A COMPARATIVE EVALUATION OF CURRENT ORTHODONTIC MINISCREW SYSTEMS

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Miniscrew placement has achieved widespread acceptance in orthodontic practice. However, selecting a suitable miniscrew system from among the available brands is not easy. The aim of this article is to help the clinician better understand the features of miniscrew systems currently available on the market and provide a useful guideline for their clinical use. The authors find that the ideal miniscrew design should include biocompatibility, bone-density–guided insertion, immediate loading, and compatibility with modern orthodontic accessories for 3-dimensional orthodontic control. World J Orthod 2007;8:136–144.

The miniscrew has become one of the most widely used temporary anchorage devices (TADs) in orthodontics.[1–3] Much of orthodontic treatment planning and biomechanics has been changed due to the innovative features of the miniscrew, including simple surgical procedures, broad indications, small dimension that can be placed into various intraoral regions, with no need for patient compliance. The first miniscrew system, the K-1 system (Dentsply-Sankin, Tokyo, Japan), was introduced into the market by Kanomi in 1997.[4] After that, Costa et al[5] developed the Aarhus anchorage system (Medicon, Tuttlingen, Germany); Kyung et al[6] developed the Micro Implant Anchorage system (MIA, Dentos, Korea); and Lin and Liou[7–9] developed the Lin/Liou Orthodontic Mini Anchor System (LOMAS; Mondeal, Tuttlingen, Germany). By 2003, the miniscrew had achieved widespread acceptance worldwide. The Spider screw (HDC, Sarcedo, Italy) by Maino et al,[10] the C-implant (Dentium, Kyungkido, Korea) by Chung et al,[11] the miniscrew anchorage system (MAS; Micerium, Avegno, Italy) by Carano et al,[12] and the Orthoimplant (IMTEC, Ardmore, OK, USA) by Cope[13] came out thereafter (Table 1). However, it is difficult for clinicians to know every characteristic of each screw system and their application in different clinical situations. The aim of this article is to summarize and evaluate various features of current miniscrew systems on the market and to provide a useful guideline for the clinician.

MINISCREW PROPERTIES

Material

In general, there are 2 types of material used for the manufacture of miniscrews: commercially pure titanium (C-P titanium), from grade 1 to grade 5 in terms of property hardness, is used by 2 of the manufacturers; titanium alloy, Ti-6Al-4V, is the other material used. Ti-6-Al-4V is a harder titanium alloy and is used by 5 of the manufacturers (see Table 1).

Clinically, the insertion technique is the main difference between the 2 materials. For the implant site with a higher

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Table 1 Features of current orthodontic bone miniscrew systems

	K-1	Aarhus anchorage system	MIA	Spider screw	C-implant	Miniscrew anchorage system (MAS)	Orthoimplant	LOMAS (OMAS)
Year	1997	1998	2001	2003	2004	2005	2005	2002
Inventor	Kanomi R (Japan)	Costa A Melsen B (Italy/Denmark)	Park HY Kyung HS et al (Korea)	Maino BG et al (Italy)	Chung KR et al (Korea)	Carano A et al (Italy)	Cope JB (USA)	Lin CY Liou JW (Taiwan)
Manufacturer	Densply-Sankin, Japan	Medicon, Germany	Dentos, Korea	HDC, Italy	Dentium, Korea	Micerium, Italy	IMTEC, USA	Mondeal, Germany
Material	C-P Titanium	Ti alloy	C-P titanium to Ti alloy	Ti alloy	-	C-P titanium (Grade-5)	Ti alloy	Ti alloy
Length (mm)	4/6/8	9/11	4–12 (9 sizes)	6/8/10 7/9/11	8.5/9.5/10.5	9/11	6/8/10	7/9/11
Diameter (mm)	1.0/1.2	1.5/2.0	1.2–1.8 (7 sizes)	1.5/2.0	1.8	1.3/1.5	1.8	1.5/2.0/2.3
Head design	Button-like head with small plate	0.022 × 0.028-in slot	7 types	0.021 × 0.025-in slot; 0.025-in round hole	2 parts 0.8-mm round hole	2 fused spheres 0.6-mm round hole	Ball head with 0.7-mm round holes (2 holes)	Hook/Quattro; 22 × 28-mil/ 18 × 25-mil slot; rectangular tube
Platform (Y/N)	Y	Y	Y	Y, regular/ low profile/flat	Y	N	Y	Flat/regular
Insertion method	Self-tapping	Self-tapping/ self-drilling	Self-tapping/ self-drilling	Self-tapping	Self-tapping	Self-tapping	Self-tapping	Self-tapping/ self-drilling
Pilot drill size (mm)	0.8/1.0	1.2/1.7	0.9/1.0/1.1/1.2	1.2/1.5	—	0.9/1.1	1.1	1.0/1.5/2.0
Loading force (g)	—	50	300–450	50–300	50–200	50–250	—	200–600
Immediate loading (Y/N)	N (6-mo healing)	Y	Y	Y	N (4–8 wk healing)	Y	Y	Y
Head exposure (Y/N)	N	Y	Y/N	Y	Y	Y	Y	Y

bone density, pre-drilling is usually necessary for the C-P titanium screw due to its softer density; without pre-drilling, a bend or breakage of the miniscrew may occur during the process of direct insertion. In addition, the limitation of sustaining heavy orthodontic loading has to be considered with the C-P titanium miniscrew.

For the screw made of Ti-6Al-4V, with its relatively harder density, the risk of a bend or breakage decreases, and drilling a pilot hole at an implant site with lower bone density is usually not suggested. Better mechanical retention, less breakage, and less chairtime are the advantages of the Ti-6Al-4V miniscrew. For example, with the MIA system, the original C-P titanium grade 3 screw material was changed to Ti-6Al-4V because of the considerations outlined above.

Using a stronger titanium alloy as the screw material is advantageous, and is likely the mainstream of future screw design.

Length

Screw length refers to the body part of the miniscrew. Length differs by manufacturer and ranges from 4 to 12 mm (see Table 1). The selection of miniscrew length should be based on the bone depth at the planned implant site, as well as the location of adjacent anatomically vital structures, such as dental roots, blood vessels, and nerves, which need to be evaluated by radiograph or 3-dimensional computerized tomography.

The appropriate length is suggested to be as long as possible, without jeopardizing the health of the adjacent tissues. However, in the MIA system,[6] the variety of screw lengths may cause potential stress on inventory control for the clinician.

Diameter

Screw diameter refers to the widest part of miniscrew body, which is the distance between 2 thread tips. The diameter differs by manufacturer and ranges from 1.0 to 2.3 mm (see Table 1). The selection of the miniscrew diameter depends on the bone width of the implant site, which needs to be confirmed by radiograph. In principle, the miniscrew with a smaller diameter should be used in a tooth-bearing area to avoid hitting the dental roots; the miniscrew with a greater diameter should be used in a non–tooth-bearing area to achieve a larger scale of tooth movement.

One of the most favorable tooth-bearing implant sites is the interseptal bone between the maxillary second premolar and first molar, because this area is wider, safer, and more convenient for clinical application. For this interseptal bone area, there is a wide variety of miniscrews, from 1.2- to 2.0-mm diameter, available among different screw systems. With such great variations, selecting a miniscrew with an appropriate diameter becomes an important consideration for the clinician.

There seems to be a greater chance of losing the anchorage potential of the miniscrew if applying a heavy orthodontic force on a miniscrew with a smaller diameter of 1.2 mm. However, the risk of hitting the dental roots may increase in an interdental area when choosing a miniscrew with a diameter of 2.0 mm. Since the width of a given implant site varies from person to person and the miniscrew is not absolutely stationary during the treatment,[14,15] it is necessary to know the clearance between the miniscrew and the dental root in each individual patient. For example, when a miniscrew with a diameter of 1.5 mm is being considered, the clinician needs to know that the possible displacement of the miniscrew is 1.5 mm[14] and the thickness of the periodontal ligament of the adjacent teeth; for this example, the periodontal ligament thickness is 0.25 mm. The clinician can calculate the clearance necessary by adding 0.25 mm + 1.5 mm + 1.5 mm + 1.5 mm + 0.25 mm = 5.0 mm; therefore, 5.0 mm is the distance that should exist to accommodate the 1.5-mm-diameter miniscrew.[15]

In the non–tooth-bearing area, since the distance from the dental roots is greater, the chance of hitting dental roots significantly decreases. However, a greater demand on anchorage arises,

Fig 1 **(a)** LOMAS Hook screw. **(b)** LOMAS Quattro screw. A rectangular tube (0.018 × 0.025/0.022 × 0.028 inch) and edgewise slot are incorporated into the Quattro screw head.

because the biomechanics of en-masse retraction or molar protraction are usually applied in this type of area. Therefore, a greater-diameter miniscrew is more appropriate. Most systems suggest the 2.0-mm diameter miniscrew.

The concept of "emergency anchor" seems to be deficient in most miniscrew systems. When the initial stability cannot be gained from insertion of the screw, another screw with greater diameter (emergency anchor) should be provided in the system. For the LOMAS system, a 2.0-mm-diameter screw plays the role of emergency anchor for the 1.5-mm-diameter screw; a 2.3-mm-diameter screw is used for the 2.0-mm-diameter screw.[8]

The greater variety of diameters within a miniscrew system may result in difficulty selecting a miniscrew and potential stress on inventory control for the clinician (for example, there are up to 7 different diameters for the MIA system; see Table 1).

Head

An ideal head design of the miniscrew should be compatible with the current edgewise bracket system.[1] It has to be able to connect with the other orthodontic accessories, such as the archwires and coil springs, to achieve the 3-dimensional orthodontic control. Therefore, compatible head designs using hook, rectangular tube, and edgewise bracket slots are essential for an ideal screw system. However, designs with a ball head or bracket-like head with a round hole are featured among many current miniscrew systems (see Table 1). The ball-type design has following drawbacks: *(1)* it is difficult to hook with more than 2 coil springs; *(2)* when the placement angulation of the screw head is greater than a certain angulation, the coil spring slips easily; and *(3)* it is limited to 2-dimensional control. The bracket-like screw head with a round hole also has drawbacks: *(1)* the bracket-like head is not a true edgewise bracket design, which results in difficulty ligating the wire; *(2)* the slot size is limited, so it may not be compatible with edgewise systems; and *(3)* a rectangular archwire cannot achieve 3-dimensional control from the round hole of the screw head.

The LOMAS system has 2 unique designs that aim to resolve the potential problems listed above: the LOMAS Hook screw (Fig 1a) and the LOMAS Quattro screw (Fig 1b).[9,16] The Hook screw allows easier attachment of coil springs without wire ligature; in addition, it can have more than 2 coil springs attached, without slippage during the retraction and intrusion procedure (Fig 2).[8] The Quattro screw was introduced into the market in 2004 and is the first miniscrew with the edgewise bracket and rectangular tube design incorporated into the screw head. The dimensions of the bracket slot and tube of the Quattro screw follow the dimensions of a conventional edgewise system. There are 0.018 × 0.025-inch and 0.022 × 0.028-inch slot dimensions

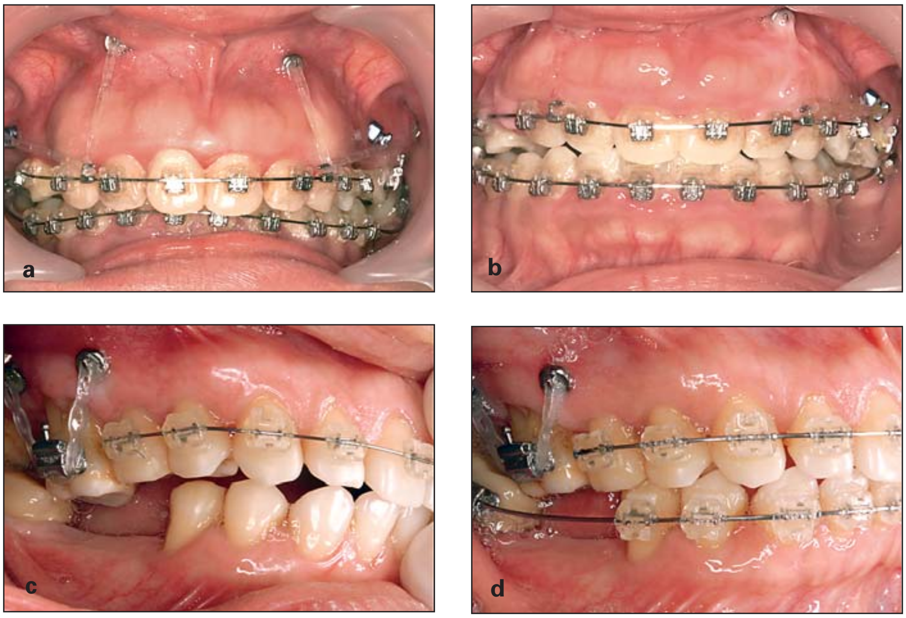
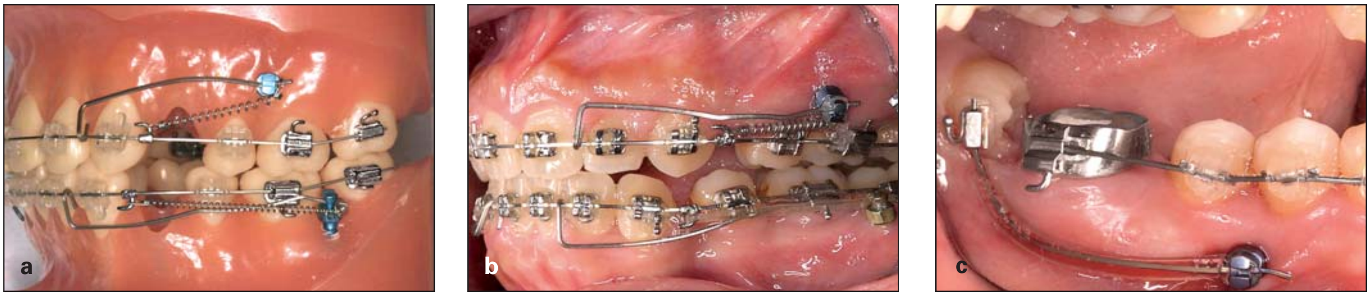


Fig 2 The LOMAS Hook screw is easily attached by elastics or coil springs for intrusion of the maxillary anterior teeth to correct deep bite, gummy smile (**a**, before treatment; **b**, after treatment), and to correct overerupted maxillary molars due to early loss of opposing mandibular tooth (**c,** before treatment; **d**, after treatment).



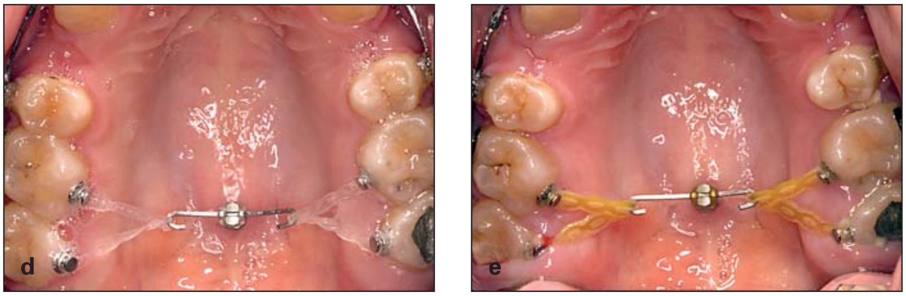


Fig 3 The LOMAS Quattro screw can connect with a rectangular archwire. Due to the rectangular tube design of the screw, the biomechanical force action is predictable and has a 3-dimensional control. After the 0.017 × 0.025-inch TMA wires were used as lever arms for intrusion of the anterior teeth, the retraction and intrusion of the maxillary and mandibular anterior teeth can be performed at the same time **(a,b)**. The Quattro screw can also be used for molar uprighting **(c)**. When the Quattro screw was placed at the midpalatal area, bilateral molar intrusion can be easily performed (**d**, before molar intrusion; **e**, after molar intrusion).

available for the Quattro screws. The main purpose of the Quattro design is to incorporate a biocompatible miniscrew system with the popular edgewise bracket system. This adaptation may allow the clinician more comprehensive applications, including tooth movements that involve anchorage preparation and torque control, leveling and aligning without the anchorage of teeth, and treatment despite an anchorage unit without sufficient periodontal support. Three-dimensional tooth control can be easily achieved when a rectangular archwire is engaged with a Quattro screw head, without a counteracting force on the anchorage teeth (Fig 3).

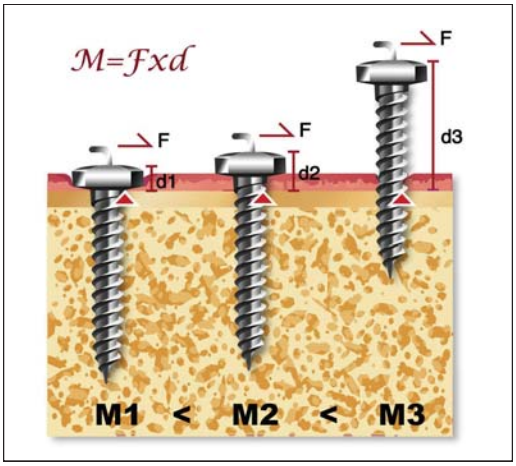


Fig 4 Extra anchorage potential can be gained when a direct contact surface of the screw to the bone exists.

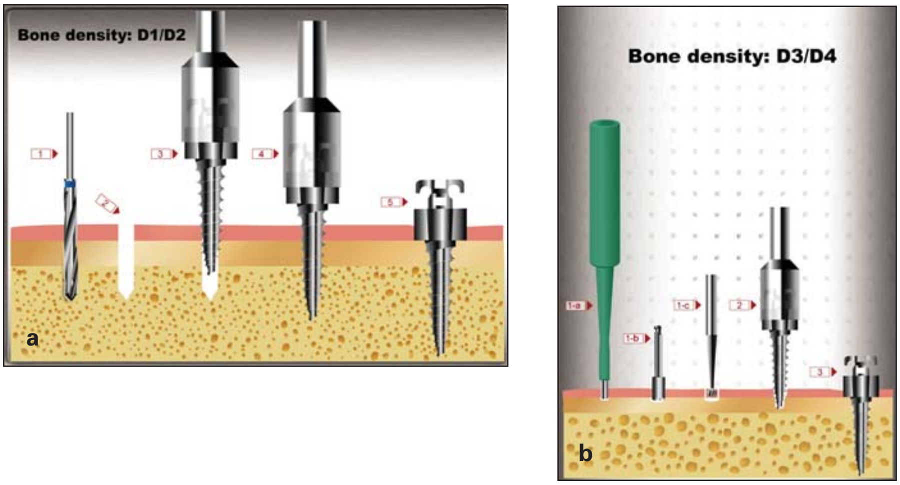


Fig 5 Bone-density–guided insertion technique. **(a)** Self-tapping insertion procedure; **(b)** self-drilling insertion procedure. The insertion technique should depend on the bone density of the implant site and the screw material.

THE PLATFORM

The main purposes of the platform design are to prevent irritation of the surrounding gingival tissue from the attached elastics or coil springs and resultant overgrowth. Suppression of the gingival tissue can keep the screw head exposed and permit easy access to the orthodontic accessories. Smooth and polished surfaces of the platform also help minimize irritation and improve wound healing. The platform design exists in most miniscrew systems, with the exception of the MAS system (see Table 1).

The appropriate platform height is usually 1 to 2 mm thicker than that of the soft tissue at the implant site; otherwise, the screw head may more easily embed in the soft tissue during treatment. With a miniscrew system, the contact surface of the platform and the underlying bone is important because greater mechanical stability can be gained from direct bone contact and platform bottom (Fig 4). The LOMAS system has a greater platform bottom compared with the other miniscrew systems; therefore, greater anchorage potential and mechanical stability can be gained when the screw is inserted and engaged with the underlying bone.

INSERTION

Skeletal tissue insertion requires 1 of 2 techniques, self-tapping or self-drilling. The recommended insertion technique may differ from system to system (see Table 1). The procedure of pre-drilling a pilot hole for insertion of the screw is actually the main difference between these 2 techniques. Pilot drilling in a miniscrew system depends on the material of the screw and the bone density of the attempted implant site.

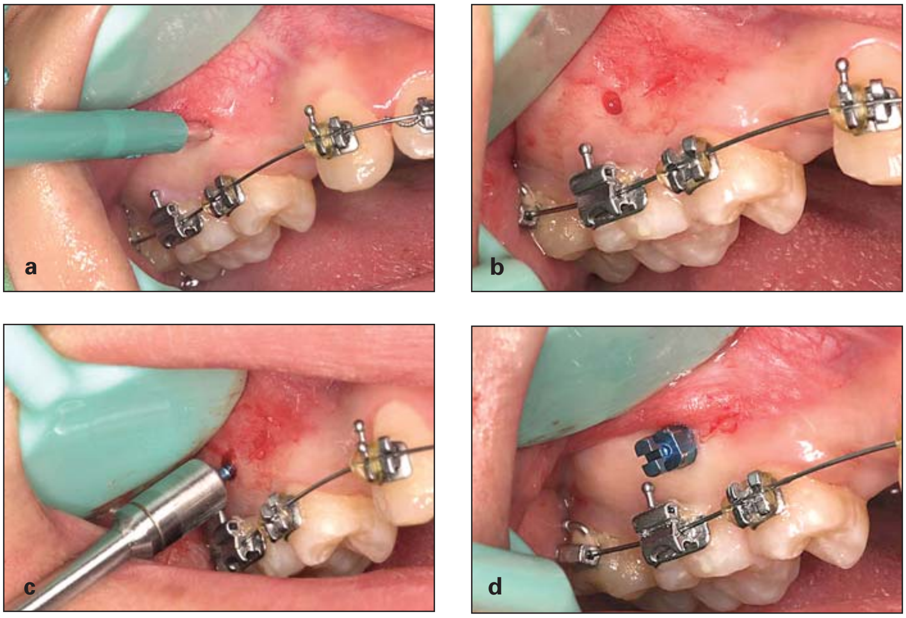


Fig 6 The procedure of screw placement. **(a)** A circular tissue biopsy punch is used for removal of gingival soft tissue. **(b)** A clean-cut margin is left, so the implant site can be easily identified. **(c)** The screw is inserted using the self-drilling technique. **(d)** The placement is completed.

For the screw composed of C-P titanium, with consideration of possible metal fatigue and screw fracture during the insertion procedure, a pilot hole made at low speeds is suggested for most implant sites. This type of insertion technique is called *self-tapping*. For titanium alloy miniscrews, direct insertion at the implant site with lower bone density can be performed. This type of insertion, without pilot drilling, is called *self-drilling*.

Self-drilling for a miniscrew system does have a number of advantages. The problems generated from accidental drilling can be avoided; these problems include overenlargement of the pilot hole,[18] overheating from high drill speeds,[1] drilling into the dental root, and fitting the screw. In addition, chairtime and drill expenses can be reduced, and the psychological stress from a longer procedure can be lessened for both the patient and the clinician.

However, for the implant site with greater bone density, self-tapping remains a recommended procedure to prevent possible bend or fracture of the screw. Therefore, the insertion method should be based upon the examination of bone density at the implant site and the screw material. In the LOMAS system, the "bone-density–guided insertion technique" (Fig 5) follows the above rules-of-thumb.[7]

Currently, using the flapless surgical procedure to place the miniscrew is a better way to manage the soft tissue, because postsurgical swelling, bleeding, and pain can be greatly reduced. However, for the LOMAS system, a circular tissue-biopsy punch is used for removal of soft tissue before insertion of the screw; this punch is used because it causes little bleeding, leaves a clean-cut margin for screw insertion, and decreases the potential of screw failure (Fig 6).

PILOT DRILL SIZE

Heidemann et al[17] proposed that the critical size of the pilot hole should be approximately 80% of the external diameter of the screw. If this critical point is exceeded, the holding power of the screw decreases rapidly (Fig 7). Based on this principle, however, oversized pilot drills were found among some miniscrew systems (see Table 1). The clinicians should be aware that any vibration during the pilot drilling with an oversized drill may cause unpredictable enlargement of the pilot hole; the initial stability of the screw will be greatly affected.

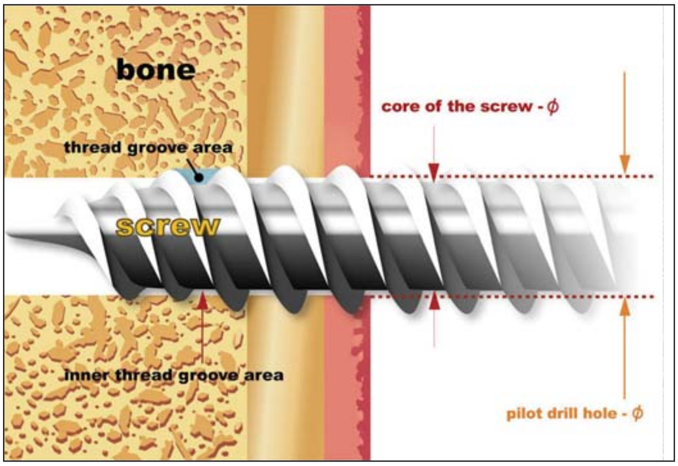


Fig 7 The ideal diameter of the pilot drill is around 80% of the external diameter of the screw. Otherwise, the initial stability of the screw decreases.

LOADING FORCE

Based on clinical experience with different miniscrew systems, there is a significant difference, 50 to 600 g, in the loading force that a miniscrew can withstand (see Table 1). This wide range may be due to the screw material, screw design, screw diameter, screw length, type of contact, implant site, bone density, action of the force, and individual variability. Interestingly, Dalstra et al[18] used a 2.0-mm-diameter and 10.2-mm-long Aarhus anchorage miniscrew in the mandible of a pig. When a 50-g lateral force was applied to the screw, the value of the peak bone strain was in the adapted window area, which implied that bone can adapt to the surrounding environment without breakage. However, when applied force exceeds this threshold, a possible fracture or resorption of the bone may occur or the screw may be loosened. Although most miniscrew systems report force limits greater than 50 g clinically, the maximum force that a miniscrew can withstand is unanswered. In addition, the possible orthopedic effects of miniscrew systems and loading-force differences between osseointegrated and non-osseointegrated screws are also unknown and need evaluation.

IMMEDIATE LOAD

Although most miniscrew systems suggest that a miniscrew can be loaded immediately, the K-1 and C-implant systems recommend that the screw not be loaded until osseointegration has occurred (see Table 1). In addition, there is a considerable time difference for osseointegration between the K-1 and the C-implant systems: 4 to 8 weeks for the C-implant system and 6 months for the K-1 system.

Immediately loadable miniscrew systems have the advantage of decreasing chairtime for the clinician and the treatment time for the patient. The anchorage potential for an immediately loadable miniscrew system is simply from the mechanical retention at the surface area contact with the bone, without the intention of osseointegration. However, for a miniscrew system that requires osseointegration, anchorage potential relies on the quantity of osseointegration; a potential problem may arise from removal of the osseointegrated screw after treatment.

HEAD EXPOSURE

Placing the miniscrew head so that it is exposed within the soft tissue is not recommended by all screw systems (see Table 1). For example, the K-1 system suggests placing the screw head completely underneath the soft tissue for any implant site; the MIA system suggests, depending on the location of the soft tissue, exposing the screw head at the attached gingival tissue, but embedded in the moveable soft tissue.

When the screw head is placed completely underneath the soft tissue with an emerging ligature wire hook for orthodontic accessories, bacteria invasion, inflammation of the soft tissue, and possible breakage of the ligature hook are associated clinical problems. If the screw head is placed exposed to the soft tissue, or specifically exposed over the attached gingiva or mucogingival junction, better oral hygiene and adaptation of the surrounding tissue can be obtained.

CONCLUSIONS

According to previous comparative evaluations of current miniscrew systems, the characteristics of an ideal anchorage device include the following:

1. The screw material is biocompatible and can withstand various directions and magnitudes of orthodontic forces without metal fatigue or fracture.
2. The screw is immediately loadable after insertion and the stability can be maintained until removal.
3. The screw has a biomechanical design, and the applied force direction is predictable so that various orthodontic biomechanics, such as intrusion, extrusion, protraction, and retraction, can be used more effectively.
4. The design of the screw head is compatible with modern edgewise systems and easy to connect with orthodontic accessories. Three-dimensional control can be obtained from the edgewise slot, molar tube, or the hook of the screw head.
5. The surgical procedure for the miniscrew system and the screw accessories are simple, efficient, and effective.

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