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MINISCREWS: DESIGN CONSIDERATIONS IN ORTHODONTICS

Orthodontics

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ABSTRACT

The field of orthodontics has seen a tremendous increase in the use of Temporary anchorage devices (TADs) , which help to cater the anchorage demands of different treatment situations, at the same time reducing unwanted effects of orthodontic forces. Miniscrews are the most commonly used TADs, which are effective in most clinical situations. This review covers in detail about the parts of a miniscrew, the materials used for fabrication and the clinical significance. Fine details like thread pitch , thread shape and thread depth of different designs of miniscrews are also explained in depth along with a note on safe zones for miniscrew placement. Relevant articles from Pubmed, Web of science and Google scholar were selected for review.

KEYWORDS

Miniscrew, Temporary anchorage device, Implant , Stability, Implant design, Thread pitch

INTRODUCTION

Miniscrews are widely used for Orthodontic treatment in the recent days due to their ability to offer immediate bony anchorage for tooth movement. Instead of using posterior teeth, especially the molars for anchorage, these screws, which are placed in either inter-radicular, extra-radicular or palatal bone, provide adequate anchorage for tooth movement, thus eliminating the problem of anchor loss.[1],[2]They are often referred to as temporary anchorage devices (TADS). The performance and utility of Tads is greatly influenced by their designs.[3] In the current literature, there is no article, to the best of our knowledge, which gives a detailed description of the design consideration of miniscrews. Hence this article aims to provide an understanding of the design considerations of miniscrews and their significance in clinical practice.

Historical Background

- Gainsforth and Higley1945 gave the first report of skeletal anchorage with 13mm Vitallium screws in mongrel dogs.[4]
- Linkow 1969 used blade implants followed by direct force application to anchor Class II elastics.[5]
- Branemark in 1983 demonstrated stable osseointegration of titanium implants.[6]
- Creekmore and Eklund 1983 intruded an elongated maxillary incisor using a Vitallium screw.[7]
- Roberts et al 1989 used a conventional two-stage endosseous implant as anchorage to successfully protract two mandibular molars 10–12 mm into an atrophic edentulous ridge.[8]
- Kanomi 1997 used a Titanium mini screw of 1.2 mm diameter and 6 mm of length for orthodontic anchorage for intrusion of a mandibular central incisor.[9]
- Block and Hoffman in 1995 employed an Onplant system consisting of a titanium alloy disc with a hydroxyapatite coating on one side and an internal thread on the other.[10]
- Melson and Costa 1997 started using a system of 2mm-diameter miniscrews with cross heads made for surgical screws in plastic surgery.[11]
- Sugawara et al. proposed a new skeletal anchorage method for correcting open bite malocclusions consisting of a titanium miniplate temporarily anchored in the maxilla or mandible for molar intrusion[12,13]

TAD SYSTEMS

System	Year	Manufacturer	Designer
Orthoanchor K-1 system	1997	Dentsply-Sankin Japan	Kanomi R
Aarhus Anchorage System	1998	Medicon, Germany	Costa A Melsen B
MIA	2001	Dentos korea	Park HY, Kyung HS et al.
LOMAS	2002	Dentaurum, Germany	Lin J, Liou E
Abso-anchor	2003	Dentos Korea	Kyng, Park, Bae et al.
Spider Screw Anchorage System	2003	HDC, Italy	Maine BG et al.
Miniscrew anchorage system (MAS)	2005	Micerium, Italy	Carano A et al.
Vector TAS	2005	Ormco, Netherlands	Graham J et al.
IMTEC Mini Ortho Implant	2005	IMTEC (USA)	Cope JB
Infinitas	2007	DB orthodontics (UK)	Cousley R
Favanchor		SH pitkar	

Design Considerations

Material

Mini screws are fabricated from Cobalt-Chromium (CoCr) base alloy, pure titanium , titanium alloy, stainless steel, ceramics and polymeric materials.

CoCr Base Alloy: Gainsforth and Highley found loss of the bone screws placed in dog jawbones. Eventhough tooth movement was obtained, the screws were not stable and were found to loosen due to adverse bone reactions . Hence the usage of this alloy was abandoned and no miniscrews are currently fabricated from this alloy.

Pure Titanium And Titanium Alloy: These are the most widely used material for miniscrews. Excellent osseointegration is one of the advantage of pure titanium but implants made of this are brittle thus reducing the penetration ability. So then came the titanium alloy which reduced breakage with self drilling as an added advantage. The most widely used titanium alloy (grade 5) for this purpose is Ti-6Al-4V. It has high strength but relatively low ductility[14].

Stainless Steel: Bioray of Taiwan came up with stainless steel miniscrews. These screws obtain retention through mechanical lock which facilitates immediate loading following insertion. Their penetration is greater when compared to miniscrews made of pure titanium or titanium alloy. The simplicity of placement of stainless steel miniscrews is another advantage[15]. Although majority of miniscrews in the market are made of titanium alloy. For extra radicular bone screws, pure stainless steel is the material of choice. This is due to their higher fracture resistance, which is essential as these are typically inserted in the Infrazygomatic crest and buccal shelf regions having DI (>1250 HU) quality bone[15].

Shape
Miniscrews are available in cylindrical, tapered and hybrid shapes.

Cylindrical – these miniscrews usually have a blunt tip, with uniform diameter from head to tip. Hence this requires pre-drilling.

Tapered/ Conical – the diameter of the tip is smaller than that of the head for easier drilling of bone. Hence predrilling is not required and the insertion procedure is made simpler. Tapered miniscrews are extensively used to reduce the chance of contact with adjacent root.

Hybrid – This type features a dual core that combines conical and cylindrical structures in a single miniscrew[17].There was no documented change in the BIC value, removal torque, or success rate in either humans or animals, despite the tapered mini-screw implant's increased torque compared to the cylindrical mini-screw[18,19].

DIAMETER
The standard diameters of available miniscrews range from 1.2 mm to 2.3 mm; this measurement often refers to the external diameter. Poggio et al, Sung et al and Park et al suggested a optimal diameter range of 1.2 to 1.5 mm[20]. Comparatively extra-radicular bone screws (IZC, BS) are larger in size with a minimum diameter of 2mm[16].

Miyawaki et al tested tested miniscrews with outer diameters of 1.0 mm, 1.5 mm, and 2.3 mm and found that all of the 1.0 mm wide miniscrews failed whereas the broader miniscrews were 84-85% successful.[21] Another study by Wiechmann et al 1.6 mm wide miniscrews had a higher success rate than 1.1 mm miniscrews.[22]

Length
Miniscrews range in length from 4mm to 15mm, which normally refers to length of the threaded shaft. A 1:1 ratio of mini-screw that is within the bone and part outside the bone is preferred. Costa et al observed that, miniscrews with a length between 6mm and 10mm are appropriate for most clinical situations.[23] Poggio et al recommended mini-screw lengths between 6mm and 8mm.[24] Miniscrews of 6mm would primarily be employed in the mandible, 8mm for applications in either the maxilla or the mandible, and 10mm in the maxilla or possibly in situations where bi-cortical anchorage is necessary or in retromolar portions of the mandible. Extra radicular bone screws which are usually larger in size than inter radicular miniscrews usually have lengths ranging from 10 to 14mm[16].

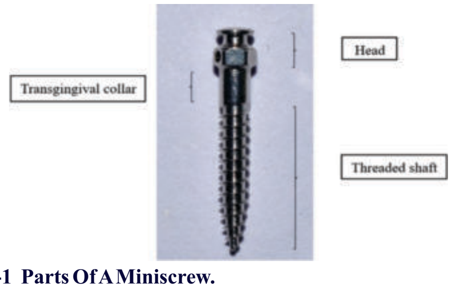

Figure-1 Parts Of A Miniscrew.

Parts Of A Miniscrew
Miniscrew consists of three parts, the head,neck/ transgingival collar and the threaded shaft (Figure-1)

HEAD
The "head" is frequently regarded as the most crucial component of miniscrews. The screw's head needs to be attached to a variety of orthodontic components like wires and accessories . There are various mini screw head design options.

Types Of Mini-Screw Head[15] (Figure 2)
- Cross cut head
- Hole head
- Hook head
- Mushroom head
- Bracket head
- Small head
- No head
- Long head
- Circle head
- Power head
- Fixation head
- Double head
- Golf head
- Tube head
- Joint head

Crosscut Head
Crosscut heads with two perpendicular grooves are a common feature of surgical screws used for bone fixation. These grooves serve to accommodate the driver during insertion. The crosscut head is too large for auxiliary attachments when used for orthodontic purposes.

Hole Head
The screw head has a hole in this design. The head of the screw is substantially higher than other screw heads to accommodate the hole. Patients may find it uncomfortable due to irritation caused by the longer head .This type of mini-screw is useful for closed method of insertion in which the mini-screw and its attachments are embedded beneath the mucosa. The drawback of holes is that it makes the head high, which weakens the screw and increases the chance of breakage.

Hook Head
It has a hook on top of the screw head. Among commercially available miniscrews, this design has the smallest head. Placement of elastics, e-chains or coil springs is made simple by the hook. The clinician, however, must be aware of the head orientation. If the mini-screw is overturned when adjusting the hook for applying orthodontic forces, the tissue impingement that results can lead to inflammation and can even cause loosening of the mini-screw. If it is de-rotated to correct the orientation, that can also lead to loosening related problems.

Mushroom Head
It has a small mushroom shaped head design that facilitates attachment and retention of orthodontic auxiliaries. The small size of the head makes it more acceptable to patients.

Bracket Head
The mini-screw can be used as an orthodontic bracket once it is inserted. Use of this type will be convenient if the mini-screw is on the same occlusal plane as the dentition, but most of the time it is not. Attaching a coil spring or power chain is challenging due to the design. They are also more expensive.

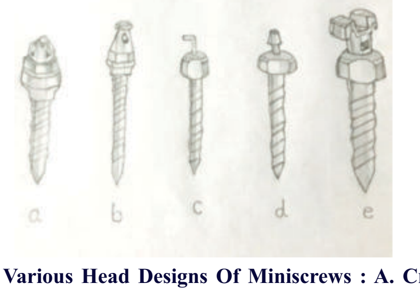

Figure 2: Various Head Designs Of Miniscrews : A. Cross Cut Head B. Hole Head C. Hook Head D. Mushroom Head E. Bracket Head

Transgingival Collar / Neck

It is the sensitive portion of miniscrews and implants. The mucosa should create a seal around the mini-screw right after insertion. This is dependent on the design and the size relationship between the transgingival collar and the head.

Mini-screw transgingival parts have been created in four basic configurations: cylindrical, conical, poly-angular and in some cases there may be no collar or neck, where the thread extends all the way to the head. For screws with a cylindrical neck, depending on the insertion angle, pressure zones can develop. The likelihood of these harmful pressure zones can be reduced by cone-shaped collars, especially if a tissue punch is employed before insertion. There will probably be a closer proximity of the soft tissue to the collar if the diameter of the transgingival section of the miniscrew is a little greater than that of the hole punch. Furthermore, the cone shape helps to seal the perforation wound, similar to how a cork shuts a bottle, and therefore minimizes bleeding. Some miniscrews have hexagonal transgingival collars because a hexagonal driver engages this region of the screw. As a result, either the insertion driver will pressure the soft tissue during insertion or the screw will not be fully inserted, both of which are undesirable.

Most miniscrews have transgingival collar lengths ranging from 1 mm to 3 mm, which meets Mampieri's requirements for traversing the usual thickness of gingival tissue in most applications[20].

Relationship Between Transgingival Collar And The Screw Head

There are three possible configurations of head-to-transgingival collar diameter relationship : diameter of collar < head, collar = head; collar > head. It is advised that the diameter of the head be less than or equal to the diameter of the collar in order to prevent inflammation around the screw. If a part of the miniscrew covers the gingiva around the screw, cleaning that area will be challenging.

Shank And Thread Geometry

The basic body of a screw is known as shank. This is the part where threads are cut. The thread geometry is a major factor affecting biomechanical properties of mini implants. Thread geometry may vary according to pitch, depth and shape. The primary goal of thread design is to maximise initial contact, increase surface area, and enable stress dissipation at the bone-implant inter-face[25].

By altering three geometric thread parameters, the functional surface area per unit of length of the implant can be modified. The following parameters can be altered (Figure 3)

- Thread pitch
- Thread shape
- Thread depth

Thread Pitch

Jones(1964) defined thread pitch as: "The distance from the center of the thread to the center of the next thread, measured parallel to the axis of a screw".[23] Thread pitch can be 0.5mm, 0.75mm, 1mm etc.

Larger removal torque values are required for smaller thread pitches[27]. When using orthodontic force, a smaller thread pitch avoids lateral displacement[28,29]. Another study concluded that smaller thread pitches have larger insertion torque[30].

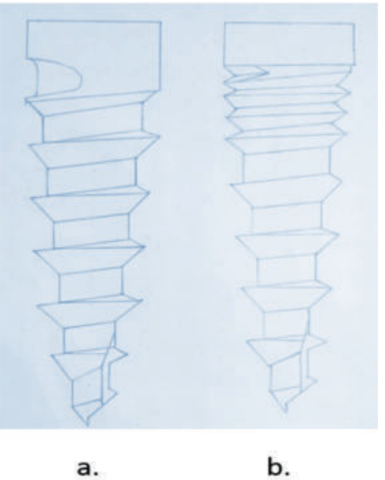

Figure 4: Two Types Of Thread Configurations A. Single Thread Shape B. Dual Thread Shape

Double or dual threading miniscrews come in two different pitches (Figure 4). To maximise contact between the upper half of the mini-screw and the cortical bone, the upper part of the mini-screw has a narrower pitch. Comparing the dual thread shape to the cylindrical and conical shapes, the dual thread shape demonstrated a lower insertion torque and a larger removal torque[31]. Dual thread miniscrews may enhance stability while being less damaging to the nearby bone structure. On contrary, Lee et al observed that dual thread miniscrews did not offer higher stability and clinical success compared to other designs.[32] This design also requires a longer insertion time, which could generate too much heat and cause tissue damage. In such cases a pilot drilling and slower rotational manoeuvring may be helpful.

Thread Shape

It has also been discovered that the geometry of the implant thread shape affects the kind of force that is applied to the nearby bone. The first implants that were introduced were V-shaped. A number of different kinds of V-shaped thread designs were created as a result of the study of stress patterns.

Thread designs of presently available dental implants are (Figure 5)

- V-shape
- Square shape
- Buttress
- Reverse buttress
- Spiral

The primary stability of the miniscrew is reportedly influenced by the thread shape.[37] According to some studies, miniscrews with asymmetric thread designs exhibit better mechanical characteristics[38,39]. Study by Gracco et al concluded that the resistance to removal of the orthodontic miniscrews was affected by thread design. The highest pullout strength was provided by the reverse buttress thread than the other designs.

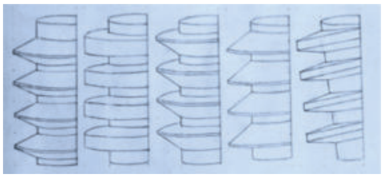

Figure 5: Different Thread Shapes : A. V Shape B. Square Shape C. Buttress D. Reverse Buttress E. Spiral Shape

Thread Depth

It is the difference between inner and outer diameter. In the harder cortical plate , thread depth should be between 0.4mm and 0.6mm. While in the softer substantia spongiosa, a greater difference is preferred.

Studies have shown that higher stability is shown by miniscrews with greater thread depth.[37,38,39] Thread shape factor (TSF) is the ratio between thread depth and pitch[36]. Smaller pitch and larger thread depth exhibit greater pullout strength[38,41,42]. According to Chang et al, miniscrews function best when the core/external diameter ratio is 0.68, for a mini-implant with a fixed external diameter of 2 mm, a thread length of 9.82 mm, and a pitch of 0.75 mm[43].

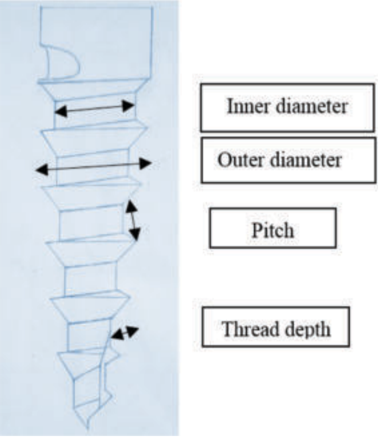

Figure 3. Detailed Description The Parameters Of Implant Design

Safe Zones For Mini-screw Positioning

Mini implants should be carefully placed without causing root damage or puncturing significant local anatomical features. According to Poggio et al[44]

In Maxillary Arch:

A) Five to eight mm from the alveolar crest of interradicular space between the first molar and second premolar.

B) Five to 11 mm from the alveolar crest between the second and first premolar and the first premolar and canine.

In Mandibular Arch:

A) Interradicular spaces between the second and first molar, and second and first premolar

B) 11 mm from alveolar crest of interradicular spaces between the first molar and second premolar and between the first premolar and canine.

CONCLUSION

Mini-screw's success appears to be primarily dependent on the following factors: Material used for fabrication, screw dimension, design and insertion technique. Hence selection of an appropriate screw plays the major role in treatment success. Anatomical concerns place a limit on the mini-screw length and diameter that can be used in a clinical procedure. On an average, a screw of length 8mm and a diameter of 1.5mm would suffice for most of the clinical applications. In order to provide wide range of possibilities for attaching mini-screw to the rest of the orthodontic device, numerous designs have been introduced recently. As a minimum requirement they should feature a neck that can vary in size to meet the varied mucosa thickness, a hole for ligature wire or elastic thread, and a collar to attach elastomeric thread, power chain, or coil springs. Ongoing research needs to be focused on creating improved operator-friendly design characteristics, so that orthodontists incorporate miniscrew usage in their routine practice.

REFERENCES

1. Al Amri MS, Sabban HM, Alsaggaf DH, Alsulaimani FF, Al-Turki GA, Al-Zahrani MS, Zawawi KH. Anatomical consideration for optimal position of orthodontic miniscrews in the maxilla: a CBCT appraisal. Annals of Saudi Medicine. 2020 Jul;40(4):330-7.
2. Yu WP, Yu JH, Wang SH, Hsu JT. The Effects of Diameter, Length and Insertion Method on the Stability of Orthodontic Miniscrew. Journal of Medical and Biological Engineering. 2022 Aug;42(4):508-15.
3. Watanabe K, Mitchell B, Sakamaki T, Hirai Y, Kim DG, Deguchi T, Suzuki M, Ueda K, Tanaka E. Mechanical stability of orthodontic miniscrew depends on a thread shape. Journal of Dental Sciences. 2022 Jul 1;17(3):1244-52.
4 Gainsforth BL, Higley LB. A study of orthodontic anchorage possibilities in basal bone. Am J Orthod Oral Surg. 1945 Aug 1;31(8):406–17.
5. Linkow LI. The endosseous blade implant and its use in orthodontics. Int J Orthod. 1969;7(4):149–54.
6. Branemark PI. Osseointegration and its experimental background. J Prosthet Dent. 1983;50(3):399–410.
7. Creekmore TD, Eklund MK. The possibility of skeletal anchorage. J Clin Orthod. 1983; 17: 266-269.
8. Roberts WE, Helm FR, Marshall KJ, Gongloff RK. Rigid endosseous implants for orthodontic and orthopedic anchorage. Angle Orthod 1989; 59: 247-255
9. Kanomi R. Mini-implant for orthodontic anchorage. J Clin Orthod. 1997; 31(11):763-767.
10. Block MS, Hoffman DR. A new device for absolute anchorage for orthodontics. Am J Orthod Dentofacial Orthop. 1995;107 (3):251–8.
11. Costa A, Raffainl M, Melsen B. Miniscrews as orthodontic anchorage: a preliminary report. Int J Adult Orthodon Orthognath Surg. 1998;13(3):201–9.
12. Umemori M, Sugawara J, Mitani H, Nagasaka H, Kawamura H. Skeletal anchorage system for open-bite correction. Am J Orthod Dentofacial Orthop. 1999;115(2):166–74.
13. Sugawara, J., Baik, U.B., Umemori, M., et al. 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 Orthod Orthognath Surg. 2002;17(4):243–253.
14. Paik CH, Park I-K, Woo YJ, Kim T-W. Orthodontic miniscrew implant. 2009.
15. Jong Lin JL. Text book of Creative Orthodontics: Blending the Damon System and TADs to Manage Difficult Malocclusions. Taipei, Taiwan: Yong Chieh; 2007
16. Ghosh A. Infra-Zygomatic Crest and Buccal Shelf - Orthodontic Bone Screws: A Leap Ahead of Micro-Implants – Clinical Perspectives. J Indian Orthod Soc. 2018;52 (4_suppl2):127–41.
17. Aldo Carano, Stefano Velo, Paola Leone GS. Clinical Applications of the Miniscrew Anchorage System. J Clin Orthod. 2005;
18. Yoo SH, Park YC, Hwang CJ, Kim JY, Choi EH, Cha JY. A comparison of tapered and cylindrical miniscrew stability. Eur J Orthod. 2014 Oct 1;36(5):557–62.
19. McManus MM, Qian F, Grosland NM, Marshall SD, Southard TE. Effect of miniscrew placement torque on resistance to miniscrew movement under load. Am J Orthod Dentofac Orthop. 2011 Sep;140(3).
20. Björn Ludwig, Sebastian Baumgaertel, S. Jay Bowman. Mini-implants in orthodontics; Innovative anchorage concepts. 2008
21. 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 Dentofac Orthop. 2003 Oct 1;124(4):373–8.
22. Wiechmann D, Meyer U, Büchter A. Success rate of mini- and micro-implants used for orthodontic anchorage: a prospective clinical study. Clin Oral Implants Res. 2007 Apr;18(2):263–7.
23. Costa A, Raffainl M, Melsen B. Miniscrews as orthodontic anchorage: a preliminary report. Int J Adult Orthodon Orthognath Surg. 1998;
24. Poggio PM, Incorvati C, Velo S, Carano A."Safe zones": A guide for miniscrew positioning in the maxillary and mandibular arch. Angle Orthod. 2006 Mar 2;76(2):191–7.
25. Ivanoff CH, Grönhahl K, Sennerby L, Bergström C, Lekholm U (1999) Influence of variations in implant diameters: a 3- to 5-year retrospective clinical report. Int J Oral Maxillofac Implants 14:173–180
26. Abuhussein H., Pagni G., Rebaudi A., Wang H.L., 2010, The effect of thread pattern upon implant osseointegration, Clinical oral implants research21(2): 129-136.
27. Kim, K.-H.; Chung, C.; Yoo, H.-M.; Park, D.-S.; Jang, I.-S.; Kyung, S.-H. The Comparison of Torque Values in Two Types of Miniscrews Placed in Rabbits: Tapered and Cylindrical Shapes—Preliminary Study. Korean J. Orthod. 2011, 41, 280.
28. Pouyafar, V.; Meshkabadi, R.; Sadr Haghighi, A.H.; Navid, A. Finite Element Simulation and Statistical Investigation of an Orthodontic Mini-Implant's Stability in a Novel Screw Design. Proc. Inst. Mech. Eng. Part H J. Eng. Med. 2021, 235, 1046–1057.
29. Budsabong, C.; Trachoo, V.; Pittayapat, P.; Chantarawaratit, P. The Association between Thread Pitch and Cortical Bone Thickness Influences the Primary Stability of Orthodontic Miniscrew Implants: A Study in Human Cadaver Palates. J. World Fed. Orthod. 2022, 11, 68–73.
30. Migliorati M, Benedicenti S, Signori A, Drago S, Barberis F, Tournier H, et al. Miniscrew design and bone characteristics: an experimental study of primary stability. Am J Orthod Dentofac Orthop. 2012;142(2):228–34
31. Kim Y-K, Kim Y-J, Yun P-Y, Kim J-W. Effects of the taper shape, dual-thread, and length on the mechanical properties of mini-implants. Angle Orthod. 2009;79(5):908–14
32. Lee Y, Choi S-H, Yu H-S, Erenebat T, Liu J, Cha J-Y. Stability and success rate of dual-thread miniscrews: a retrospective study using the buccal alveolar region as the insertion site. Angle Orthod 2012;91:509e14.
33. Wilmes B, Ottenstreuer S, Su Y-Y, Drescher D. Impact of implant design on primary stability of orthodontic mini-implants. J Orofac Orthop 2008;69(1):42–50.
34. Carano A, Lonardo P, Velo S, Incorvati C. Mechanical properties of three different commercially available miniscrews for skeletal anchorage. Prog Orthod. 2005;6(1):82–97.
35. Hou S-M, Hsu C-C, Wang J-L, Chao C-K, Lin J. Mechanical tests and fi nite element models for bone holding power of tibial locking screws. Clin Biomech (Bristol Avon). 2004;19(7):738–45.
36. Gracco A, Giagnorio C, Incerti Parenti S, Alessandri Bonetti G, Siciliani G. Effects of thread shape on the pullout strength of miniscrews. Am J Orthod Dentofac Orthop. 2012;142(2):186–90.
37. DeCoster TA, Heetderks DB, Downey DJ, Ferries JS, Jones W. Optimizing bone screw pullout force. J Orthop Trauma. 1990;4(2):169–74.
38. Chapman JR, Harrington RM, Lee KM, Anderson PA, Tencer AF, Kowalski D. Factors affecting the pullout strength of cancellous bone screws. J Biomech Eng. 1996;118(3):391–8.
39. Johnson NL, Galuppo LD, Stover SM, Taylor KT. An in vitro biomechanical comparison of the insertion variables and pullout mechanical properties of 6.5-mm standard cancellous and 7.3-mm self-tapping, cannulated bone screws in foal femoral bone. Vet Surg. 2004;33(6):681–90.
40. Migliorati M, Signori A, Silvestrini-Biavati A. Temporary anchorage device stability: an evaluation of thread shape factor. Eur J Orthod. 2012;34(5): 582–6.
41. Migliorati M, Benedicenti S, Signori A, Drago S, Barberis F, Tournier H, et al. Miniscrew design and bone characteristics: an experimental study of primary stability. Am J Orthod Dentofac Orthop. 2012;142(2):228–34.
42. Migliorati M, Benedicenti S, Signori A, Drago S, Cirillo P, Barberis F, et al. Thread shape factor: evaluation of three different orthodontic miniscrews stability. Eur J Orthod. 2013;35
43. Chang JZ-C, Chen Y-J, Tung Y-Y, Chiang Y-Y, Lai EH-H, Chen W-P, et al. Effects of thread depth, taper shape, and taper length on the mechanical properties of mini-implants. Am J Orthod Dentofac Orthop. 2012;141(3):279–88.
44. Poggio PM, Incorvati C, Velo S, Carano A. Safe zones": a guide for miniscrew positioning in the maxillary and mandibular arch. Angle Orthod. 2006;76(2):191–7.