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Risk factors associated with the failure of miniscrews - A ten-year cross sectional study

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Abstract: The aims of this study were to identify (1) patient-related factors (sex, age, craniofacial pattern and smoking habit), (2) miniscrews implants (MSI)-related factors (length and diameter) and (3) location-related factors [bone (maxilla or mandible) and area (buccal, lingual and alveolar ridge)] that may be associated with MSI loss of stability. A total of 1356 MSI were installed in 570 patients (423 females and 147 males) with mean age of 42.7 during a 10-year period and were clinically evaluated once a month until the end of the proposed movement. Length (5, 7, 9 and 11 mm) and diameter (1.3, 1.4 and 1.6 mm) of the MSI were selected according to insertion site. The evidence of clinical mobility during treatment or fracture during insertion was considered as failure. A total success rate of 89.1% was observed. There was no statistically significant difference in loss of stability when considering age, sex, craniofacial pattern or smoking habit. Considering diameter, there was no statistically significant difference ($p = 0.645$), but the shorter miniscrews (5 mm) showed higher failure rates ($p < 0.001$) than the longer ones. There were more loses ($p < 0.001$) in the mandible than in the maxilla, but the area (buccal, lingual or alveolar ridge) did not interfere in the results ($p = 0,421$). It can be concluded that MSIs are effective for skeletal anchorage in orthodontics. Patient-related factors, such as sex, age, smoking habit and craniofacial pattern, did not affect MSI success. However, the use of shorter MSIs (5 mm) was inversely proportional to failure probability, and loss of stability was greater in the mandible.

Keywords: Orthodontic Anchorage Procedures; Orthodontics.

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Introduction

Since their introduction in orthodontic practice, mini-screw implants (MSIs) have been extensively used and investigated[1,2,3,4,5,6]. Previous studies have reported success rates varying from 74% to 93%[3,7,8,9,10]. However, variables that directly interfere with implant stability have remained unclear[3,5,10,11].

The main factors suggested to increase the loss of stability are root proximity during MSI insertion[1,5,12] and screw length, which can directly influence this risk[13]. A study showed that MSIs 4–6 mm in length were safe in most regions of the maxilla and mandible[14]. However, it remains unknown whether a shorter screw length is associated with an increased failure rate[10,13]. Reducing MSI diameter can also decrease the risk of root contact; however, several groups[2,7] observed a greater impact of MSI diameter on primary stability. Bone quality and cortical width at the site of MSI insertion are other important parameters for primary and secondary stability[15,16,17], and researchers have found a correlation between craniofacial pattern and cortical bone width[18]. Last, although the association between smoking habit and MSI failure has been poorly discussed in the literature, Bayat and Bauss[19] recently reported higher inflammation rates and loss of peri-MSI bone in heavy smokers (>10 cigarettes/day).

As the use of MSIs is increasing in orthodontic practice, it is critical to understand which variables may interfere with MSI success. Thus, the aims of this study were to identify (1) patient-related factors (sex, age, craniofacial pattern and smoking habit), (2) MSI-related factors (length and diameter) and (3) location-related factors [bone (maxilla or mandible) and area (buccal, lingual and alveolar ridge)] that may be associated with MSI loss of stability.

Methodology

This retrospective, cross-sectional study was conducted according to the principles laid down in the Declaration of Helsinki and approved by the Neurologic Institute of Curitiba Ethical Committee (no. 948.944) with informed consent.

The medical records of consecutive patients who received MSIs during a 10-year period (2004–2013) were initially selected from the archives of the Latin American Institute of Dental Research and Education (ILAPEO, Curitiba, Brazil). The inclusion criterion was patients needing skeletal anchorage for orthodontic movement in their permanent dentition. Patients who failed to complete orthodontic treatment were excluded.

All MSIs (Neodent, Curitiba, Brazil) were conical shaped; 5, 7, 9 or 11 mm in length; and 1.3, 1.4 or 1.6 mm in diameter. Treatment planning of the implantation site was determined by the orthodontist according to bone availability observed in periapical radiographs taken immediately before MSI insertion, clinical evaluation of soft tissues and the force system used for dental movement. MSI insertion was performed under local anesthesia. Maximum torque was anticipated to be lower than 10 N.cm for 1.3- and 1.4-mm MSIs and 15 N.cm for 1.6-mm MSIs, as recommended by the manufacturer. Immediate loading was preferred and the magnitude of force used was the force indicated for the specific movement.

The exposure variables studied were classified as (1) patient-related factors: sex, age, smoking habit and craniofacial skeletal pattern [dolichofacial (vertical), mesofacial (balanced) or brachyfacial (horizontal)]; (2) MSI-related factors: length and diameter; and (3) location-related factors: bone (maxilla or mandible) and area (buccal, lingual or alveolar ridge).

To classify patients according to growth pattern, cephalometric measurements were made using initial lateral radiographs. The cephalometric angles used were NS.GoMe, NS.Gn and FMA, with reference values of 32°, 67° and 25°, respectively. Values higher than the reference values indicated a dolichofacial pattern, while lower values indicated a brachyfacial pattern. The same researcher performed all tracings and measurements manually.

The outcome, MSI failure, was determined as evidence of clinical mobility during treatment or fracture during insertion.

Statistical analysis

Student's *t*-test was used for comparisons of age and sex between patients who exhibited implant loss of stability and those who did not. Fisher's exact The Chi-squared test was used to evaluate the association between loss of stability and qualitative variables. Finally, a multilevel model with two levels was used, with level 1 corresponding to MSI-related factors and level 2 corresponding to patient-related factors. Level 1 variables that demonstrated statistical significance ($p < 0.05$) were included in the final model with level 2 variables. After adjusting for confounders, the odds ratio (OR) was estimated with respective 95% confidence intervals (95% CIs). $P < 0.05$ indicated statistical significance. Statistical analyses were performed using SPSS software (v. 20, Chicago, IL, USA). Confounders were adjusted for using MLwiN software (v.2.30, Center for Multilevel Modelling, University of Bristol, Bristol, UK).

Results

The cohort comprised 570 patients (1,356 MSIs). The cohort was predominantly female (n = 423; 74.2%), with a mean age of 42.7 years (range: 12–73 years). Patients (n = 101) who did not complete dental treatment at ILAPEO were excluded.

Patient characteristics, including sex, smoking habit and craniofacial pattern, are shown in Table 1. The data concerning smoking habit were missing for 3 patients, and only 227 patients had craniofacial pattern included in their records.

The overall MSI failure rate was 10.9% (n = 148; 95%CI: 9.3–12.6%). Seven mini-screws fractured during insertion. Patient-related factors are described in Tables 2–5.

The results concerning MSI-related factors are described in Tables 6 and 7.

The results for location-related factors are shown in Tables 8 and 9.

We then conducted a multivariate analysis to identify associations between MSI-related factors and patient-related factors (Tables 10 and 11).

Discussion

Temporary skeletal anchorage devices have been widely used in orthodontic clinics; however, factors that influence the risk of failure remain unclear. The aims of this study were to identify MSI-related factors, patient-related factors and location-related factors that may be associated with MSI instability.

The overall success rate was 89.10%, which is in accordance with other studies that reported values ranging from 81% to 93%[3,4,7,8,9]. In the present study, the success rate was evaluated as the complete absence of screw mobility during orthodontic movement.

Neither sex (Table 2) nor age (Table 3) had an effect on MSI failure, which is in agreement with other studies[1,3,8]. Additionally, an association between smoking habit and probability of MSI instability was not observed (Table 4). Bayat and Bauss[19] reported higher rates of peri-implant inflammation and bone loss in heavy smokers (> 10 cigarettes/day). A possible explanation for the discrepancy between these results may be the lack of differentiation between light and heavy smokers in our cohort. In addition, as the present study was retrospective and cross-sectional in nature, it was not possible to confirm temporal relationships between exposure variables and MSI failure.

We did not observe a correlation between craniofacial pattern and MSI failure (Table 5), which is in agreement with some studies[1,3,15]. However, other studies[7,17] reported that patients with low mandibular plane angles showed better MSI stability.

According to our findings, screw length was associated with MSI success (Tables 7, 10 and 11). Shorter MSIs (5 mm) showed a significant tendency to fail (25.35%) compared with 7 mm (10.90%), 9 mm

Table 1. Distribution of patients according to sex, age and craniofacial pattern.

Variable	Frequency	%
Sex		
Female	423	74.2
Male	147	25.8
Total	570	100
Smoking		
No	517	91.2
Yes	50	8.8
Total	567	100
Craniofacial pattern		
Brachyfacial	69	30.4
Mesofacial	58	25.6
Dolichofacial	100	44.1
Total	227	100.0

Table 2. Miniscrews failure according to sex.

Failure	Sex	
	Female (%)	Male (%)
No	344 (81.32)	113 (76.87)
At least one	79 (18.68)	34 (23.13)
Total	423	147

p = 0.243 (Chi-squared test).

Table 3. Miniscrews failure according to age.

Failure	Age						p*
	n	mean	median	minimum	maximum	SD	
No	455	42.5	43.0	12.0	73.0	12.1	-
At least one	112	43.5	46.0	13.0	70.0	12.3	0.407

*Student's τ-test for independent samples.

Table 4. MSI failure according to smoking habit.

Failure	Smoking	
	No (%)	Yes (%)
No	415 (80.27)	40 (80.00)
At least one	102 (19.73)	10 (20.00)
Total	517	50

p = 0.963 (Chi-squared test).

(10.55%) and 11 mm (4.96%) MSIs. Our results are in line with those studies that used shorter MSIs (5–6 mm). Suzuki et al.[13], with a sample of 186 mini-screws of 5, 6 and 7 mm in length, reported an overall success rate of 93.4% in the maxilla and 70.3% in the mandible. They concluded that the minimum length for success in the maxilla and mandible was 5 and 6 mm, respectively. Sarul et al.[10], using a prospective split-mouth study with female patients, reported a success rate of 81.5% for 8 mm-long mini-screws and 66% for 6 mm-long screws. Other researchers[3,7] did not show any association with length; however, it is important to note that the mini-screws used in such studies were longer than those used in this study (minimum of 6 mm).

Regarding other MSI-related factors, no significant difference was observed between MSI failure and screw diameter (Table 6). However, a previous study[4] found greater success with smaller-diameter screws (1.3 mm). Moreover, we observed no significant difference in relation to area (buccal, lingual or alveolar crest) (Table 9), as previously suggested[1]. However, in our previous study[9], palatal MSIs presented a higher tendency to fail (12.12%) than buccal MSIs (9.93%). This discrepancy may be explained by the change in screw-neck length (from 2 mm to 1 mm). As MSIs

Table 5. MSI failure according to craniofacial pattern.

Failure	Facial pattern		
	Brachi (%)	Meso (%)	Dolicho (%)
No	55 (79.71)	45 (77.59)	70 (70.00)
At least one	14 (20.29)	13 (22.41)	30 (30.00)
Total	69	58	100

p = 0.309 (Chi-squared test).

Table 6. MSI loss of stability according to diameter.

Loss	Diameter		
	1.3 (%)	1.4 (%)	1.6 (%)
No	174 (88.32)	41 (93.18)	993 (89.06)
Yes	23 (11.68)	3 (6.82)	122 (10.94)
Total	197	44	1,115

p = 0.645 (Chi-squared test)

Table 7. MSI loss of stability according to length.

Loss	Length			
	5 (%)	7 (%)	9 (%)	11 (%)
No	53 (74.65)	613 (89.10)	407 (89.45)	134 (95.04)
Yes	18 (25.35)	75 (10.90)	48 (10.55)	7 (4.96)
Total	71	688	455	141

p < 0.001 (Chi-squared test).

Table 8. MSI failure according to bone location.

Failure	Maxillary	
	Maxilla (%)	Mandible (%)
No	756 (92.65)	451 (83.67)
Yes	60 (7.35)	88 (16.33)
Total	816	539

p < 0.001 (Chi-squared test).

Table 9. MSI loss of stability according to area.

Loss	Area		
	Buccal (%)	Lingual (%)	Alveolar ridge (%)
No	844 (89.50)	249 (89.25)	114(85.71)
Yes	99 (10.50)	30 (10.75)	19 (14.29)
Total	943	279	133

p = 0.421 (Chi-squared test).

Table 10. Multilevel model analysis considering diameter, length, bone location and area.

Variable	p*
Diameter	
1.3 (ref)	-
1.4	0.331
1.6	0.776
Length	
5 (ref)	-
7	0.001
9	0.001
11	< 0.001
Maxillary	
Maxilla (ref)	-
Mandible	< 0.001
Area	
Lingual (ref)	-
Alveolar ridge	0.380
Buccal	0.856

*Multilevel univariate model and Wald test.

with a shorter neck are more comfortable for patients, complications observed in the palatal area decreased.

In this study, significant MSI failure was observed in the mandible (16.33%) compared with the maxilla (7.35%) (Tables 8, 10 and 11). Other researchers[4,5,8] also reported a higher failure rate in MSIs installed in the mandible, although Miyawaki et al.[7] did not observe any differences when comparing the maxilla and mandible. Papageorgiou et al.[5] argued that possible reasons for the increased failure rate in the mandible may be greater bone density compared with the maxilla, which can lead to higher insertion torques, overheating during insertion and a narrower vestibule, preventing patients from cleaning the area thoroughly. In the present study, a possible explanation may be that shorter MSIs were mostly used in the mandible (n = 57, 80.29%) than in the maxilla (n = 14, 19.71%). Other authors[13] also reported a higher failure rate with 5 mm-long MSIs inserted in the mandible.

There are some limitations associated with this study. First, retrospective cross-sectional studies can be influenced by confounding variables that may lead to bias, such as systemic conditions of the patients, which can interfere with MSI stability. Second, missing data and multiple operators (*e.g.*, students and experienced professionals) can also result in bias. However, one major strength of this study is the large sample size.

Table 11. Multilevel model analysis considering length, bone location, sex and smoking habit.

Variable	p	OR	95%CI
Length			
5 (ref)	-	-	-
7	0.001	0.35	0.19–0.66
9	0.019	0.44	0.23–0.87
11	0.001	0.20	0.08–0.53
Maxillary			
Maxilla (ref)	-	-	-
Mandible	< 0.001	2.57	1.74–3.79
Sex			
Female (ref)	-	-	-
Male	0.162	1.32	0.89–1.96
Smoking			
No (ref)	-	-	-
Yes	0.592	1.18	0.65–2.14
Number of MSIs	< 0.001	1.58	1.41–1.78

*Multilevel adjusted model and Wald test

Conclusion

In this study, we showed that MSIs are effective for skeletal anchorage in orthodontics. Patient-related factors, such as sex, age, smoking habit and craniofacial pattern, did not affect MSI success. However, the use of shorter MSIs (5 mm) was inversely proportional to failure probability, and loss of stability was greater in the mandible.

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