ORIGINAL Aichi Gakuin Dent Sci 34 : 7–17, 2021

EVALUATING THE PROGNOSTIC STABILITY OF MIDPALATAL ORTHODONTIC ANCHOR SCREWS IN THE MOLAR REGION USING PERIOTEST VALUES

YUJI KOJIMA, MISUZU KAWAGUCHI, TAKEO SEKIYA, NORIKO SHIMURA, MASAKO TABUCHI, KEN MIYAZAWA AND SHIGEMI GOTO

Department of Orthodontics, School of Dentistry, Aichi Gakuin University, Nagoya 464-8651, Japan

SYNOPSIS

Use of orthodontic anchor screws (hereinafter referred to as anchor screws) is an effective treatment option. On the other hand, anchor screws may become dislodged or break. It has been reported that the thickness of the cortical bone and the insertion torque value during implantation affect the dislodgement of the anchor screw on the buccal aspect, and that periotest (PT) value is an important prognostic predictor after implantation. With the aim of evaluating the success rate of midpalatal screw implantation in the molar region, this study examined factors that affect the success rate as well as prognosis after implantation. The study examined 81 midpalatal orthodontic anchor screws inserted in the molar region of 51 patients (2 men and 49 women). We compared a group of patients for whom treatment was successful and that of patients for whom screw dislodgement occurred by measuring the following: 1. the dislodgement rate; 2. the thickness of palatal bone and mucosa; 3. the insertion torque value during implantation; and 4. PT values.

The success rate was 87.7%, and the dislodgement rate was 12.3%. Midpalatal screws inserted in the molar region were considered stable. No significant difference was observed between the two groups in terms of the thickness of palatal bone and mucosa. However, there was a tendency for palatal bone to be thick and palatal mucosa to be thin in the success group. No significant difference was observed between the two groups in insertion torque values, which were 27.97±5.15 Ncm in the success group and 27.95±5.46 Ncm in the dislodgement group. Meanwhile, PT values directly after implantation were significantly smaller in the dislodgement group than in the success group. However, the values in the dislodgement group drastically increased with time. At 3 months following implantation, PT values in the dislodgement group were significantly greater than those in the success group. The above findings suggested that it is important to intraoperatively monitor PT values when inserting a midpalatal screw for orthodontic anchorage in the molar region to ensure that PT values are not excessively low.

Key words: midpalatal, orthodontic anchor screw, periotest

INTRODUCTION

Recent years have seen an increase in the use of orthodontic anchor screws (hereinafter referred to as anchor screws) in orthodontic treatment. A study has found that anchor screws provide an effective source of absolute fixation for patients requiring the maximum anchorage, and that the outcomes of treatment using such screws are highly predictable[1]. Using anchor screws is beneficial not only to the orthodontist but also to the patient because of benefits such as a reduced treatment period. On the other hand, use of anchor screws involves various risks such as screw dislodgement and breakage, dental root contact and damage, dental nerve damage, and maxillary perforation[2-4]. Also, the dislodgement of an anchor screw can affect the orthodontic treatment plan, potentially posing a significant burden on the orthodontist and patient, such as changing the treatment plan and extending the

Corresponding author at: Ken Miyazawa, Department of Orthodontics, School of Dentistry, Aichi Gakuin University
Received for publication August 10, 2021
Accepted for publication October 6, 2021

treatment period due to re-implantation.

Moreover, recent studies have reported on the implantation of midpalatal anchor screws in the molar region while a considerate amount of existing research has been focused on areas between dental roots on the buccal aspect[1]. Implantation of a midpalatal anchor screw in the molar region has an advantage that the midpalatal area does not involve any anatomical structures such as dental roots, blood vessels, and nerves[5]. It is considered that from a morphological perspective, the midpalatal area is a suitable site for the implantation of an anchor screw[6]. However, the success rate of midpalatal anchor screw implantation in the molar region varies ranging from 76% to 92% even if a surgeon with 7-8 years of clinical experience performs the procedure[7]. Various studies have therefore been conducted with the aim of increasing the success rate of anchor screw implantation in the midpalatal area. These studies have suggested that the following aspects may affect the stability of the anchor screw: patient factors; the length and shape of the anchor screw; and the surgical technique employed during implantation[8]. However, the cause of fluctuation in the success rate remains unknown. Meanwhile, Watanabe et al.[9] implanted anchor screws between molar roots on the buccal aspect. The researchers stated that insertion torque values and periotest values (hereinafter referred to as PT values) may be important indicators in predicting prognosis after implantation. This study, therefore, aimed to explore the factors that may affect prognosis after the implantation of midpalatal anchor screws in the molar region. In so doing, the following aspects were measured and evaluated: the insertion torque values and PT values of anchor screws; and the thickness of palatal bone and mucosa.

Materials and Methods

1. Materials

Subjects were 51 patients (2 men and 49 women with a mean age of 24.6±8.3 years) who gave consent to participate in this study, which was conducted at the Department of Orthodontics at Aichi Gakuin University Dental Hospital. The patients required orthodontic treatment involving the implantation of a midpalatal orthodontic anchor screw in the molar region. The eligibility criteria for this study were as follows: not exhibiting a cleft lip or cleft palate; having no impacted tooth at the site of implantation; and having no systemic disease. The study examined 81 anchor screws with a diameter of 2.0 mm and a length of 6.0 mm (Dual-Top Auto Screw, Proseed, Japan) that were implanted in the midpalatal area of the molar region of the subjects.

To examine the thickness of palatal bone and mucosa at the site of implantation as well as considering the orientation of implantation prior to the implantation procedure, we prepared a surgical guide stent with reference to methods by Miyazawa et al.[10]. The stent was prepared using a study model (Fig. 1). The surgical guide stent was then placed in the mouth of the patient, and images were taken with a slice thickness of 0.2 mm by cone beam CT (hereinafter referred to as CBCT) (Alphard VEGA, Asahi Roentgen, Japan), to consider the orientation of implantation.

2. Methods

A surgical guide stent was used for all patients during implantation, and the same surgeon implanted 1 or 2 midpalatal screws in the molar region using the same surgical technique. For all patients, ligature wires were used in fixing the anchor screws in the midpalatal area along with a modified transpalatal bar that was attached to the maxillary first molars (Fig. 2). A load was applied after the completion of a 2-week load-free period[1]. A successful procedure was defined as one in which the anchor screw was not dislodged during the period from

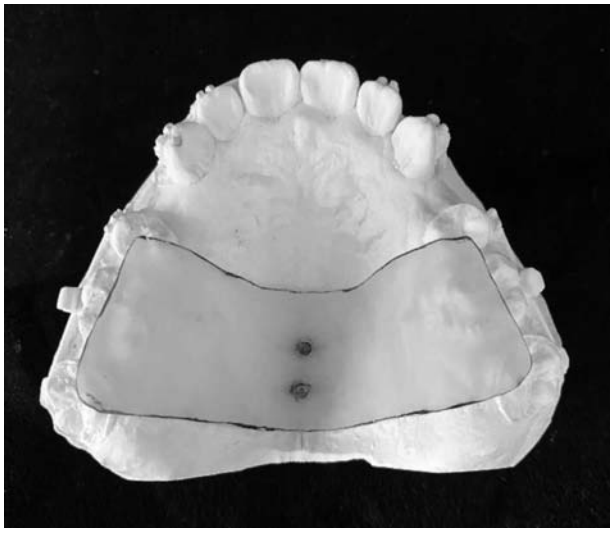


Fig. 1. A surgical guide stent used during implantation

implantation to the completion of orthodontic treatment. Dislodgement was defined as a case where either the anchor screw was spontaneously dislodged during the period from implantation to the completion of orthodontic treatment, or the screw was removed due to infection or mobility.

This study examined the following four items: 1. the rate of anchor screw dislodgement and the time of dislodgement; 2. the thickness of palatal bone and mucosa at the site of implantation; 3. insertion torque values during implantation; and 4. the degree of anchor screw mobility after implantation (PT values) and chronological changes. The time of dislodgement was classified into the following 3 groups for examination: from directly after implantation to less than 3 months; from 3 months after implantation to less than 6 months; and 6 or more months after implantation.

The thickness of palate bone and mucosa at the site of implantation was measured using image measuring software (Aquarius Net Viewer Ver. 4.4, Terarecon, US) as well as CBCT images. In doing so, the following was used as a reference point: a stainless-steel guide tube (SUS-304, Nilaco, Japan) that was implanted at the center between the first molars on the midpalatal aspect of the surgical guide stent. The measurement plane was adjusted in a way such that the frontal section and sagittal section remained parallel to the major axis of the stent tube. The thickness of palatal bone and mucosa was then measured (Fig. 3). Insertion torque values during implantation were measured using a torque driver (KANON umbrella-type torque driver, Nakamura Mfg, Japan) and an electric torque driver (ORTHONIA, Proseed, Japan) (Fig. 4).

Periotest (Tokyo Dental Industrial, Japan) was used in measuring anchor screw mobility. PT values range from -8 to +50. A PT value of -8 to +9 indicates normal, physiological tooth mobility; a low PT value indicates low mobility (i.e., high stability)[10]. A method devised by Watanabe et al.[9] was used in adjusting PT values in this study: 8 was added to all PT values obtained so that all

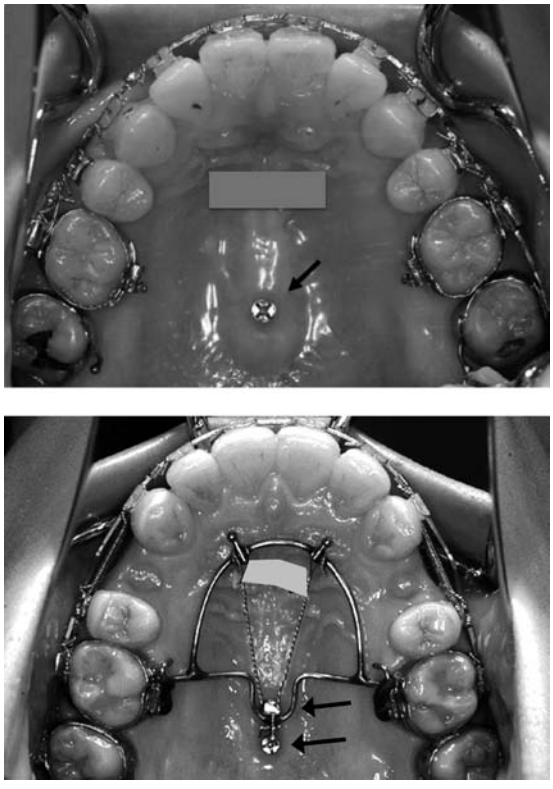


Fig. 2. An anchor screw implanted in the midpalatal area of the molar region, and a modified transpalatal bar
Arrow: Anchorage screw

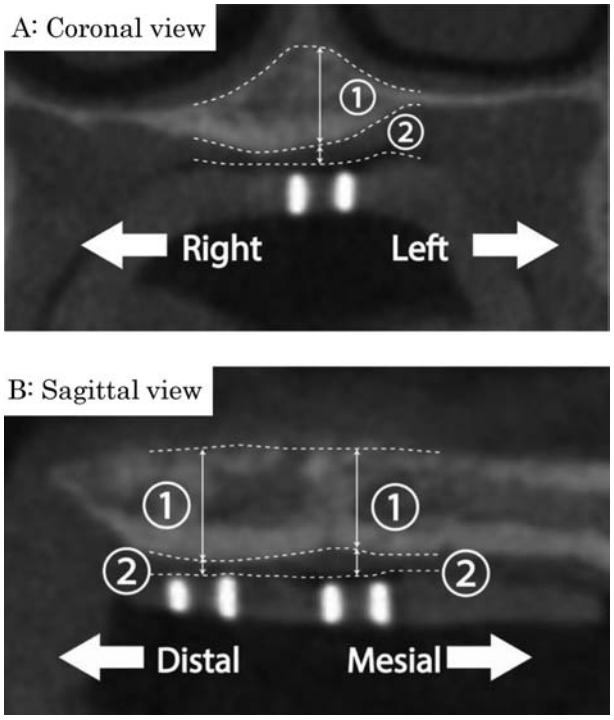


Fig. 3. CBCT images when a surgical guide stent for implantation was placed while measuring the thickness of palatal bone and mucosa
A: coronal view, B: sagittal view
1: Thickness of palatal bone, 2: Mucosal thickness

measurement values would be 0 or greater. Additionally, it was difficult to measure the anchor screw in the vertical or horizontal direction because the midpalatal area of the molar region is likely affected by the degree of mouth opening of the patient as well as by the maxillary and mandibular anterior teeth when inserting a periotest handpiece into the mouth.

A handpiece was inserted into the mouth at an angle of 60-70 degrees relative to the occlusal plane to make it easy to use the handpiece. PT values were measured 10 times for each anchor screw, and the mean values were used as measurement values (Fig. 5). Chronological changes in PT values were measured at the time of implantation of the anchor screw, and at 2 weeks, 1 month, 3 months, 6 months, and 12 months after implantation. The success group and the dislodgement group were then compared.

3. Statistical analysis

Data obtained are shown with mean values and

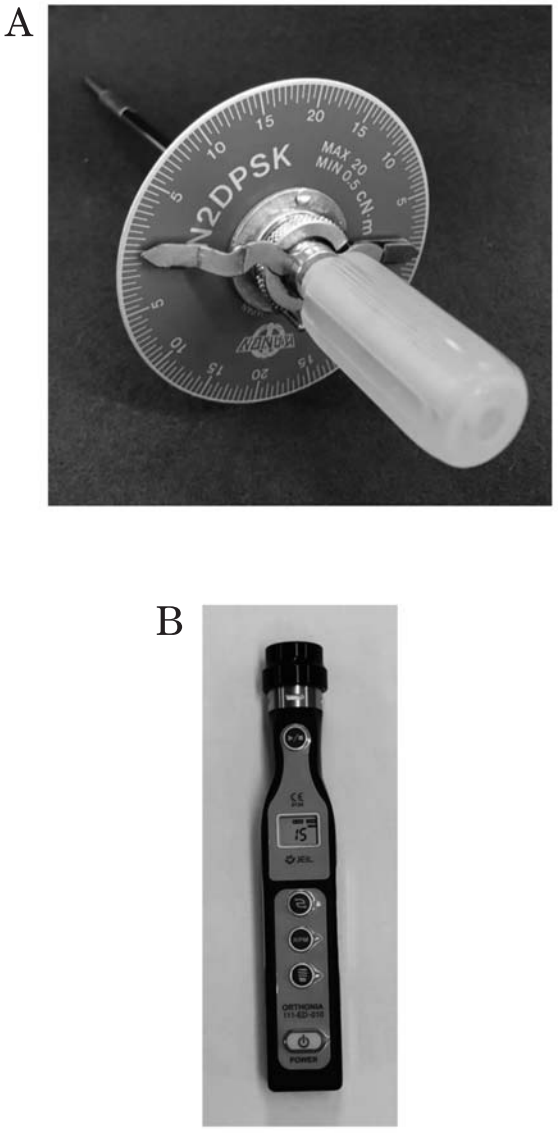


Fig. 4. Tools used in measuring insertion torque values
A: Torque driver, B: Electric torque driver

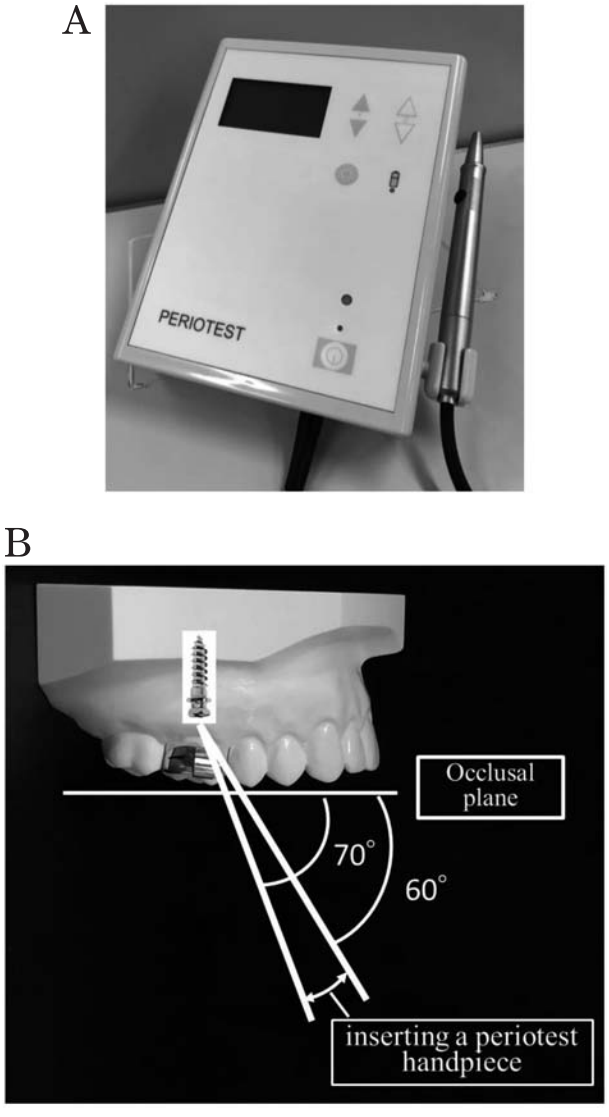


Fig. 5. Periotest and the method of intraoral measurement
A: Periotest used in examining the degrees of mobility
B: The method of inserting the handpiece during measurement

standard deviation. In testing statistically significant differences, the Wilcoxon rank-sum test was performed using statistical analysis software (JMP Ver. 14.0.0, SAS, US); the Kruskal–Wallis test was performed for chronological changes in PT values. Statistical significance was defined as $p<0.05$.

This study was approved by the institutional review board of Aichi Gakuin University, School of Dentistry. (Approval No. 11).

Results

1. Rate and time of dislodgement

The rate of anchor screw dislodgement was 12.3%; 10 out of 81 screws became dislodged during the orthodontic treatment period. From among a total of 81 anchor screws implanted, the percentage and time of dislodgement were as follows: 4.9% (4 screws) during the period from directly after implantation to less than 3 months; and 2.5% (2 screws) from 3 to less than 6 months. It was found that 7.4% of all screws examined were dislodged at an early stage after implantation (i.e., less than 6 months) (Fig. 6, Table 1).

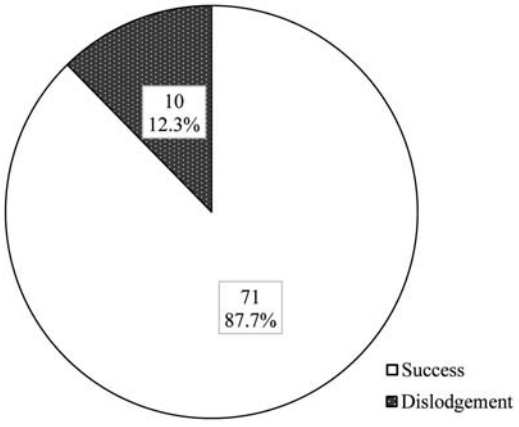


Fig. 6. The dislodgement rate of anchor screws implanted in the midpalatal area of the molar region

Table 1. Time of dislodgement and the number of screws dislodged

	Time of dislodgement (month)		
	0-3	3-6	6-12
Rate of anchor screw dislodgement (%)	4.9	2.5	4.9
Number of anchor screw dislodgement	4	2	4

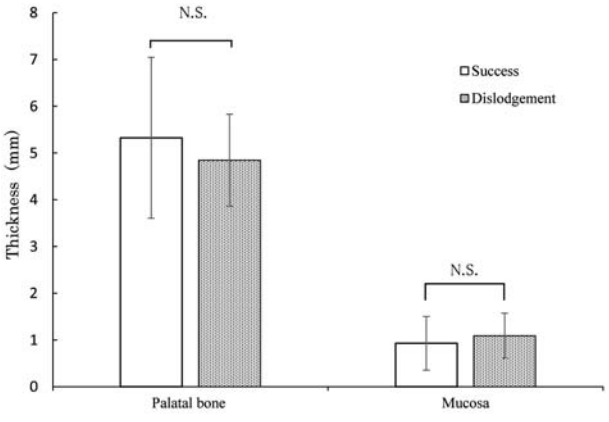
2. Thickness of palatal bone and mucosa

The mean thickness of palatal bone at the site of implantation was 5.32±1.72 mm in the success group whereas that in the dislodgement group was 4.85±0.99 mm. While no significant difference was observed between the 2 groups, palatal bone at the site of implantation was slightly thicker in the success group than in the dislodgement group.

The mean mucosal thickness at the site of implantation was 0.93±0.57 mm in the success group whereas that in the dislodgement group was 1.09±0.48 mm. While no significant difference was observed between the 2 groups, the mucosa at the site of implantation was slightly thinner in the success group than in the dislodgement group (Fig. 7).

3. Insertion torque values

The mean insertion torque value of the anchor screw was 27.97±5.15 Ncm in the success group whereas that in the dislodgement group was 27.95±5.46 Ncm. No significant difference was observed in insertion torque values between the 2 groups (Fig. 8).



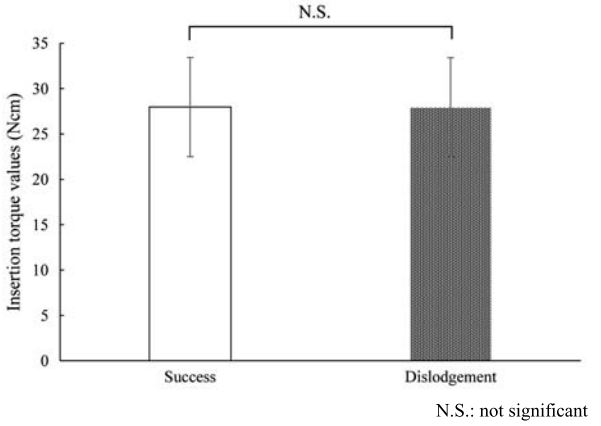
N.S.: not significant

	Success	Dislodgement	Wilcoxon test	P value
Palatal bone (mm)	5.32±1.72	4.85±0.99	N.S.	0.449
Mucosa (mm)	0.93±0.57	1.09±0.48	N.S.	0.292

Fig. 7. Thickness of palatal bone and mucosa at the site of implantation

4. Degree of anchor screw mobility (PT values) and chronological changes

Chronological changes in PT values in the success group were as follows: the mean PT value at the time of implantation was 11.95±2.94; that at Week 2 was 11.29±3.68, from which PT values gradually increased; and a significant difference in mean PT values was observed between Week 2 and Month 12 (Fig. 9A). Chronological changes in PT values in the dislodgement group were as follows: the mean PT value at the time of implantation was 9.39±2.87; there was a significant increase in PT values from the time of implantation to 11.40±4.25 at Week 2 and 17.23±4.20 at Month 1; and the mean PT value at Month 1 was approximately 1.85 times greater than that at the time of implantation, indicating a significant increase (Fig. 9B). Meanwhile, a comparison between the success group and the dislodgement group found that PT values in the dislodgement group were significantly lower than those in the success group at the time of implantation. However, at Week 2, the values were greater in the dislodgement group than in the success group. After Week 2 PT values in the dislodgement continued to increase, and at 3 months after implantation, PT values in the dislodgement group were significantly greater than those in the success group (Fig. 9C).



	Success	Dislodgement	Wilcoxon test	P value
Insertion torque values (Ncm)	27.97±5.15	27.95±5.46	N.S.	0.921

Fig. 8. Insertion torque values at the time of implantation

Discussion

1. Methods of implanting midpalatal orthodontic anchor screws in the molar region, and the site of implantation

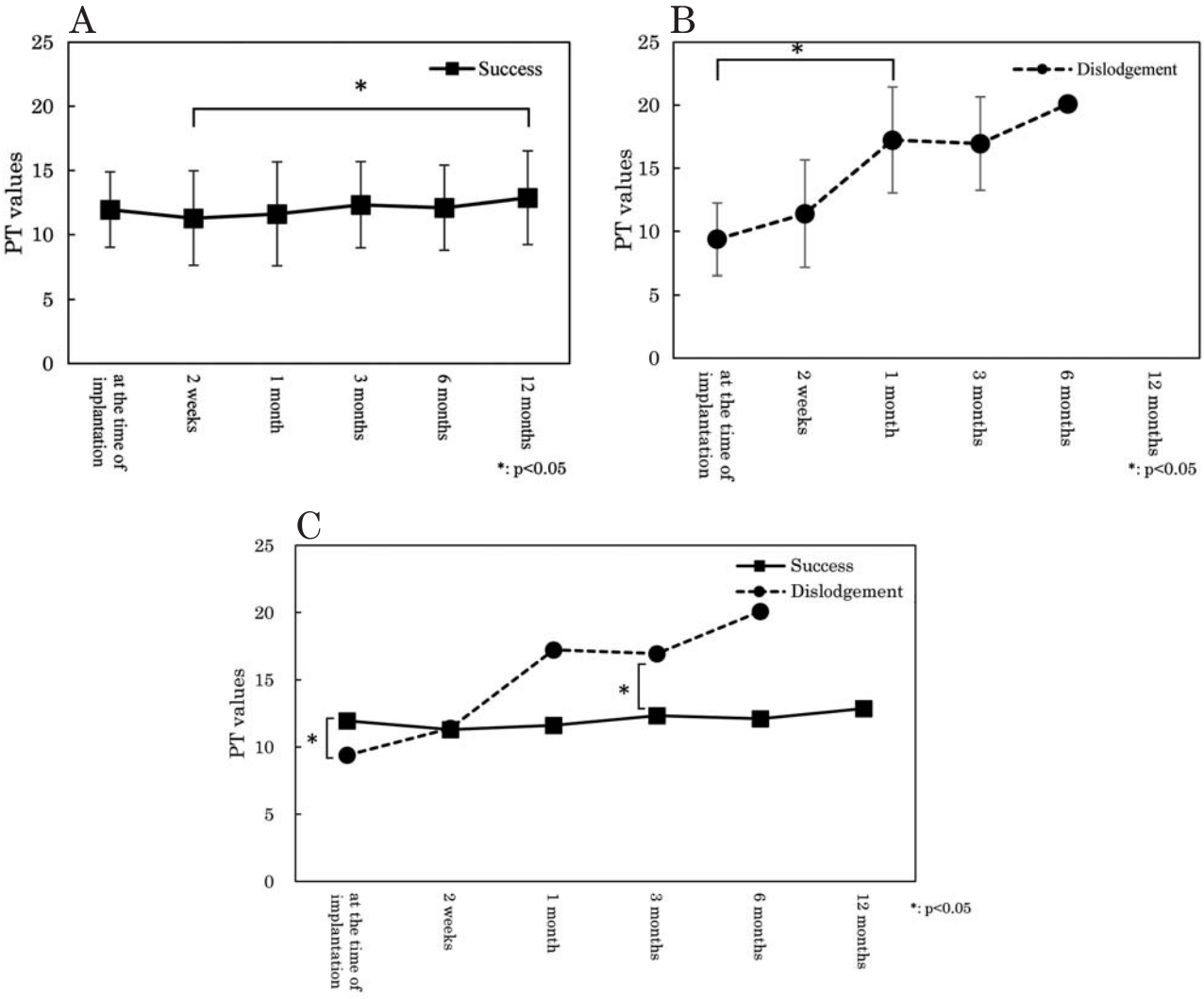
When implanting anchor screws in this study, we referred to a report by Miyazawa et al.[10]. Specifically, a surgical guide stent for implantation was used, which was prepared for the midpalatal area of the molar region; 2/3 of an anchor screw was inserted through the stent; pre-drilling was performed to make a guide hole; thereafter, the same anchor screw was again inserted and completely implanted in the site. Because this method reportedly helps insert anchor screws in a safe and accurate manner, it was used for all the subjects of this study.

Kim et al.[11] found that an anchor screw inserted in the midpalatal area can withstand an orthodontic force of 500-800 g, and they reported that the midpalatal area is an appropriate site of implantation where a source of strong orthodontic force can be secured for purposes such as the distal movement and intrusion of molars, as well as the retraction of anterior teeth. Additionally, the palatal mucosa is covered by immobile, stratified squamous keratinized epithelium, which can reportedly hold the implant in a secure manner because it strongly resists mechanical stimuli. Studies have suggested that it is unlikely that post-implantation inflammation occurs in palatal mucosa. Moreover, from an anatomical perspective, the palate is an extremely effective site for anchor screw implantation because no nerves, vessels, or other anatomical structures are located in the palate[12,13]. In this study, therefore, the midpalatal area of the molar region was selected for the site of implantation, where a modified transpalatal bar and an anchor screw were ligated so as to secure the anchorage for the intrusion and distal movement of the molars[1].

2. Rate and time of anchor screw dislodgement

A study by Watanabe et al., which reported on the implantation of an anchor screw with a diameter of 1.4 mm and a length of 6.0 mm between dental roots on the buccal aspect, stated that the rate of dislodgement was 22.0%[9]. Meanwhile, in a separate study which reported on the implantation of 2 anchor screws with a diameter of 2.0 mm and a length of 9.0 mm following the formation of a guide hole in the midpalatal area of

the molar region, Ichinohe et al.[7] stated that the rates of dislodgement were 24.0% for the anterior aspect and 8.0% for the posterior aspect. Also, in a study by Kim et al.[11], anchor screws with a diameter of 1.5-2.0 mm and a length of 5.0 mm were implanted in the midpalatal area of the molar region. The researchers found that the dislodgement rate was low at 9.2% and stated that the midpalatal area of the molar region is a suitable site for anchor screw implantation. The rate of anchor screw dislodgement (2.0 mm in diameter, 6.0 mm in length) in this study was 12.3%. This finding cannot be generalized because the diameters and lengths of anchor screws used in settings vary. That being said, it was considered that the anchor screws examined in



	Success	Dislodgement	Wilcoxon test	P value
at the time of implantation	11.95±2.94	9.39±2.87	*	0.015
2 weeks	11.29±3.68	11.40±4.25	N.S.	0.866
1 month	11.62±4.05	17.23±4.20	N.S.	0.066
3 months	12.33±3.36	16.95±3.71	*	0.020
6 months	12.10±3.31	20.10	-	-
12 months	12.87±3.65	-	-	-

Fig. 9. A: Chronological changes in PT values in the success group
B: Chronological changes in PT values in the dislodgement group
C: PT values in the 2 groups, namely the success group and the dislodgement group

this study remained stable in the midpalatal area of the molar region because the dislodgement rate in this study was as low as the rates observed in other reports on the midpalatal area[7,11,14].

A study that reported on the time of dislodgement stated that 70.4% of screws implanted between dental roots on the buccal aspect of the maxilla became dislodged at an early stage (up to 6 months)[9]. Moon et al. found that over 90% of screws implanted between dental roots on the buccal aspect of the maxilla and mandible in the dislodgement group became dislodged within 4 months of implantation[15]. This study also found that 6 out of 10 screws (60.0%) implanted in the midpalatal area of the molar region in the dislodgement group became dislodged within 6 months of implantation. While the cause of dislodgement remains unknown, it was considered that anchor screw dislodgement tends to occur at an early stage after implantation. These findings suggest that when implanting an anchor screw in the midpalatal area of the molar region as part of a clinical procedure, great care should be taken in applying a load, particularly for the first 6 months after implantation, to prevent dislodgement.

3. Thickness of palatal bone and mucosa at the site of anchor screw implantation

Studies that measured the thickness of palatal bone in the midpalatal area of the molar region found that the thickness of the palatal bone was 4.7-5.2 mm and that of the mucosa was 0.79-1.01 mm[16-19]. These findings are consistent with the results of this study. Watanabe et al.[9] found that the outcomes of anchor screw implantation were associated with the thickness of cortical bone on the buccal aspect. Although no significant difference was observed in the thickness of palatal bone in this study, there was a tendency for palatal bone to be thicker in the success group than in the dislodgement group. Additionally, there was a tendency for the mucosa examined in this study to be thicker in the dislodgement group than in the success group, although no significant difference was observed. On the basis of these findings, the thickness of palatal bone and mucosa in the midpalatal area of the molar region could not be defined as a predictor of the prognosis of anchor screw implantation. However, palatal bone, which was adopted as a site of implantation in this study, has abundant anatomical advantages, with thick cortical bone and a small amount of cancellous bone. It is considered, therefore, that palatal bone should not be simply compared with the alveolar process on the buccal aspect. Further research is needed on this issue.

4. Insertion torque values during anchor screw implantation, degree of mobility, and prognosis prediction

If an anchor screw becomes dislodged in clinical orthodontic treatment, subsequent treatment mechanics are likely to be challenging. The dislodgement rate can be reduced if the prognosis of anchor screw implantation can be predicted during implantation. This should help provide safe and secure treatment. This study therefore examined potential predictors for the prognosis of anchor screw implantation in the midpalatal area of the molar region.

A study reported that the median insertion torque value during implantation in the alveolar process on the buccal aspect was 8.7±2.2 Ncm in the success group when an anchor screw with a diameter of 1.4 mm was used[9]. Another study reported that an insertion torque value of 5-10 Ncm is appropriate for the implantation of an anchor screw with a diameter of 1.6 mm[20]. Ohtani et al.[21] implanted an anchor screw with a diameter of 1.6 mm in the alveolar process of the maxilla of rats and reported that an extremely high level of stability was achieved at an early stage when the insertion torque value was approximately 5-10 Ncm. Meanwhile, Suzuki et al.[22] examined the insertion torque values of anchor screws with a diameter of 1.5 mm which were implanted in the midpalatal region. The researchers found that insertion torque values were 13.9-15.0 Ncm when a pre-drilling type, which is implanted after a guide hole is created, was used, whereas insertion torque values were 20.3-21.9 Ncm when a self-drilling type, which is implanted without a guide hole being created, was used. The researchers also stated that insertion torque values in the midpalatal region were higher than those on the buccal aspect. Kim et al.[18] found that the site of midpalatal suture consisted of highly dense cortical bone, suggesting that insertion torque values in the palatal region are high compared to those on the buccal aspect. In this study, in which implantation was performed after making a guide hole,

the mean insertion torque value was 27.97±5.15 Ncm in the success group when an anchor screw with a diameter of 2.0 mm and a length of 6.0 mm was used. The mean value was much higher than that for the above-mentioned alveolar process on the buccal aspect.

However, this study did not find a significant difference between the success group and the dislodgement group. Findings from this study suggested that it is difficult to predict prognosis solely based on insertion torque values during implantation. Meanwhile, PT values at the time of implantation in the dislodgement were different from those in the success group. PT values in the success group were stable with a slight increase from the time of implantation, whereas those in the dislodgement group were significantly lower than those in the success group at the time of implantation, but drastically increased thereafter. PT values in the dislodgement group continued to increase through to the time when screw dislodgement occurred. Hence, it was considered that PT values are an effective indicator in predicting the prognosis of anchor screw implantation in the midpalatal area of the molar region. The periotest is the most widely used method for evaluating initial stability by measuring mobility after implantation[23]. The smaller the value of the periotest, the less the mobility and the higher the stability. It has been reported that low periotest values are important for initial stability in assessing the implantation of buccal anchor screws[9]. However, in this study, the prognosis of the anchor screw implanted in the midpalatal was evaluated, and the periotest values were different. The reason is that studies have reported that causes of anchor screw dislodgement include microcracks on the bone surface, which can occur irrespective of either the orientation of implantation or the shape, diameter, and length of the screw[24,25]. A study that examined the impact of tightening anchor screws in porcine pelvic bones with the aim of identifying causes of microcracks in the cortical bone during implantation compared the following three models: 1. bones in which only a guide hole was created; 2. bones into which an anchor screw was inserted to a limited depth of 1 mm from the bone surface; 3. bones into which an entire anchor screw was inserted, and the screw was subsequently rotated a quarter of a turn to be further inserted. The results of the study found that a greater number of microcracks were present in the cortical bone when an anchor screw was inserted more deeply[26]. This study found that PT values at the time of implantation were significantly lower in the dislodgement group. It was considered that this was because anchor screws were inserted deeply into cortical bone, thereby leading to microcracks. Thereafter, in the dislodgement group, damage caused by microcracks might have led to screw mobility and increased PT values with time, which resulted in dislodgement. When an anchor screw with a diameter of 2 mm and a length of 6 mm is implanted in the midpalatal area of the molar region in clinical orthodontic treatment, torque values should remain within the range of 27.97±5.15 Ncm during implantation, as observed in the success group of this study. Findings from this study also suggest that it is important to monitor intraoperative PT values during implantation so that the values will remain within the range that was observed in the success group. This should help prevent excessively deep insertion of the anchor screw into cortical bone, which can excessively reduce mobility, and can reduce the occurrence of microcracks. By doing so, it may be possible to further reduce dislodgement rates going forward.

Conclusion

This study suggested that PT values at the time of implantation are an important factor in evaluating the prognostic stability of anchor screws. Additionally, it was also suggested that to avoid excessively low PT values, it is important to monitor PT values during implantation, given the finding that PT values in the dislodgement group were significantly lower than those in the success group directly after implantation. Monitoring PT values in this manner may help improve the success rate of the procedure.

None of the authors of this manuscript have any conflicts of interest (COI) to declare.

References

1) Lee J, Miyazawa K, Tabuchi M, Kawaguchi M, Shibata M, Goto S: Midpalatal miniscrews and high-pull headgear for anteroposterior and vertical anchorage control: cephalometric comparisons of treatment changes. Am J Orthod Dentofacial Orthop, **144**(2): 238-250, 2013.

2) Kuroda S, Yamada K, Deguchi T, Hashimoto T, Kyung HM, Takano-Yamamoto T: Root proximity is a major factor for screw failure in orthodontic anchorage. Am J Orthod Dentofacial Orthop, **131**(4 suppl): S68-73, 2007.
3) Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamamoto T: Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. Am J Orthod Dentofacial Orthop, **129**(6): 721.e7-12, 2006.
4) Mohammed H, Wafaie K, Rizk MZ, Almuzian M, Sosly R, Bearn DR: Role of anatomical sites and correlated risk factors on the survival of orthodontic miniscrew implants: a systematic review and meta-analysis. Prog Orthod, **19**(1): 36, 2018.
5) Wehrbein H, Merz BR, Diedrich P: Palatal bone support for orthodontic implant anchorage: a clinical and radiological study. Eur J Orthod, **21**(1): 65-70, 1999.
6) Jung BA, Kunkel M, Göllner P, Liechti T, Wehrbein H: Success rate of second-generation palatal implants. Angle Orthod, **79**(1): 85-90, 2009.
7) Ichinohe M, Motoyoshi M, Inaba M, Uchida Y, Kaneko M, Matsuike R, Shimizu N: Risk factor for failure of orthodontic mini-screws placed in the median palate. J Oral Sci, **61**(1): 13-18, 2019.
8) Uesugi S, Kokai S, Kanno Z, Ono T: Stability of secondarily inserted orthodontic miniscrews after failure of the primary insertion for maxillary anchorage: maxillary buccal area vs midpalatal suture area. Am J Orthod Dentofacial Orthop, **153**(1): 54-60, 2018.
9) Watanabe T, Miyazawa K, Fujiwara T, Kawaguchi M, Tabuchi M, Goto S: Insertion torque and Periotest values are important factors predicting outcome after orthodontic miniscrew placement. Am J Orthod Dentofacial Orthop, **152**(4): 483-488, 2017.
10) Miyazawa K, Kawaguchi M, Tabuchi M, Goto S: Accurate pre-surgical determination for self-drilling miniscrew implant placement using surgical guides and cone-beam computed tomography. Eur J Orthod, **32**(6): 735-740, 2010.
11) Kim YH, Yang SM, Kim S, Lee JY, Kim KE, Gianelly AA, Kyung SH: Midpalatal miniscrews for orthodontic anchorage: factors affecting clinical success. Am J Orthod Dentofacial Orthop, **137**(1): 66-72, 2010.
12) Paik CH, Park IK, Woo YJ, Kim TW: Anatomic Considerations and Placement/Removal of Orthodontic Miniscrew Implants. Orthodontic Miniscrew Implants. Mosby (St. Louis), 34-41, 2009.
13) Lee JS, Kim JK, Park YC, Vanarsdall RL: Application of Orthodontic Mini-Implants. Quintessence Publishing (Batavia), 51-85, 2009.
14) Kakali L, Alharbi M, Pandis N, Gkantidis N, Kloukos D: Success of palatal implants or mini-screws placed median or paramedian for the reinforcement of anchorage during orthodontic treatment: a systematic review. Eur J Orthod, **41**(1): 9-20, 2019.
15) Moon CH, Lee DG, Lee HS, Im JS, Baek SH: Factors associated with the success rate of orthodontic miniscrews placed in the upper and lower posterior buccal region. Angle Orthod, **78**(1): 101-106, 2008.
16) Hourfar J, Kanavakis G, Bister D, Schätzle M, Awad L, Nienkemper M, Goldbecher C, Ludwig C: Three dimensional anatomical exploration of the anterior hard palate at the level of the third ruga for the placement of mini-implants: a cone-beam CT study. Eur J Orthod, **37**(6): 589-595, 2015.
17) Stockmann P, Schlegel KA, Srour S, Neukam FW, Fenner M, Felszeghy E: Which region of the median palate is a suitable location of temporary orthodontic anchorage devices? A histomorphometric study on human cadavers aged 15-20 years. Clin Oral Implants Res, **20**(3): 306-312, 2009.
18) Kim HJ, Yun HS, Park HD, Kim DH, Park YC: Soft-tissue and cortical-bone thickness at orthodontic implant sites. Am J Orthod Dentofacial Orthop, **130**(2): 177-182, 2006.
19) Parmar R, Reddy V, Reddy SK, Reddy D: Determination of soft tissue thickness at orthodontic miniscrew placement sites using ultrasonography for customizing screw selection. Am J Orthod Dentofacial Orthop, **150**(4): 651-658, 2016.
20) Motoyoshi M, Hirabayashi M, Uemura M, Shimizu N: Recommended placement torque when tightening an orthodontic mini-implant. Clin Oral Implants Res, **17**(1): 109-114, 2006.
21) Ohtani J, Sunagawa H, Fujita T, Kawata T, Kaku M, Tohma Y, Motokawa M, Tsuka N, Marques RA,

Koseki H, Sano R, Tanne K: Stability of mini screw as an implant anchorage placed onto rat maxilla. Jpn J Orthod Waves, **67**(3): 125-131, 2008. (in Japanese)

22) Suzuki EY, Suzuki B: Placement and removal torque values of orthodontic miniscrew implants. Am J Orthod Dentofacial Orthop, **139**(5): 669-678, 2011.

23) Atsumi M, Park SH, Wang HL: Methods used to assess implant stability: current status. Int J Oral Maxillofac Implants, **22**(5): 743-754, 2007.

24) Yadav S, Upadhyay M, Liu S, Roberts E, Neace WP, Nanda R: Microdamage of the cortical bone during mini-implant insertion with self-drilling and self-tapping techniques: a randomized controlled trial. Am J Orthod Dentofacial Orthop, **141**(5): 538-546, 2012.

25) Taing-Watson E, Katona TR, Stewart KT, Ghoneima A, Chu GT, Kyung HM, Liu SS: Microdamage generation by tapered and cylindrical mini-screw implants after pilot drilling. Angle Orthod, **85**(5): 859-867, 2015.

26) Wawrzinek C, Sommer T, Fischer-Brandies H: Microdamage in cortical bone due to the overtightening of orthodontic microscrews. J Orofac Ortop, **69**(2): 121-134, 2008.