CHAPTER 2

LITERATURE REVIEW

The review was divided into four parts as follows:

2.1 History of skeletal anchorage

2.2 Clinical assessment of sites for miniscrew implant placement in dento-alveolar bone

2.3 Availability of interradicular space for miniscrew implant placement

2.4 Dento-alveolar compensation in skeletal discrepancies

2.1 History of skeletal anchorage

The first attempt to implant a stable device to be used for orthodontic anchorage was made by Gainsforth and Higley[37] in 1945 by inserting vitallium screws and wires in the dog ramus. There were no more published reports of attempts to use endosseous implants to move the teeth until the clinical reports of Linkow[38] in 1969. Linkow used a blade vent implant as a posterior mandibular anchorage for retraction of maxillary incisors. After Branemark et al[39] in 1970 reported the successful osseointegration of implants to bone, there were several reports of using endosseous implants for orthodontic anchorage.[40-42]

Although the use of dental implants had been considered an effective approach to achieve orthodontic anchorage, the clinical application of this method was limited by the small number of possible placement sites.[6,8] Moreover, endosseous dental implants are expensive, require an invasive surgical procedure, are limited to the edentulous regions, such as the mandibular retromolar region and midpalatal suture area,[43] and require relatively long waiting periods before load application to allow adequate osseointegration. Other limitations are the direction of force application, severity of surgery, the discomfort of initial healing, the difficulty of maintaining oral hygiene, and the difficulty of removal after orthodontic treatment.[6,8,12]

In order to overcome these difficulties, Block and Hoffman,[44] in 1995, designed a thin titanium alloy disk, or “onplant,” as a skeletal anchorage device for orthodontics. Following the same principles as used for dental implants, the onplants were designed to be placed on the palatal bone, where they could achieve osseointegration to the bone. The onplants were coated with hydroxylapatite on one surface. The other surface consisted of a mesh. The onplant was inserted subperiosteally with the hydroxylapatite-coated side against bone for osseointegration. However, the high costs, long waiting period before applying force, and the necessity for special hardware to connect the onplant to the orthodontic appliance have limited the clinical application of the onplant.

To overcome these problems, devices temporarily fixed to bone for providing orthodontic anchorage and subsequently removed after use, so-called temporary skeletal anchorage devices, have been introduced.[6,12,45-47]

The first clinical report of the use of a temporary skeletal anchorage device was described by Creekmore and Eklund[48] in 1983. The authors inserted a vitalium surgical screw below the anterior nasal spine for deep bite correction. The screw was stable throughout the duration of orthodontic treatment. A similar outcome was achieved by Kanomi[45] in 1997 for the intrusion of lower incisors, using titanium surgical screws.

In 1998, Costa et al[12] developed a miniscrew especially for orthodontic therapy. This titanium miniscrew has a 2 mm diameter and a 9 mm length. The screw was inserted manually with a screw driver, directly through the mucosa, without making a flap, and was loaded immediately. The following year, Umemori et al[49] used surgical miniplates as orthodontic anchorage for intrusion of molar teeth in patients with open bites.

Recently, miniscrew implants have been widely used to enhance anchorage because they have several advantages, such as ease of insertion and removal of miniscrew implants, immediate or early loading, low cost, a wide range of clinical applications and adequate anchorage support for orthodontic tooth movement.[15]

2.2 Clinical assessment of sites for miniscrew implant placement in dento-alveolar bone

Miniscrew implants offer a variety of locations for insertion.[4] The dento-alveolar bone was the most favored placement site because it allows the clinician to use simple mechanics for orthodontic tooth movement.[13,14] However, the placement of miniscrew implants poses a challenge to the orthodontist because of the limited space available for implant placement and the potential risk of root damage during implant placement.[8,10,15,25,46] Miniscrew implant failure can be attributed to several factors, among which damage to adjacent tooth roots may be the most important.[8,10,15] Therefore, diagnosis and treatment planning are essential for the successful application of miniscrew implants, to both avoid damaging dental roots and ensure a predictable outcome.[8,10] Precise pre-surgical planning is very important to avoid damaging dental roots and periodontal ligament.[8,10] Furthermore, pre-surgical planning should include estimation of bone quantity and quality, and careful selection of the diameter and length of the miniscrew implant, of the placement site, and of the direction of placement.[50]

To achieve precise placement of miniscrew implants, several methods have been developed.[18,24-28,30,32,50,51] Pre-surgical diagnosis of bone quantity and transferring of the information to the surgical sites are important in miniscrew implant placement.[8,27] Standard dental radiographs, such as panoramic, periapical and bitewing radiographs, allow the clinician to make an assessment of available interradicular space and the proximity of adjacent root structures, and to confirm the positional details post-operatively.[52] However, as 2-dimensional images, standard dental radiographs give no indication of bone width.[52] In combination with clinical examination, they may provide enough information to plan treatment without using more complex imaging techniques.[52]

Panoramic radiography is widely used and is often a tool used in routine dental examinations.[53] Panoramic radiography is an excellent technique if used with the realization that it has greater value for observations rather than for making precise measurements.[53] The panoramic radiograph provides more information about associated anatomical structures than does the periapical radiograph but with less fine detail of the teeth.[52] The magnification factor of panoramic images is approximately 1.3 times.[52] Advantages of the panoramic radiograph include low radiation dose, low operator time usage, relatively short patient exposure time, reproducibility, and excellent patient comfort.[54]

However, the panoramic radiograph has disadvantages related to reliability and accuracy in the assessment of size, location, and form.[54] The traditional panoramic radiograph provides a distorted image of the jaws and the dentition.[54] Distortion on panoramic radiographs of the angles between the inclined teeth is the result of the combined distortions in the vertical and horizontal dimensions.[55,56] McKee et al[55] reported that 74% of the maxillary and mandibular mesiodistal image angulations were significantly different from the true angulations. Distortion, on panoramic radiographs, of the angle between the inclined adjacent teeth influences the accuracy of assessment of available interradicular space, and is vital to precise miniscrew implant placement.[3,52] Therefore, a pre-treatment panoramic radiograph is useful for surveying.[52] Clinicians may want to make periapical or bitewing radiographs of the involved region, particularly if the miniscrew implant is to be inserted in the alveolar process.[3]

Simple serial periapical or bitewing radiographs, using the long-cone paralleling technique, are clinically useful in dental treatment. They provide images of the teeth with minimal distortion.[52] These radiographs are used for the evaluation of the quality of bone available for miniscrew implant placement in the alveolar bone.[6] However, the amount of space between the roots shown on the radiograph is often influenced by the projection angle of the x-ray beam.[57] Direction and angulation of the central ray during film exposure are important factors in minimizing distortion of periapical or bitewing radiographs.[57] The object and the recording surface of the film should be parallel.[57] The central ray should pass through the center of the interseptal bone of the adjacent teeth and the recording surface at right angles. The image of the space on the resultant film shows the largest amount of space available for placement of the miniscrew implant.[50] If the central ray does not pass through them at right angles, the image of the space available will appear smaller than it actually is because of the overlapping images of the adjacent teeth.[50]

Transferring radiographic information to the surgical site is an important task in the surgical procedure.[18,24,25] Several methods have been proposed to accurately transfer miniscrew implant location information from 2-dimensional radiographs used for surgical planning.[18,24-27,30,32,50] Radiographic markers along with 2-dimensional radiographs have been most often recommended for avoiding damage to periodontal ligament and dental roots.[14] There are many kinds of radiographic markers, such as brass wire,[8] acrylic resin,[46] bendable stainless steel wire,[6] 3-D stents[30] and 3-D surgical guides.[18,24,25] Aranyawongsakorn et al[14] reported that periapical radiographs with radiographic markers have been used more often than other methods for assessment of miniscrew implant placement sites.

Interestingly, some authors have suggested the use of computed tomography to assess the bone quality and morphology at potential sites for both dental implants and miniscrew implants.[22,31,58] This method has been applied to investigate the availability and anatomical characteristics of the interradicular space for miniscrew implant placement by several authors. Although the high accuracy and the reliability of computed tomography are known, the use of computed tomography increases radiation exposure, is more expensive, and is, therefore, difficult to justify in routine clinical practice.[1,31]

2.3 Availability of interradicular space for miniscrew implant placement

Miniscrew implants typically have diameters ranging from 1.2 to 2.0 mm and lengths of 6, 8, and 10 mm.[19] For miniscrew implant placement without damage to the periodontal ligament and dental root, a minimal clearance of one mm of alveolar bone around the screw is needed.[23] When the diameter of the miniscrew implant and the minimum clearance of alveolar bone are considered, interradicular space of at least 3 mm is needed for safe miniscrew implant placement.[21]

Several articles have attempted to report the “availability” of interradicular space for miniscrew implant placement.[9,11,20-23,31] In 2004, Schnelle et al[9] evaluated the availability of bone for placement of miniscrew implants by using the pre-treatment and post-treatment panoramic radiographs of 30 orthodontic patients. They reported that adequate bone for placement, 3-4 mm interradicular distance, was located more than halfway down the root length, which typically would be covered by movable mucosa.

Poggio et al,[23] in 2006, determined safe zones for miniscrew implant placement from volumetric tomographic images of 25 maxillae and 25 mandibles. They reported that in the maxillary buccal region, the greatest amount of interradicular bone was between the second premolar and the first molar, 5-8 mm from the alveolar crest. In the mandibular buccal region, they found that the greatest amount of interradicular bone was either between the second premolar and first molar, or between the first and second molar, approximately 11 mm from the alveolar crest.

In the same year, Deguchi et al[19] used 3-dimensional computed tomographic images to evaluate cortical bone thickness. Cortical bone thickness was measured in 10 patients, with skeletal Class I (ANB angle 2° $\pm$ 2°); Angle Class I (n = 4), Class II (n = 4), and Class III (n = 2) relationships. They reported that the safest location for placing miniscrew implants was mesial or distal to the first molar.

Two years later, Hernández et al[20] provided a bone map generated by computed tomography for safe placement of miniscrews. Twenty-one computed tomographic images of maxilla and mandible, from 14 males and seven females, were used to measure interradicular space in the mesiodistal plane and vestibulo-lingual thickness of the maxillary and mandibular alveolar processes. They reported that the greatest amount of mesiodistal bone was between the first and second mandibular molars on the vestibular and between the fist and second mandibular molars on the lingual side. To determine the optimum length of miniscrew implant for safe placement, the clinician must consider the vestibulo-lingual bone thickness. The greatest amount of vestibulo-lingual bone was between the first and second mandibular molars, whereas the least amount was between the central and lateral mandibular incisors. They also concluded that the mesiodistal bone thickness on the vestibular side should be considered when inserting the miniscrew implant between the dental roots, to prevent damaging the dental tissue. Mesiodistal interradicular space measurements on the palatal or lingual side do not present problems when inserting miniscrew implants.

The following year, Hu et al[21] (2009) measured the interradicular distances of anterior and posterior teeth in dehydrated human jaw specimens. They reported that the interradicular distance increased from anterior to posterior teeth and from the cervical line to the root apex in both the maxilla and the mandible. In the maxilla, the greatest interradicular distance was between the second premolar and the first molar. In the mandible, the greatest interradicular distance was between the first and second molars. They concluded that the safest zone for placement of a miniscrew in the maxilla was between the second premolar and the first molar, from 6 to 8 mm from the cervical line. The safest zone for placement of a miniscrew in the mandible was between the first and second molars, less than 5 mm from the cervical line.

In the same year, Lee et al[31] analyzed tooth-bearing alveolar bone for miniscrew implant placement by using computed tomography. They reported that in the maxilla, the greatest interradicular distance was observed between the first molar and the second premolar, 8 mm from the cemento-enamel junction. In the mandible, the greatest interradicular distance was between the first and second premolars, 8 mm from the cemento-enamel junction. Overall bone thickness overlying the buccal surface of each root was greater in the posterior regions, than in the anterior region.

2.4 Dento-alveolar compensation in skeletal discrepancies

During facial growth and development, normal occlusion can be attained and maintained, despite some variations in facial pattern, primarily as a result of dental compensation.[34,35,59] The cant of the occlusal plane also adjusts sagittal relationships between the maxillary and mandibular dental arches.[60,61]

Dento-alveolar compensation is a phenomenon seen usually on lateral cephalometric radiographs where the upper and lower teeth are inclined to "camouflage" the underlying skeletal base.[62] The sagittal growth difference between the jaws is largely absorbed by a dento-alveolar compensation.[63] Typically, the lower incisors may be proclined and the upper incisors may be of normal or upright inclination in a patient with a Class II skeletal base.[62] In Class III skeletal relationships, the sagittal jaw growth difference is mostly absorbed by mesial displacement of maxillary first molars and counterclockwise rotation of the occlusal plane.[63] In the developing occlusion, the maxillary second and third molars may become stacked and impacted.[62] Moreover, the maxillary incisors incline more labially and the mandibular incisors more lingually.[34]