head variant for each potential application in their range, such as:

- hook tops;
- ball-shaped heads;
- eyelets;
- simple slots;
- cross-shaped slots; and
- universal heads (Figs. 8a–8d).

The screw head should be very small and compact, to ensure that the patient experiences minimal discomfort. However, it must be large enough for the coupling elements to be securely fastened to it (Figs. 9a, 9b).

Transgingival portion
The transgingival portion, also known as the gingival neck, is the most vulnerable part of an implant or a miniscrew. Perforation of the gingiva provides a potential access point for microorganisms, posing the risk of perimucositis or peri-implantitis. This is one of the main causes of the premature loss of miniscrews.35–36 During the immediate post-operative phase, the mucosa should be as close as possible to the screw, to seal the area.37 The most advantageous shape transgingival collum is that of a cone, as this shape naturally results in safe sealing without a pressure zone. This makes it more difficult for micro-organisms to penetrate, thus preventing infections. The cone shape also seals the perforation wound, as a cork would seal a bottle, thus reducing bleeding.

Conclusion
The correct method of anchorage with regard to shape and quality is crucial for successful treatment. Maximum anchorage is not necessary in all cases, and thus, neither is the use of a miniscrew necessarily essential. From an historical point of view, the cortical anchorage system is, in common with other jaw orthodontic techniques, not new at all. The idea was conceived more than 75 years ago.

Of all forms of skeletal anchorage, the mini-implant is the most universally used and is the most suitable for routine use. However, before practitioners can select the most appropriate miniscrew for use in their practice from the large range on offer, they will need to review the literature thoroughly.38

Editorial note: A complete list of references is available from the publisher. This article first appeared in Dental Tribune Asia Pacific, Nos. 1 & 2, 2009. The next edition of Ortho Tribune will feature “Part II — Basic information on the insertion of miniscrews.” All photos were provided by the authors.