CHAPTER 3

LOADING PROTOCOLS FOR MINISCREW IMPLANTS USED FOR ORTHODONTIC ANCHORAGE: A SYSTEMATIC REVIEW

3.1 Introduction

Recently, there has been an increasing tendency towards the publication of scientific studies of miniscrew implants for providing maximum anchorage in orthodontic treatment (Labanauskaite *et al.*, 2005). Most of these studies indicate that the miniscrew implant is an excellent device for anchorage control with a high success rate (Chen *et al.*, 2006; Miyawaki *et al.*, 2003; Park *et al.*, 2006). Although miniscrew implants seem to be effective alternatives for anchorage in orthodontics, there are some factors to consider before using them. All these appliances should have sufficient primary stability to accept the force applied to them (Huja *et al.*, 2005).

To obtain the appropriate primary stability, a period of time has to be determined where no force would be applied on these devices, thus reducing the risk of failure (Higuchi and Slack, 1991). However, several studies have stated that forces can be applied immediately after the placement of such devices (Bohm and Fuhrmann, 2006; Chae, 2006; Cheng *et al.*, 2004; Giancotti *et al.*, 2004; Yun *et al.*, 2005). Moreover, force magnitudes applied to miniscrew implants in delayed or immediate protocols may affect the primary stability of the miniscrew implant. Excessive force per unit (stress) leads to destruction of surrounding tissue and decreases the bone contact area between implant and surrounding bone. However, a lower level of stress/strain than the optimum range can also increase the bone resorptive rate (Melsen and Lang, 2001).

These reports create a controversy regarding the loading protocol for the use of miniscrew implants after their insertion in the mouth for orthodontic purposes. A systematic literature review was conducted to identify the most frequently-used waiting period before loading miniscrew implants and the force magnitude most frequently-used with miniscrew implants in orthodontics.

3.1.1 Definitions in this review

Loading protocol refers to the procedure to apply loads to miniscrew implants, including the *waiting period before loading* and the *force system*.

Waiting period before loading refers to the duration from insertion of the miniscrew implant into bone to the application of load to the miniscrew implant by the clinician. There are two types of waiting period, immediate loading and delayed loading (Ohashi *et al.*, 2006).

Force system includes the magnitude of force applied to move the teeth and to create the reactive force toward the miniscrew implant, to which the clinician attaches the movement devices, and the mechanics of tooth movement (Poggio *et al.*, 2006).

Surgical procedure refers to the process that the clinician uses to insert the miniscrew implant into the insertion site. Surgical procedures for miniscrew insertion can be divided into two types; pre-drilling and self-drilling (Carano *et al.*, 2005; Heidemann *et al.*, 2001; Kim *et al.*, 2005).

3.2 Materials and methods

3.2.1 Search strategy

To identify all articles that examined properties of miniscrew implants, a literature survey was conducted in the Medline data base (http://www.ncbi.nlm.nih. gov/entrez/ query.fcgi). The survey covered the period from the inception of the Medline data base to December 2007 and the keywords for this literature review were; “miniscrew,” “micro-screw,” “micro-implant,” “mini-implant” and “skeletal anchorage for orthodontics.”

3.2.2 Selection criteria and data collection

Inclusion criteria for this literature survey were English language human studies and case reports. Exclusion criteria were animal studies, *in vitro* studies, review articles, letters, interviews and articles not written in English. The numbers of articles identified by the search strategy are listed in Figure 3.1.

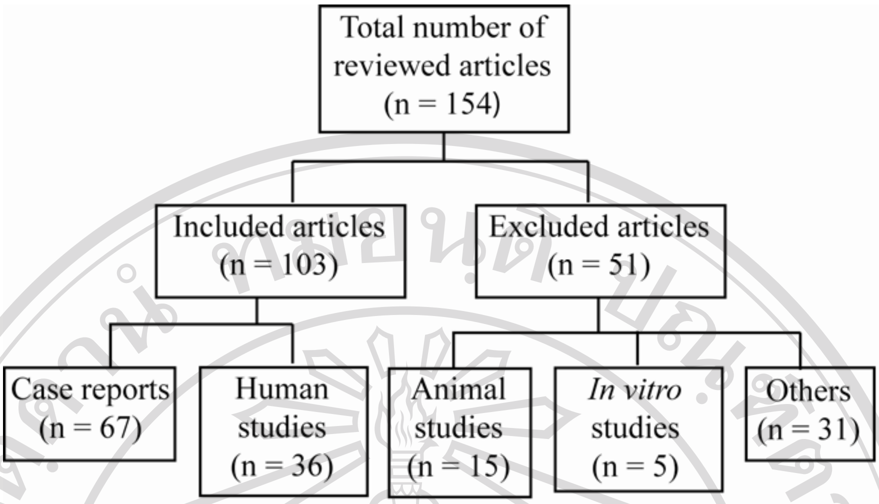

Figure 3.1 Diagram presenting the process of inclusion and exclusion for this reviewed article

The following data were collected: author; year of publication; study design; waiting period before loading; surgical procedure; insertion site; force magnitude of miniscrew implant and mechanics of tooth movement. Subsequently, data were analyzed and described in numbers and percentages.

3.3 Results

Of the total number of reviewed articles (n = 154), there were 103 included articles consisting of 67 case reports and 36 human studies (Figure 3.1).

3.3.1 Waiting period before loading

Of the total number of included articles, 59 articles presented information on waiting periods before loading. In general, there were more delayed loading protocols presented than immediate loading protocols. The total number of miniscrew implants in the reviewed articles was 1381, immediate loading was applied to 345 screws (25.0 %) and delayed loading to 1036 screws (75.0 %). In terms of the frequency of protocols cited in the articles, the percentages of immediate loading and delayed loading were 36.0% and 64.0%, respectively. In delayed loading protocols, the percentages for waiting periods of 1-2 weeks, 4 weeks, 6-8 weeks and 10-12 weeks were 32.8 %, 10.9 %, 10.9 % and 9.4 %, respectively. However, in terms of the numbers of miniscrew implants, the percentage in the 4-week group (33.5 %) was highest, whereas the that in the 1-2 week group (26.4%) was second (Table 3.1).

Table 3.1 Numbers of miniscrew implants and frequency of cited protocols distributed by waiting period

Waiting period	Frequency of protocol cited in articles		Frequency of miniscrew implant	
	Number	%	Number	%
Immediate loading	23	36.0	345	25.0
Delayed loading				
1-2 weeks	21	32.8	364	26.4
4 weeks	7	10.9	463	33.5
6-8 weeks	6	9.4	39	2.8
10 – 32 weeks	7	10.9	170	12.3
Total	64*		1381	

* From total 59 articles, 3 articles presented 2 protocols and 1 article presented 3 protocols

3.3.2 Waiting period and surgical procedure

There were more pre-drilling types of miniscrew (78.5 %) than self-drilling types (21.5 %) in both immediate and delayed loading protocols. In immediate loading protocols, the percentages were 89.6 % and 10.4 % for self-drilling and pre-drilling types, respectively. In delayed loading protocols, the respective percentages were 74.8 % and 25.2 % (Table 3.2).

Table 3.2 Numbers of miniscrew implants distributed by waiting period and surgical procedure

Surgical procedure	Immediate loading	Delayed loading	Total (%)
	Number (%)	Number (%)	
Self-drilling	36 (10.4)	261 (25.2)	297 (21.5)
Pre-drilling	309 (89.6)	775 (74.8)	1084 (78.5)
Total (%)	345	1036	1381 (100.0)

3.3.3 Waiting period and insertion site

Insertion sites for miniscrew implants are numerous, in both maxilla and mandible. Because of their small size this type of skeletal anchorage can be inserted in several oral regions. However, insertion sites are mainly divided by the characteristics of the tissues presented in the insertion areas, such as attached and non-attached gingival (Poggio *et al.*, 2006). In general, more miniscrew implants were inserted in non-attached gingiva (53.3%) than in attached gingiva (46.7%). However, in immediate loading protocols, attached gingival sites predominated (91.6% compared to 8.4% for non-attached sites). In contrast, in delayed loading protocols, the percentages were 68.2% for non-attached gingiva and 31.8% for attached gingiva (Table 3.3).

Table 3.3 Numbers of miniscrew implants distributed by waiting period and insertion site

Insertion site	Immediate loading	Delayed loading	Total (%)
	Number (%)	Number (%)	
Attached gingiva	316 (91.6)	329 (31.8)	645 (46.7)
Non-attached gingiva	29 (8.4)	707 (68.2)	736 (53.3)
Total (%)	345	1036	1381 (100.0)

3.3.4 Magnitude of force and mechanics of tooth movement

Of the total number of included articles, 43 articles presented information on magnitude of force and mechanics of tooth movement. In general, magnitudes of force applied to miniscrew implants ranged from 20 g to 500 g. The most frequently-identified force magnitude was in the 200-250 g range (77.2%), followed by the 100-150 g range (15.9%), the 300-500 g range (5.6%) and the 20-70 g range (1.3%). The most frequently-identified category of mechanics of tooth movement was contraction (*En mass*) of anterior teeth (68.3%), followed by intrusion of posterior teeth (17.6%) and distalization whole arches (3.5%). In the 20-70 g range, the most frequently-identified category of mechanics of tooth movement was canine retraction (42.9%). In the 100-150 g range, it was intrusion of posterior teeth (57.8%). In the 200-250 g and the 300-500 g ranges, the most frequently-identified category of mechanics of tooth movement was contraction of anterior teeth *(En mass)* with incidences of 84.1% and 52.4%, respectively (Table 3.4).

Table 3.4 Numbers of miniscrew implants distributed by force magnitude and mechanics of tooth movement

Mechanics of tooth movement	Magnitude of force (g)				Total
	20-70	100-150	200-250	300-500	
Intrusion					
Anterior teeth	2 (14.3 %)	1 (0.6 %)	0 (0 %)	0 (0 %)	3 (0.3 %)
Posterior teeth	0 (0%)	100 (57.8 %)	91 (10.8 %)	0 (0%)	191 (17.6 %)
Extrusion					
Anterior teeth	2 (14.3 %)	0 (0%)	0 (0%)	0 (0%)	2 (0.2 %)
Posterior teeth	1 (7.1 %)	2 (1.2 %)	0 (0%)	0 (0%)	3 (0.2 %)
Canine retraction	6 (42.9 %)	59 (34.1 %)	0 (0%)	0 (0%)	65 (6.0 %)
Molar mesialization	0 (0 %)	2 (1.2 %)	0 (0 %)	2 (3.3 %)	4 (0.4 %)
Distalization					
Whole arch	0 (0 %)	0 (0 %)	38 (4.5 %)	0 (0%)	38 (3.5 %)
Posterior teeth	0 (0 %)	4 (2.3 %)	5 (0.6 %)	27 (44.3 %)	36 (3.3 %)
Contraction	0 (0 %)	5 (2.8 %)	706 (84.1 %)	32 (52.4 %)	743 (68.3 %)
(En mass)					
Molar uprighting	3 (21.4 %)	0 (0 %)	0 (0%)	0 (0 %)	3 (0.2 %)
Total	14 (1.3 %)	173 (15.9 %)	840 (77.2 %)	61(5.6 %)	1088 (100.0 %)

3.4 Discussion

Excellent anchorage control with miniscrew implants is resulting in increased reporting of clinical applications. Moreover, several articles have reported the high success rate of miniscrew implants (Cheng *et al.*, 2004; Miyawaki *et al.*, 2003; Park *et al.*, 2006; Wiechmann *et al.*, 2007). Although miniscrew implants seem to be effective alternatives for anchorage in orthodontics, loading protocol, one of the factors associated with primary stability, is still controversial. Thus, the purpose of this study was to perform a systematic literature review to assess the most frequently-used waiting period before loading and the force magnitude applied to miniscrew implants used in orthodontics.

3.4.1 Waiting period before loading

In this review, the percentage of articles reporting delayed loading was higher than that reporting immediate loading. This result differed from that in the review article presented by Ohashi *et al.* (2006). They reported that four articles presented immediate loading and two articles presented delayed loading. However, the number of articles included in the present study was more than that in the review article presented by Ohashi *et al.*, because of different inclusion criteria. Therefore, it was difficult to compare these two studies.

In the delayed loading articles, the percentage of pre-drill surgical procedures was more than that of self-drilling procedures. The higher numbers of miniscrews used with delayed loading protocols and pre-drilling surgical procedure represented the clinical protocols used traditionally. In the early days of miniscrew implant use, since clinicians tried to prevent complications, such as fracture of miniscrew implant or fracture of surrounding bone, arising from their clinical procedures, they preferred to pre-drill the bone before insertion of miniscrew implants, and did not apply force immediately after screw insertion (Kanomi, 1997; Kyung *et al.*, 2003). The results in this review agreewith those of an animal study (on dogs) performed by Deguchi *et al.* (2003). They assessed histomorphometric properties in different healing groups. The results showed that there were no significant differences between three- and 12-week healing groups. They concluded that a three-week healing period is sufficient for orthodontic loading in dogs, extrapolated to about 4-5 weeks of healing in humans.

However, researchers have tried to develop new systems that decrease treatment time and increase success rate by using self-drilling types of miniscrews (Carano *et al.*, 2005; Kim *et al.*, 2005). Moreover, the review in Chapter 2 indicated a tendency to increased use in self-drilling screw types. Therefore, results may be different in further studies.

In the immediate loading articles, the percentage of miniscrews inserted in attached gingival areas was higher than that in non-attached gingival areas. The explanation of this result is the difference in surgical procedure. Most insertions in non-attached gingival areas require an open flap technique. Consequently, waiting for wound healing before loading force is essential (Lin and Liou, 2003; Liou *et al.*, 2004). Miniscrews can be inserted in attached gingival areas using a closed technique. So, immediate loading force without a waiting period is possible (Bohm and Fuhrmann, 2006; Chae, 2006; Chang *et al.*, 2004; Giancotti *et al.*, 2004; Yun *et al.*, 2005). However, testing of the miniscrew implant's primary stability before load is important. When a miniscrew implant is movable, delaying load by at least 1 week provides a favorable result.

Miyawaki *et al.* (2003) reported on factors associated with success rates of titanium screw use for orthodontic anchorage. They found that success rates of waiting periods of less than one month (<1), one month to less than three months (1-<3) and three months and above (≥ 3) were 85.0 %, 82.8 % and 87.5 %, respectively. However, Huja *et al.* (2005) explained that miniscrew implants need primary stability for a favorable clinical result. Their animal study showed that there was no difference in the pullout strengths of miniscrews used with immediate loading protocols and those of miniscrews where loading was delayed for 8 weeks. Moreover, Park *et al.* (2006) performed a study to evaluate factors affecting the clinical success of screw implants used for orthodontic anchorage. They reported that healing periods ranged form immediate loading to 5 weeks and there was no significant difference in success according to onset of force application.

The waiting periods before loading force for dental implants and miniscrew implants are different (Ohashi *et al.*, 2006). Roberts *et al.* (1989, 1990) applied loading force to dental implants after osteointegration was complete, around 3-6 months after the insertion procedure. Others (Bohm and Fuhrmann, 2006; Chen *et al.*, 2006; Fritz *et al.*, 2004; Kawakami *et al.*, 2004) applied loading force to miniscrew implants at intervals ranging from immediate loading to 32 weeks after the insertion procedure. Clinician tend to use miniscrew implants rather than dental implants for absolute anchorage because of the reduction in treatment time (Labanauskaite *et al.*, 2005).

3.4.2 Magnitude of force applied to miniscrew implant

In orthodontics, forces are applied to increase pressure in the surrounding bone, resulting in movement of the teeth. The orthodontic force is an extrinsic mechanical stimulus that induces a biological cellular response of the periodontal supporting tissue (Ren *et al*., 2003). However, orthodontic force not only influences the response of the tissue surrounding the tooth but also influence the response of the tissue surrounding the miniscrew implant. Excessive force per unit (stress) leads to destruction of surrounding tissue and decreases the stability of the miniscrew implant (Melsen and Lang, 2001).

According to Ren *et al.* (2003) the force magnitudes used for tooth movement range form 18 g to 375 g. Iwasaki *et al.* (2000) found that a force of only 18 g could move the tooth, whereas, Lee (1995) found that force of 337-388 g provided the maximum rate of tipping tooth movement. Therefore, the force applied to miniscrew implants may be decreased or increased, depending on the biomechanics of tooth movement.

The force magnitudes loaded on the miniscrew implants presented in this review varied from 20 to 500 g. The most frequently-reported range of force was 200-250 g. This range of force is the range used for contraction of upper anterior teeth or *en masse* movement. Moreover, the mechanics of tooth movement most frequently presented in this study was also that used for contraction of upper anterior teeth. The explanation for this result is that most *en masse* movement needs maximum anchorage. Thus, clinicians have attempted to prevent this undesirable result by enhancement of anchorage with several approaches (Cope, 2005; Proffit *et al*., 2007).

The maximum force magnitude identified in this review was 500 g. (Gelgor et al., 2004) This magnitude can be classified as an orthopedic force. The explanation for the use of such a heavy load is that the authors applied the load in an indirect approach, which they believed safe for the miniscrew. However, Buchter *et al.* (2005) studied the influence of orthodontic load on the stability of miniscrew implants and found that an applied load of 300 g at the 3 mm neck/bone distance level resulted in a moment of 900 cNmm and in a decrease of the stability of the miniscrew implants.

Even though variation of force magnitude has been reported, a prospective study of risk factors associated with failure of mini-implants used for orthodontic anchorage Cheng (2004) found that a load in the range of 100-200 g could be well sustained by the mini-implants, with no significant difference in the magnitude of load between successful and failed implants.

In general, dental implants are loaded by occlusal force from 10 to 50 Kg and by oblique force from 3 to 10 Kg (Bozkaya *et al.*, 2004; Hekimoglu *et al.*, 2004; Mellal *et al.*, 2004), whereas miniscrew implants are loaded by orthodontic force from 50 to 500 g (Gelgor *et al.*, 2004; Kyung *et al.*, 2004; Ohnishi *et al.*, 2005; Park *et al.*, 2004). However, Robert *et al.* (1989) used retromolar dental implants for orthodontic purposes. These dental implants were not used as prostheses; they were used for anchorage only. Therefore, magnitudes of the loading forces applied to these dental implants were not different from those of the forces applied to miniscrew implants.

3.5 Conclusions

Loading protocols for miniscrew implants varied depending on different surgical procedures and biomechanics of tooth movement. However, several studies of success rate reported that there was no significant difference in success rates among these varied loading protocols. Therefore, further study to clarify the optimum loading protocol should be performed.