

Factors influencing the stability of miniscrews. A retrospective study on 300 miniscrews

Antonio Manni*, Mauro Cozzani**, Fabio Tamborrino***, Sergio De Rinaldis*** and Anna Menini****

Private Practices, *Racale (LE), **La Spezia, ***Lecce and ****Monterosso (SP), Italy

Correspondence to: Mauro Cozzani, Via Fontevivo 21 N, 19125 La Spezia, Italy. E-mail: maurocozzani@gmail.com

SUMMARY The aim of this study was to investigate, over a period of approximately 3 years, the reactions to orthodontic loading of a type V titanium miniscrew.

In this retrospective study, conducted in a private practice, the records of 300 miniscrews inserted in 132 consecutive patients (80 females, 60.6 per cent) by the same surgeon were evaluated. The mean age of the patients was 23.2 years. Three types of miniscrews (type A: diameter 1.5 mm, length 9 mm; type B: diameter 1.5 mm, length 11 mm; and type C: diameter 1.3 mm, length 11 mm) were used. The clinical variables evaluated included the loading time and location of the miniscrew in relation to the gingiva and root. The success rates with different variables were compared using chi-square or Fisher's exact test where appropriate.

A cumulative survival rate of 81 per cent (243/300) was found using Kaplan–Meier analysis, with an optimum success rate for the 1.3 mm wide miniscrew inserted in the attached gingiva, with immediate loading applied. Cox proportional hazard regression showed significant differences between success rate and the following parameters: gender, loading time, gingival or bone localization, and diameter of the miniscrews.

Considering the clinically controllable parameters, and within the limits of this retrospective study, 1.3 mm diameter miniscrews inserted in attached gingiva and immediately loaded had the most favourable prognosis.

Introduction

Miniscrews have been used to accomplish optimal dental movement in traditional treatment plans, such as molar protraction (Giancotti *et al.*, 2004b), canine retraction (Herman *et al.*, 2006), correction of the dental midline (Youn, 2006), space closure (Carano *et al.*, 2004), maxillary incisor retraction (Hong *et al.*, 2005), and maxillary molar distalization (Velo *et al.*, 2007). In addition, they enable clinicians to attain results which require more demanding approaches, such as enucleation of an impacted second molar (Giancotti *et al.*, 2004a), enucleation of an impacted canine (Carano *et al.*, 2005), intrusion of maxillary and mandibular molars (Ohmae *et al.*, 2001; Park *et al.*, 2003; Yao *et al.*, 2005), and correction of canted occlusal planes (Carano *et al.*, 2005; Jeon *et al.*, 2006). It is therefore important that clinicians have an understanding of the reliability of the clinical approach, its success rates, and the factors that may cause possible failure.

Miniscrews (1.3–2.0 mm of diameter) do not require flap surgery, which frequently causes pain (Miyawaki *et al.*, 2003; Kuroda *et al.*, 2007) and swelling. Theoretically, the incorrect insertion of miniscrews can damage vascular and nerve structures, maxillary sinuses, and dental roots (Fabbroni *et al.*, 2004; Asscherickx *et al.*, 2005). These

risks may be avoided with a correctly applied surgical procedure and if the amount of bone tissue between the roots is sufficient to host the miniscrew (Schnelle *et al.*, 2004).

The aim of the present study was to investigate, over a period of approximately 3 years, the reactions to orthodontic loading of type V titanium screws with an untreated surface. The following variables were analysed: age, gender, miniscrew mobility, loading time, size of the miniscrew, screw location with respect to bone, gingiva and root, type of handpiece used for screw placement, cooling of the screw, and instructions given to patients.

Subjects and methods

A retrospective analysis was performed in a private practice of 300 miniscrews implanted in 132 consecutive patients treated by the same surgeon, 80 females (60.6 per cent), with a mean age of 25.9 years but with a very wide range (8.4–59.1 years; SD ± 11.6 years) and 52 males (39.4 per cent), with a mean age of 19.6 (SD ± 10.1). All miniscrews used were made of type V titanium and had untreated surfaces (MAS® system; Micerium, Avegno, Italy), characterized by an asymmetric buttress and no

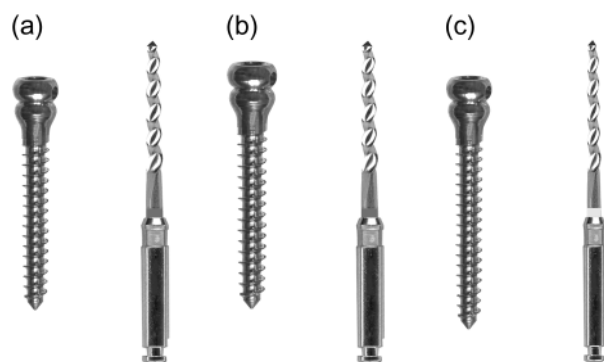


Figure 1 The implant screws used in the study: type A: diameter 1.5 mm, length 9 mm, drill bit 1.1 mm; type B: diameter 1.5 mm, length 11 mm, drill bit 1.1 mm; and type C: diameter 1.3 mm, length 11 mm, drill bit 0.9 mm.

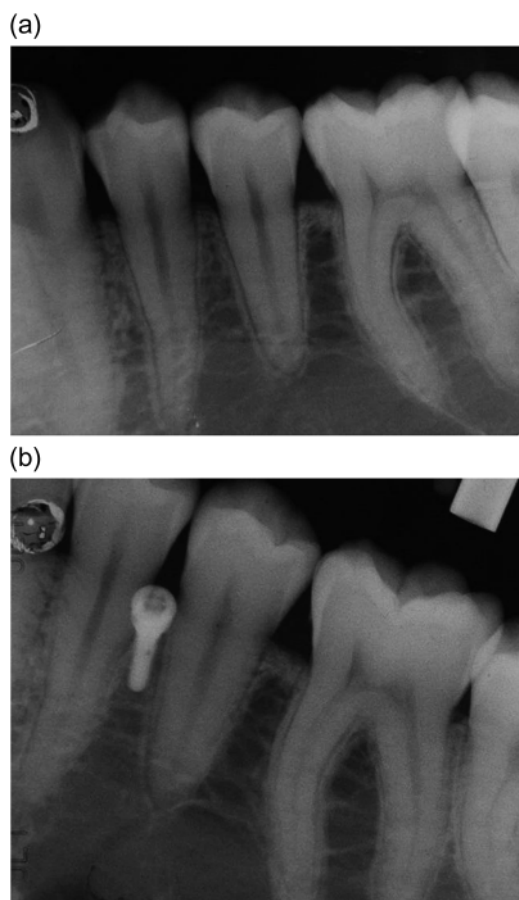


Figure 2 Long-cone radiographs of two lower premolars before (a) and after (b) screw insertion.

cutting flutes, either with a diameter of 1.3 or 1.5 mm (Figure 1).

The miniscrews were inserted only after informed consent of the patients or their parents was obtained. No ethical approval was required because miniscrew insertion did not require any additional procedure and did not differ from the normal protocol used in similar cases.

The available placement sites were identified on a long-cone radiograph as the area where the minimum distance between the adjacent teeth was 3.3 mm (Poggio *et al.*, 2006; Figure 2). In a few subjects where the available bony surface was insufficient, a fixed orthodontic appliance was used to upright the roots before screw placement.

Surgical method

Under topical anaesthesia with articaine chlorohydrate 4 per cent and adrenaline 1/2 000 000 (Septanest; Septodont, Saint Maur des-Fossés Cedex, France), a hole was drilled in the cortical bone without opening a flap. Only 51.7 per cent of screws were applied using drill bits on a 1200 r.p.m. handpiece for implants with a 20:1 speed reducing attachment (ImplantMed; Dentalwerk Bürmoos GmbH, Bürmoos, Austria) and controlled torque (20 N) and cooled using NaCl saline solution. The remaining 48.3 per cent were placed with a standard handpiece (KaVo intramatic 20 CH; Kavo Dental GmbH, Biberach, Germany).

To prevent heating of the screw and bone tissue during insertion, 51.7 per cent of screws (152/300) were cooled to -6°C . Both the cooling method and the handpieces were randomly chosen.

The miniscrew was manually inserted until the prescribed depth was reached. The size of the drill bits used was 0.9 mm for the 1.3 mm miniscrew and 1.1 mm for the 1.5 mm miniscrew (Figure 1). The choice of screw length was random.

The patients were instructed to use a 0.12 per cent chlorhexidine mouthwash twice a day (after breakfast and dinner) for 7 days.

The miniscrews used were of three different sizes: 110/300 type A: diameter 1.5 mm, length 9 mm; 87/300 type B: diameter 1.5 mm, length 11 mm; and 103/300 type C: diameter 1.3 mm, length 11 mm. Screw diameter was selected based on the amount of available bone tissue. The choice of type A or B screws was random.

Assessment of results

Success rates were calculated by applying two criteria: absence of evident inflammation and absence of clinical signs of loosening. When clinical signs of inflammation requiring the administration of antibiotics or analgesics, and/or instability of the miniscrew were present, the latter was removed and the case was classified as a failure. All miniscrews were observed for a period of 346 days.

The miniscrews had been inserted in all segments of the dental arches, although most were located on the buccal side (283/300) and only a few on the palatal side (17/300). In order to analyse the sites of miniscrew insertion, the arches were arbitrarily divided into four segments: maxillary arch mesial to the second premolars: 98 miniscrews (48 on the right and 50 on the left); maxillary arch distal to the second premolars: 39 miniscrews (21 on the right and 18 on

the left); mandibular arch mesial to the second premolars: 131 miniscrews (69 on the right and 62 on the left); and mandibular arch distal to the second premolars: 32 miniscrews (15 on the right and 17 on the left).

Most miniscrews were inserted in the anterior segment, with no statistically significant difference between the right and left side or the maxillary and mandibular arch. Analysis of the miniscrew insertion sites in the vertical plane was based on two parameters: position relative to the attached gingiva and position compared with the adjacent roots. The screw was surrounded by attached gingiva (103 screws), free gingiva (121 screws), or were in the mucogingival line (76 screws).

The space between the roots of the two adjacent teeth was divided into three areas in the corono-apical plane: the coronal third, closest to crowns; the apical third, closest to the root tips; and the intermediate area. Ninety-three screws were placed in the coronal third length, 158 in the intermediate area and 49 in the apical third of the root length.

As one cause of failure could be trauma to the screw head, which may compromise primary stability, for instance contact of the tongue with the miniscrew head, patients were instructed on how to prevent this occurrence. More than half (56 per cent) received specific instructions.

Loading forces

Orthodontic force application was either started immediately after surgery (54 miniscrews) or postponed (246 miniscrews). The choice was random.

Loading forces, transmitted to the screws by elastic ligatures, were calculated on the basis of their magnitude (light 150 or heavy loading 250 g) and the time of application (from 0 to 115 days from screw placement). Loading magnitude was measured with a dynamometer (Dinamometro Correx; Libra Ortodonzia Srl, Arezzo, Italy). Light loading was used for 45.3 per cent of the miniscrews (136) and heavy loading for 43 per cent (129).

Statistical analysis

The success rates with different variables were compared using chi-square or Fisher's exact test, where appropriate. Cumulative survival population was computed by Kaplan–Meier analysis. Hazard ratios concerning survival rates were estimated by Cox proportional hazard regression using the software, Stats4U (Version 1, Revision 6, Release 7, <http://www.statpages.org/miller/openstat/Stats4U.htm>). The level of significance was set at $P = 0.05$.

Results

The overall success rate was 81 per cent (243/300); 57 miniscrews were lost (19 per cent failure rate). Of these, 35 (61.4 per cent) were removed because of loosening,

Table 1 Success rate and number of screws as a function of different clinical variables.

Clinical variables	Success rate		
	Failures (rate), <i>n</i> (%)	Success (rate), <i>n</i> (%)	
Gender			
Male	14 (11.9)	104 (88.1)	*
Female	43 (23.6)	139 (76.4)	*
Loading			
Immediate	3 (5.6)	51 (94.4)	*
Delayed	54 (22.0)	192 (78.0)	*
Screw type			
A (diameter 1.5 mm, length 9 mm)	27 (24.5)	83 (75.5)	*
B (diameter 1.5 mm, length 11 mm)	18 (20.7)	69 (79.3)	*
C (diameter 1.3 mm, length 11 mm)	12 (11.7)	91 (88.3)	*
Dental arch			
Maxilla	18 (13.1)	119 (86.9)	**
Mandible	39 (23.9)	124 (76.1)	**
Left/right			
Right	31 (20.3)	122 (79.7)	ns
Left	26 (17.7)	121 (82.3)	ns
Anterior/posterior localization			
Anterior	42 (18.3)	187 (81.7)	ns
Posterior	15 (21.1)	56 (78.8)	ns
Location in the gingiva			
A Attached gingiva	15 (14.6)	88 (85.4)	*
B Mucogingival line	12 (15.8)	64 (84.2)	*
C Mucosa	30 (24.8)	91 (75.2)	*
Location relative to the root			
A Coronal third of the root length	16 (17.2)	77 (82.8)	ns
B Middle third of the root length	29 (18.4)	129 (81.6)	ns
C Apical third of the root length	12 (24.5)	37 (75.5)	ns
Loading			
150 g	11 (8.0)	125 (92.0)	ns
250 g	11 (8.5)	118 (91.5)	ns
Verbal warnings			
Yes	30 (17.9)	138 (82.1)	ns
No	27 (20.5)	105 (79.5)	ns
Handpiece			
Reduction	27 (17.4)	128 (82.6)	ns
Normal	30 (20.7)	115 (79.3)	ns
Cooling			
Yes	27 (17.8)	125 (82.2)	ns
No	30 (20.3)	118 (79.7)	ns

ns, not significant. * $P < 0.05$, ** $P < 0.01$.

4 (7.1 per cent) were removed as a result of excessive postoperative inflammation, and the remaining 18 (31.6 per cent), were spontaneously lost. There was no significant difference in the mean age of the patients where the implants were successful (23.3 ± 11.2 years) or failed (23.2 ± 11.9 years).

Analysis of implant survival showed a high likelihood of having a successful outcome in both genders (success rates were never below 75 per cent; Table 1). However, males (88.1 per cent success rate) had a better prognosis: the risk of failure in females (76.4 per cent success rate) was twice as high (Table 2) as in males (Figure 3a).

All implant failures (57/300) occurred during the first 300 days, 47 in the first 100 days, 23 of which failed in the first 50 days. Consequently, the risk of failure was higher

Table 2 Statistically significant parameters according to Cox proportional hazard regression analysis: hazard ratio, confidence interval (CI), and probability.

Variable	Hazard ratio	95% CI	P
Loading	3.316	1.035–10.62	0.015*
Gingival	1.729	1.028–2.908	0.039*
Gender	2.033	1.112–3.717	0.021*
Arch	2.136	1.220–3.737	0.008**
Diameter	2.044	1.081–3.865	0.019*

* $P < 0.05$, ** $P < 0.01$.

during the first 100 days and then gradually decreased reaching 0 at 300 days post-surgery. In cases where immediate loading was applied (54/300), there were only three failures, which occurred within 68 days.

In 35/57 cases of failure (11.7 per cent of the total number of screws placed), loading was never applied; 82.4 per cent of these (29/35) failed within 2 months. For 18 per cent of screws (54/300), orthodontic force was applied immediately. In the other cases, this was carried out after a mean period of 26 days (± 21.6 ; range 0–115), or failed before loading (11.7 per cent).

Although the number was relatively small, a highly significant difference was found between immediate loading and all other cases (including those that failed before loading). Failure risk (hazard ratio) with postponed loading was about 3.3 (Table 2). The success rate was 94.4 per cent with immediate loading and 78 per cent with delayed loading (Table 1; Figure 3b).

Miniscrew size

The number of type A screws applied (110, 36.7 per cent) was slightly higher than type B (87, 29 per cent) and type C (103, 34.3 per cent) screws. Statistical analysis showed that screw size was important: smaller diameter screws (type C) had a significantly better success rate (88.3 per cent), their failure risk was approximately 50 per cent of that of larger diameter screws (type A 75.5 per cent and type B 79.3 per cent success rates; Table 2; Figure 3c).

Screw location in the bone

Comparison of screws located in different segments of the arch showed that in the anterior part of the lower jaw (77.1 per cent success rate), the risk of failure was twice as high as in the same segment of the upper jaw (87.8 per cent success rate). In the posterior part of the lower jaw (71.9 per cent success rate), the risk of failure was about 2.5 times as high as in the corresponding portion of the upper jaw (84.6 per cent success rate). The probability of success for a screw implant in the maxilla, therefore, was 86.9 per cent as against 76.1 per cent in the mandible (a 2-fold hazard ratio; Tables 1 and Figure 3d).

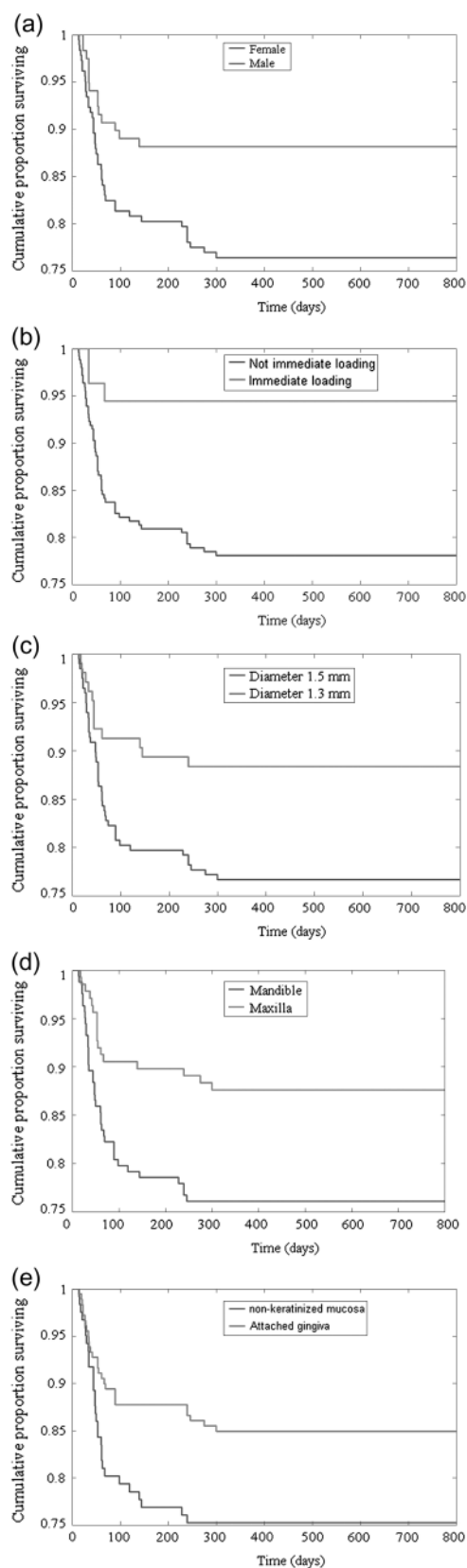


Figure 3 Success rate as a function of gender and time (a), type of loading and time (b), screw diameter and time (c), bone site and time (d), and soft tissue site and time (e).

No statistically significant differences were found between success rates on the right (79.7 per cent) or left (82.3 per cent) or between the anterior (81.7 per cent) and posterior (78.8 per cent) segments (Table 1).

Screw location in the gingiva

Success rates of miniscrews implanted in the attached gingiva and the mucogingival line did not show statistically significant differences (85.4 and 84.2 per cent, respectively; Table 1). However, a difference was found between these two sites and the free gingiva (75.2 per cent success rate; $P < 0.05$). Consequently, the risk of failure when the miniscrew was located in the free gingiva was significantly higher (Table 1; Figure 3e).

Screw location in relation to the root

No statistically significant difference was found in the success rates of screws located in the three segments considered, although the figure was slightly higher for the coronal and middle thirds (82.8 and 81.6 per cent, respectively) versus 75.5 per cent in the apical third (Table 1).

Other variables

No significant differences were found with regard to the other variables (screw application with a controlled torque handpiece, amount of force applied, -150 or 250 g, screw cooling, or instructions to patients; Table 1).

For the 19 screws that were reimplanted, three of them (15.8 per cent) failed again indicating that the success rate of such a procedure is not significantly different from the cumulative success rate.

Discussion

The overall success rate in this study (81.0 per cent) is lower than that reported in similar research, ranging from 83.9 to 91.1 per cent (Miyawaki *et al.*, 2003; Cheng *et al.*, 2004; Tseng *et al.*, 2006; Kuroda *et al.*, 2007; Wiechmann *et al.*, 2007). This slight difference could be due to sample size or to other factors such as screw loading, location, diameter, etc.

Berens *et al.* (2006), in a comparable study of 239 miniscrews placed in 85 patients, reported a success rate of 76.7 per cent; it was lower in the first 133/239 screws, whereas it was significantly higher (95.3 per cent) for the second group of 106/239 screws, but the criteria used to measure success rates were different. Slightly loosened screws where loading was applied (7.5 per cent) and screws that were removed because of excessive mobilization (7.5 per cent) were not viewed as failures.

Gender

Success rates were better in male (88.1 per cent) than in female (76.4 per cent) patients. This finding is difficult to

interpret and is in contrast with the information in the literature (Miyawaki *et al.*, 2003; Cheng *et al.*, 2004; Kuroda *et al.*, 2007). A possible explanation could be the large number of miniscrews reviewed in this sample, the different types of screws used, as well as anatomical differences (e.g. different thickness of the cortical bone) and/or hormonal differences.

Screw mobilization time

Most failures occurred during the first weeks from insertion: 47 of the 57 that failed were lost in the first 100 days and 23 in the first 50 days. The hypothesis that miniscrews may be more likely to fail because of excessive loading or because they become unscrewed as a result of interacting forces (Costa *et al.*, 1998) could be indirectly confirmed by the absence of inflammatory tissue on some miniscrews that became mobilized at a later stage. Success rates might be increased by avoiding the application of torquing forces acting in a counterclockwise direction. Moreover, Liou *et al.* (2004) observed that miniscrews are not in a state of absolute stability; this might cause irritation of the adjacent tissues and result in less support given by the bone to the screws.

Time of load application

There are a number of reports concerning the immediate loading effect on orthodontic implants, with many and different results. For example, some authors (Becker *et al.*, 1994; Schnitman *et al.*, 1997) postulated or demonstrated (Trisi and Rebaudi, 2005) that immediate loading might destabilize prosthetic implants and increase the number of failures, while others (Majzoub *et al.*, 1999; Buchter *et al.*, 2005; Berens *et al.*, 2006) showed that immediate loading can be applied without loss of stability. Moreover, immediate loading seems to have a positive effect on bone, increasing the cellular turnover and density in the areas adjacent to loaded implants in comparison with implants with no force applied (Melsen and Lang, 2001), suggesting that orthodontic loading may have a protective effect. Nkenke *et al.* (2003), on the other hand, found no significant difference in terms of daily bone apposition, bone-implant contact, and bone density in the presence or absence of early loading.

A correlation between the time of force application and success rate is not always found (Miyawaki *et al.*, 2003), and in comparison of some studies on consecutive patients, it is possible to find discordant results. Cheng *et al.* (2004) reported a success rate of 89 per cent with application of orthodontic forces after 2–4 weeks, while Costa *et al.* (1998) found almost the same results with immediate loading (87.5 per cent).

In the present study, in agreement with Kuroda *et al.* (2007), immediate loading seemed to have a positive and significant influence on the success rate as these were 94.9 per cent with immediate loading and 78 per cent with

delayed loading. Immediate loading was applied on only 18.0 per cent of miniscrews (54/300) and this could explain why the success rate (81.0 per cent) was lower than those reported in similar investigations.

Size of miniscrews

Tseng *et al.* (2006) showed that the success rate was higher (100 per cent) with 14 mm long screws and lower (80 per cent) with the 8.0 mm versions. On the contrary, the results of the present investigation confirmed the findings of most studies (Miyawaki *et al.*, 2003; Cheng *et al.*, 2004; Tseng *et al.*, 2006; Kuroda *et al.*, 2007; Wiechmann *et al.*, 2007) that screw length has no influence on stability as this was not increased by contact of the screw with the bone marrow.

Gallas *et al.* (2005) demonstrated that stress is concentrated around the peak of the dental implant and surrounding bone, reaching its apex at the cervical edge of the implant and first thread. Miyawaki *et al.* (2003) showed that screw diameter was directly proportional to success rate, which was 83.9 per cent with the 1.5 mm screw and 85.0 per cent with the 2.3 mm screw. This difference was not statistically significant, but with 1.0 mm screws, the success rate decreases to 0 per cent. Wiechmann *et al.* (2007) confirmed the findings of previous authors, reporting a success rate of 87.0 per cent with 1.6 mm screws and 1.1 per cent with the 1.1 mm versions.

Conversely, Berens *et al.* (2006) reported a higher success rate with larger screws (2.0 mm) but only in the mandible. Kuroda *et al.* (2007) found that the success rate was higher with 1.3 mm screws (88.6 per cent) than with 2.0 and 2.3 mm screws (81.1 per cent). The results from the current study show that success rate and screw diameter were inversely proportional (88.3 per cent for 1.3 mm and 77.2 per cent for 1.5 mm). The major difference between this study and that of Kuroda *et al.* (2007) is that in the present research the miniscrews were randomly applied in the free or attached gingiva, while in their study, all 1.3 mm screws were placed in the attached gingiva. The smaller sample size in the study of Kuroda *et al.* (2007) might be the reason why the difference was not statistically significant. Moreover, 1.3, 2.0, and 2.3 mm screws are not comparable because the latter are applied using flap surgery and located in soft tissues, a variable that has a significant impact on the likelihood of achieving a successful outcome. This finding of the present study seem to suggest that a diameter of 1.3 mm is superior to a 1.5 mm screw diameter to achieve primary stability, minimal trauma to the surrounding tissues, and minimal or no trauma for tissues around the root.

Screw location in the root

Poggio *et al.* (2006) and Asscherickx *et al.* (2008) suggested that the minimum amount of bone tissue surrounding the screw to guarantee its stability should be 1 mm. This is

possibly indirectly confirmed by the higher success rates reported in the anatomical areas from the middle of the root length to the apical area (Schnelle *et al.*, 2004). In the present study, although the difference was not statistically significant, the success rate was lower in the apical (75.5 per cent) than in the cervical area with less bone substance (82.2 per cent). These results could be due to the 'area of screw emergence' (attached gingiva/free gingiva) rather than to the 'miniscrew stem location'. It may be that the emerging area of the screw head has a greater influence on the success rate than the position of the screw body in the bone.

Screw location in the bone

Miyawaki *et al.* (2003) suggested a higher success rate for miniscrews inserted in the posterior part of the mandible than in the maxilla due to the greater thickness of the bone cortex. Cheng *et al.* (2004), Kuroda *et al.* (2007), and Wiechmann *et al.* (2007) reported a significantly higher success rate for miniscrews inserted in the maxilla than for those in the mandible. In all the cases studied, miniscrews were not applied in the anterior part of the dental arch. Berens *et al.* (2006) found that success rates were always higher for miniscrews inserted in the maxilla. In the present study, miniscrew locations were evenly distributed between the two jaws and the two sides. Most screws were inserted in the anterior portion of the jaws (229 anterior; 71 posterior). The success rates were significantly higher for the miniscrews in the maxilla (86.9 per cent) than in the mandible (76.1 per cent) and this may be due to the more frequent screw application in the anterior portion of the arches. These results may also be influenced by other factors, such as the greater amount of keratinized tissue, the less demanding surgical procedure, and the greater vascularization of the upper jaw.

Screw location in the gingiva

Adell *et al.* (1981) and Albrektsson *et al.* (1986) found no difference between the success rates of prosthetic implants located in the attached or free gingiva. Warrer *et al.* (1995) claimed that the absence of mucosal keratinization implies a higher susceptibility to destruction of peri-implant tissues induced by plaque. Chung *et al.* (2006) found more plaque accumulation and inflammation in the absence of keratinized mucosa but not an increase in loss of peri-implant bone. Cheng *et al.* (2004), Berens *et al.* (2006), and Wiechmann *et al.* (2007) reported a better prognosis for miniscrews located in the attached gingiva. The success rates in the current study were significantly higher when the screw heads emerged through the attached gingiva or the mucogingival line and, consequently, the rate of screw dislocation was significantly higher on the lingual side of the mandible, where there is only free gingiva (Berens *et al.*, 2006; Wiechmann *et al.* 2007).

Conclusions

Within the limits of this retrospective study, the clinically controllable factors that proved to be related to a better prognosis suggest:

1. The success rate is better in male patients (88.1 per cent).
2. The 1.3 mm wide 11 mm length miniscrew has a better success rate (88.3 per cent).
3. The most favourable position for insertion with respect to the soft tissues is in the attached gingiva (success rate 85.4 per cent) immediately followed by insertion in the mucogingival line (84.2 per cent).
4. The optimum success rate (95.2 per cent) was found for the 1.3 mm wide miniscrew emerging in the attached gingiva; this rate was significantly higher than that of a 1.5 mm screw inserted in the free gingiva (78.0 per cent).
5. Miniscrews inserted in the maxilla had a higher success rate (86.9 per cent) than those inserted in the mandible (76.1 per cent).
6. The most favourable position relative to the root is in the coronal third (success rate 82.8 per cent).
7. Loading not exceeding 150–250 g should be immediately applied to the screw.

Acknowledgement

We would like to thank Professor Roberto Felice Grassi for his cooperation and helpfulness in the development of this research, mainly in positioning the miniscrews.

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