A Prospective Study of the Risk Factors Associated with Failure of Mini-implants Used for Orthodontic Anchorage

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Purpose: *The aim of this prospective clinical study was to assess the risk factors associated with failure of mini-implants used for orthodontic anchorage.* ***Materials and Methods:*** *A total of 140 mini-implants in 44 patients, including 48 miniplates and 92 freestanding miniscrews, were examined in the study. A variety of orthodontic loads were applied. The majority of implants were placed in the posterior maxilla (104/140), and the next most common location was the posterior mandible (34/140).* ***Results:*** *A cumulative survival rate of 89% (125/140) was found by Kaplan-Meier analysis. There was no significant difference in the survival rate between miniplates and freestanding miniscrews, but miniplates were used in more hazardous situations. The Cox proportional-hazards regression model identified anatomic location and peri-implant soft tissue character as 2 independent prognostic indicators. The estimated relative risk of implant failure in the posterior mandible was 1.101 (95% confidence interval, 0.942 to 1.301;* $P = .046$*). The risk ratio of failure for implants surrounded by nonkeratinized mucosa was 1.117 (95% confidence interval, 0.899 to 1.405;* $P = .026$*).* ***Discussion and Conclusion:*** *The results confirmed the effectiveness of orthodontic mini-implants, but in certain situations adjustment of the treatment plan or modifications in the technique of implant placement may lead to improved success rates.* INT J ORAL MAXILLOFAC IMPLANTS 2004;19:100–106

Key words: *complications, failure, mini-implants, orthodontic implants, risk factors*

Anchorage is a prerequisite for orthodontic treatment with fixed appliances. Implants are an excellent alternative to traditional orthodontic anchorage methodologies, and they are a necessity when dental elements lack quantity or quality, when extraoral devices are impractical, or when noncompliance during treatment is likely.[1] In recent years, the use of dental implants for orthodontic anchorage has increased in popularity. However, conventional dental implants can be placed only in edentulous and retromolar areas. Midpalatal implants designed for orthodontic anchorage avoid the problem of space limitation, but they can be used only in the maxilla. In addition, the stress of 2-stage surgeries, the high cost, limitations in the direction of force application, possible nerve damage or altered sensation, and difficulty in hygiene care all limit the use of dental implants in orthodontics. It is obvious that more versatile implant systems are needed for the purpose of augmentation of orthodontic anchorage in all segments of the dental arches.[2,3]

In the last few years, implants of smaller sizes have been designed for orthodontic anchorage. These mini-implants are small enough for placement at any surface of the alveolar process, even in the interdental areas. They are relatively inexpensive, and techniques for their placement and retrieval are simple. In a canine model, Ohmae and coworkers[4]

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proved the effectiveness of 1-mm-diameter miniscrews as anchors for orthodontic intrusion. Miniscrews 2 mm in diameter have been successfully used as anchorage for orthodontic patients.[2,3,5] However, most of the previous accounts concerning the use of mini-implants for orthodontic purposes were in the form of case reports[5] or were preliminary studies sharing experience on only a limited number of patients.[2,3] The clinical use of 1.2-mm-diameter miniscrews as orthodontic anchors has also been shown,[6–9] but again only in case reports. To the authors' knowledge, studies focused on the failure rate of orthodontic mini-implants and the associated risk factors have not been published.

The aim of this prospective study was to investigate the complications and failures of orthodontic mini-implants in a series of consecutive patients. The risk factors associated with the failure and complications were analyzed.

MATERIALS AND METHODS

Patients

Forty-four consecutive patients who required skeletal anchorage for orthodontic therapy were included in a prospective study. There were a total of 140 implant sites among the 44 patients (6 men and 38 women). All patients were treated at the Departments of Orthodontics and Oral and Maxillofacial Surgery, National Taiwan University Medical Center, Taipei, Taiwan, between January 1999 and May 2002. The mean (± SD) age of the patients was 29 (± 8.9) years (range 13 to 55 years).

Preoperative Planning

All patients underwent a standard pretreatment examination, including facial and intraoral photography, dental model analysis, panoramic radiography, and cephalometry. Orthodontists established the indications for implant anchorage. The position of implant placement in each case was determined by an orthodontist and a surgeon working together according to the particular biomechanics and availability of bone.

Surgical Procedure

Titanium mini-implants (Leibinger, Freiburg, Germany; or Mondeal, Tuttlingen, Germany) were used. One of the 2 implant systems was randomly chosen for each patient. The configurations of the implants in the 2 systems were identical. They provided miniscrews of different lengths and 0.6-mm-thick miniplates of various shapes (Fig 1). However, only L-shaped plates were used in the study. The screws were 2 mm in diameter and 5 to 15 mm long. Emergency screws 2.3 mm in diameter and 7 mm in length were also available. Anchorage with a single miniscrew (9 to 15 mm in length) was employed when *(1)* interdental bone was suitable for screw fixation or *(2)* neighboring basal bone more than 2 mm in thickness was available. Otherwise, an L-shaped plate fixed by 2 or 3 miniscrews (5 or 7 mm in length) was used.

Fig 1 Mini-implants were chosen as orthodontic anchors. Miniscrews of different lengths and L-shaped miniplates were used. The screws were 2 mm in diameter and 5 to 15 mm long.

Informed consent was obtained from every patient before surgery. Placement of the mini-implant was performed under local anesthesia by a senior oral surgeon (SJC or SHK). First, a mucoperiosteal incision was made at the site where emergence of the anchor was desirable. The mucoperiosteal flap was then reflected to expose the cortical bone. When a miniplate was to be used, an L-shaped plate was adjusted to fit the contour of the bone surface and fixed by 2 or 3 monocortical miniscrews (5 or 7 mm long). The screw holes were made by a 1.5-mm twist drill at 1,000 rpm with continuous normal saline irrigation. The 2-mm miniscrews were then placed in a self-tapped fashion. The terminal hole at the long arm of the plate was exposed to the oral cavity from the incised wound (Figs 2a and 2b). For freestanding miniscrew anchors, no adaptation of the bone plate was needed, and a monocortical screw of appropriate length (9 to 15 mm) was placed in the same self-tapped manner. The screw head was adjusted to a level 2 mm above the mucosa to be exposed to the oral cavity through the incision (Figs 2c and 2d). Every effort was made to avoid damage to the dental roots or adjacent vital structures. The mucoperiosteal incision was sutured with 3-0 silk.

Postoperative Care

The sutures were removed 7 to 10 days after surgery. The patients were instructed to cleanse the exposed mini-implants with a single-tuft brush.

Figs 2a to 2d Application of mini-implants for orthodontic anchorage.

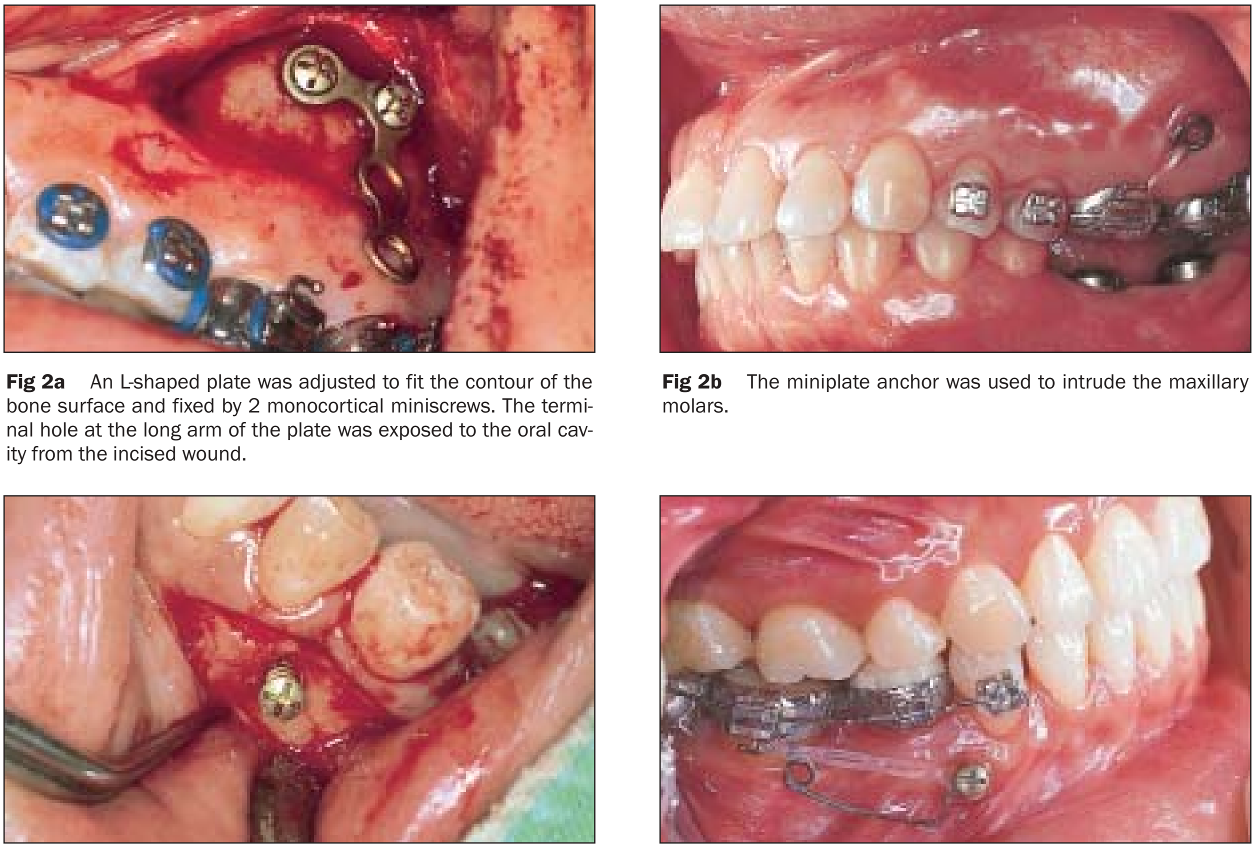

Fig 2a An L-shaped plate was adjusted to fit the contour of the bone surface and fixed by 2 monocortical miniscrews. The terminal hole at the long arm of the plate was exposed to the oral cavity from the incised wound.

Fig 2b The miniplate anchor was used to intrude the maxillary molars.

Fig 2c A monocortical miniscrew was placed in the interdental bone. The screw head was adjusted to a level 2 mm above the mucosa and exposed to the oral cavity through the incision.

Fig 2d The miniscrew anchor was used to protract mandibular molars.

Orthodontic treatment was started 2 to 4 weeks after the surgery. The orthodontic load applied to the implants was estimated to be 100 to 200 g. The directions of force applied to the mini-implants were mainly lateral; torsional or extrusive load was avoided.

Outcome Evaluation

Orthodontic indications, implant systems (Leibinger versus Mondeal), anchor types (miniscrew versus miniplate), length of miniscrews, magnitude of orthodontic load, implant locations (anterior and posterior maxilla versus anterior and posterior mandible), and character of the soft tissue at the implant emergence site (keratinized versus nonkeratinized) were recorded for each patient in addition to the demographic information. Gingival Index[10] (GI) was assessed after the beginning of orthodontic treatment. Unacceptable oral hygiene was defined as GI > 1.

Complications associated with the mini-implants were evaluated monthly during the course of orthodontic treatment. Peri-implant infection was defined as persistent pain and swelling of the tissue surrounding the implant that required analgesics and antibiotics for relief. Implant mobility was detected by the firm grasp of cotton pliers.

Criteria for the success of orthodontic mini-implants were as follows: *(1)* absence of inflammation, *(2)* absence of clinically detectable mobility, and *(3)* capability of sustaining the function of anchorage throughout the course of orthodontic treatment. The survival duration was measured from the time of implant placement to the time of failure (complete) or to the last follow-up or implant retrieval on the completion of treatment (censored).

Statistical Analysis

Possible correlations between various clinical parameters and implant failure and complications were evaluated by the chi-square or Fisher exact tests where appropriate. Cumulative survival of the implants over time was analyzed with the Kaplan-Meier product limit method. Comparison of cumulative survival between groups was performed using the log-rank test with the software Statistica 6.0 (Statsoft, Tulsa, OK). The risk factors affecting survival were assessed by a Cox proportional hazards regression model using the software Statistical Analysis System Version 8.1 (SAS Institute, Cary, NC). *P* values less than .05 were considered statistically significant.

RESULTS

The orthodontic indications for the 140 mini-implants are listed in Table 1. More than two thirds of the implants were used for molar intrusion or uprighting. The rest of the implants were used for retraction of anterior teeth or protraction of posterior teeth. Of the 140 implant anchors, 48 were miniplates and 92 were freestanding miniscrews. Sixty-seven Leibinger implants and 73 Mondeal implants were used. The majority of the mini-implants were placed in the posterior maxilla (104/140) and the next most common location was the posterior mandible (34/140). Only 2 implants in this series were placed in anterior regions (Table 2).

Peri-implant infection was found at 7 implants. In 5 of the 7 cases, infection was associated with implant mobility. However, for the other 2 implants, the infection resolved after appropriate hygiene care and antibiotic therapy. In 1 patient who had a history of chronic sinusitis, symptoms and signs of maxillary sinusitis were noted after the implant surgery and were resolved by antibiotics.

Implant mobility or complete exfoliation was found for 15 implants. Four of them failed before the application of orthodontic load, and 6 implants were lost after loading of less than 1 month. The remaining 5 failed implants were loaded for 3 to 12

Table 1 Orthodontic Indications for 140 Mini-implants

Indication	No. of implants
Retraction of protruded anterior teeth	15
Protraction of retruded posterior teeth	25
Molar intrusion	79
Molar uprighting	21

Table 2 Correlation Between Peri-implant Infection and Failure of Mini-implants and Clinical Parameters

	Peri-implant infection		Implant failure	
	Yes (n = 7)	No (n = 133)	Yes (n = 15)	No (n = 125)
Orthodontic indication				
Protraction	1	14	2	13
Retraction	2	23	6	19
Intrusion	3	76	5	74
Uprighting	1	20	2	19
Anchorage				
Miniplate	4	44	7	41
Miniscrew	3	89	8	84
Implant system				
Leibinger	3	64	5	62
Mondeal	4	69	10	63
Length of miniscrew				
5 or 7 mm	4	44	7	41
9 mm	1	30	2	29
11 mm	1	30	2	29
13 mm	1	19	3	17
15 mm	0	10	1	9
Location*				
Anterior maxilla	0	1	0	1
Posterior maxilla	1	103	7	97
Anterior mandible	0	1	0	1
Posterior mandible	6	28	8	26
Surrounding mucosa*				
Keratinized	1	120	9	112
Nonkeratinized	6	13	6	13
Oral hygiene				
Acceptable	7	132	14	124
Unacceptable	0	1	1	1

*$P < .05$.

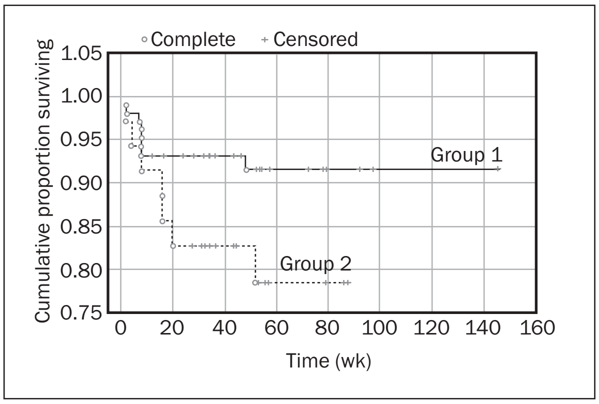

Fig 3 Kaplan-Meier analysis of implant failure according to anatomic location of the mini-implants. The duration of survival was measured from mini-implant placement to the time of failure (complete) or to the last follow-up or completion of treatment (censored). The cumulative survival for implants in the posterior maxilla (group 1) was significantly longer than for those in the posterior mandible (group 2) (P = .041; log-rank test).

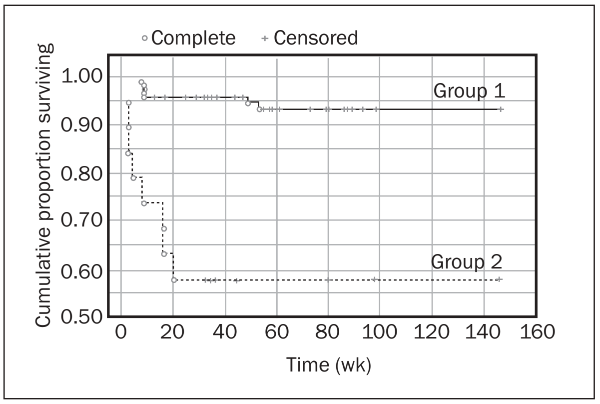

Fig 4 Kaplan-Meier analysis of implant failure according to the character of surrounding tissue. The duration of survival was measured from mini-implant placement to the time of failure (complete) or to the last follow-up or completion of treatment (censored). The cumulative survival for implants that emerged from keratinized mucosa (group 1) was significantly longer than for those that emerged from nonkeratinized tissue (group 2) (P < .001; log-rank test).

Table 3 Cox Proportional Hazards Regression Model for Overall Survival with Prognostic Factors

	Univariate			Multivariate		
	Risk ratio	95% CI	*P*	Risk ratio	95% CI	*P*
Location	1.118	0.951–1.311	.045	1.101	0.942–1.301	.046
Emergence site	1.213	0.991–1.531	.020	1.117	0.899–1.405	.026

months before failure. The other 125 mini-implants sustained the orthodontic load satisfactorily without any detectable mobility or significant inflammation. Therefore, the cumulative success rate of orthodontic mini-implants in the series was 89% (125/140).

Correlations between various clinical parameters and peri-implant infection and implant failure are shown in Table 2. Age and gender of the patients and magnitude of orthodontic load had no significant relationship to the outcome of the orthodontic implants (data not shown). Orthodontic indications, anchor type, implant system used, length of miniscrews, and oral hygiene status of the patient did not significantly correlate with the occurrence of implant infection or failure (Table 2). On the other hand, anatomic location of the implant and the character of the soft tissue at the implant emergence site appeared to have significant influences on the outcome of the implants. Implants in the posterior mandible and those surrounded by nonkeratinized mucosa were prone to failure (P = .02 and P = .006, respectively). Furthermore, location in the posterior mandible and nonkeratinized emergence site also predisposed the implants to infection (P < .001 and P < .001, respectively).

Kaplan-Meier analysis showed a tendency toward shorter survival for miniscrews versus miniplates, but the difference was not statistically significant (figure not shown; P = .081). Implants in the posterior maxilla had longer survival than those in the posterior mandible (P = .041; Fig 3). In addition, implants exposed in keratinized mucosa had longer survival than those surrounded by nonkeratinized tissue; this difference was also statistically significant (P < .001; Fig 4).

The Cox proportional hazards regression model was used to assess the prognostic value of implant location and character of the peri-implant tissue (Table 3). The estimated relative risk of implant failure in the posterior region of the mandible was 1.101 (95% confidence interval, 0.942 to 1.301; P = .046). The risk ratio for failure of implants surrounded by nonkeratinized mucosa was 1.117 (95% confidence interval, 0.899 to 1.405; P = .026).

DISCUSSION

Since the introduction of fixed appliances, the question of anchorage in orthodontics has attracted considerable interest and remained a major problem. Development of intraoral, extradental anchorage systems has been welcomed, because the related difficulties are far from being solved by traditional methods of orthodontic anchorage. Several types of these extradental anchors have been used in orthodontics: the conventional osseointegrated implant,[11,12] the onplant,[13] and more recently the mini-implant.[2,3,5] Mini-implants have the advantages of low cost, simple surgical placement, and high versatility.

Although orthodontic implants have been in use for decades, their clinical performance and factors affecting their success have not been well studied. Many authors have demonstrated the efficacy of titanium endosseous implants as anchors for orthodontic or orthopedic movement in animals.[11,12,14–18] However, most of the clinical reports on orthodontic endosseous implants have been in the form of case reports or focused mainly on technical description.[19–23] Higuchi and Slack[24] reported the use of 14 titanium implants (Nobelpharma, Göteborg, Sweden) in 7 patients for orthodontic tooth movement and stated that all implants remained stable during the entire treatment period. Wehrbein and coworkers[23] reinforced orthodontic anchorage with palatal titanium screws (Orthosystem; Straumann, Waldenburg, Switzerland) in 9 patients. All 9 implants remained stable throughout the treatment period, with only a minimal loss of anchorage. Bernhart and associates[25] used short epithetic implants (Nobel Biocare, Göteborg, Sweden) in the paramedian region of the palate for augmentation of orthodontic anchorage, and a survival rate of 84.8% (18/21) was obtained.

As for orthodontic mini-implants, Ohmae and colleagues[4] showed that miniscrews 1 mm in diameter were able to sustain an intrusive force of 150 g for 12 to 18 weeks in beagle dogs. However, only preliminary studies can be found concerning the clinical applications of mini-implants as orthodontic anchorage. Costa and coworkers[2] used 2-mm titanium miniscrews as anchorage for various types of tooth movement, and a failure rate of 12.5% (2/16) was found. They noted that a force system that generated a moment to the screw in the unscrewing direction condemned an implant to failure. Freudenthaler and associates[3] placed 2-mm bicortical titanium screws in the interdental alveoli of mandibles for the protraction of posterior teeth, and 3 of the 12 screws (25%) were considered failures. Risk factors associated with implant failure were not mentioned in the report.

According to the criteria for success, a cumulative success rate of 89% (125/140) was found for the orthodontic mini-implants used in the present patient series. Two-thirds of the failures were noted before loading or within 1 month after orthodontic loading was initiated. In view of the variety of orthodontic loads applied in the study, this result confirmed the effectiveness and versatility of mini-implants as orthodontic anchors. Nevertheless, it is noteworthy that torsional and extrusive loads were avoided, since they were thought to be detrimental to implant survival. The 2 implant systems (Leibinger and Mondeal), which were of identical configuration, showed no difference in their success. Miniplates, each fixed by 2 to 3 short miniscrews (5 or 7 mm), had a slightly higher success rate than freestanding miniscrews, but the difference was not statistically significant. However, it should be noted that miniplates were used in more hazardous situations; they sustained loads with a longer lever arm or were fixed in thinner bone than were the freestanding miniscrews.

In the present study, the length of miniscrews had no effect on implant survival. The short screws used for the fixation of miniplate implants did not jeopardize their performance. For the longer freestanding miniscrews, the screw length was usually determined by the transmucosal depth (the distance between the anchoring bone surface and the emergence point through the mucosa), rather than by the depth of bone available for anchorage. Longer implants did not necessarily result in greater bone support. Therefore, it is not surprising that screw length did not influence the outcome of orthodontic mini-implants in the study. With regard to the magnitude of orthodontic load, it was found that a load in the range of 100 to 200 g could be well sustained by the mini-implants. No significant difference was noted in the magnitude of load between successful and failed implants.

Soft tissue character and anatomic location were identified in this study as factors that were significantly associated with peri-implant infection and failure. The necessity of peri-implant keratinized mucosa for the maintenance of implant health has long been a debatable issue for endosseous dental implants. Retrospective clinical surveys have failed to reveal major differences in the survival of implants placed in keratinized or nonkeratinized mucosa.[26,27] In an experimental study in monkeys, however, Warrer and associates[28] discovered that the absence of keratinized mucosa around endosseous dental implants increased the susceptibility of the peri-implant region to plaque-induced tissue destruction. The results of the present study are in accord with those of the latter, as it was found that the absence of keratinized mucosa around mini-implants significantly increased the risk of infection and failure. Also, the present findings seem to indicate a bacterial role in the failure of orthodontic mini-implants, since peri-implant infection was associated with a high rate of implant failure (71%, ie, 5 of 7 failed).

Implants in the posterior mandible were more susceptible to infection, mainly because less attached gingiva is available in this region. However, where implant failure is concerned, factors other than keratinized mucosa may also be involved, since posterior mandibles had more implant failures and the influence remained statistically significant in multivariate analysis. In addition to the lack of sufficient masticatory mucosa, bone in the posterior mandible is dense and overheating is more likely to occur during implant placement, especially when the screws are placed in a self-tapped manner. It is suggested that a larger final drill and/or placement of the screws in a pretapped fashion may help minimize the trauma and lower the failure rate.

CONCLUSION

The present study confirmed the reliability of miniscrews and miniplates as orthodontic anchors. However, failure was more likely when the implants were placed in alveolar mucosa and in the posterior mandible. Adjustment of the treatment plan or modifications in the technique of implant placement may help improve the success rate.

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