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Original Article

Clinical Study of Temporary Anchorage Devices for Orthodontic Treatment —Stability of Micro/Mini-screws and Mini-plates: Experience with 455 Cases—

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Abstract

The aim of this retrospective study was to determine factors that might cause complications in use of temporary anchorage devices (TADs) for orthodontic anchorage. We investigated 904 TADs in 455 patients. Clinical diagnoses requiring orthodontic treatment were malocclusion, jaw deformity, various syndromes, cleft lip and palate and impacted teeth. All patients underwent surgery at Tokyo Dental College Chiba Hospital between November 2000 and June 2009. Three kinds of titanium screw of different diameter and length were used: self-drilling mini-screws (Dual Top Autoscrew® and OSAS®), pre-drilling micro-screws (K1 system®) and palatal screws (PIAS®). Mini-plates fixed with 2 or 3 screws (SAS system®) were also used for skeletal anchorage. Patients were aged between 8 and 68 years (25.7 ± 9.8 years). A total of 460 screw-type and 444 plate-type TADs were used. These comprised the following: mini-plates, 444; self-drilling mini-screws, 225; pre-drilling micro-screws, 83; and palatal screws, 152. Each type of implant had a high success rate of over about 90%. Failure rates were as follows: micro-screws, 7%; mini-screws, 6%; palatal implants, 11%; and mini-plates, 6%. Inflammation rate occurring in soft tissue surrounding TADs was follows: plate-type, 7.6%; mini-screws, 1.3%; micro-screws, 0%; and palatal implants, 2.5%. Inflammation frequencies depended on degree of mucosal penetration. Granulation rate in soft tissue surrounding TADs occurred as follows: micro-screws, 5.7%; self-drilling mini-screws, 0%; palatal screws, 0.6%; plate-type, 0.9%. Both plate- and screw-type orthodontic implants showed excellent clinical performance.

Key words: Anchorage—TADs—Micro-implant—Mini-implant—SAS

Introduction

Orthodontic anchorage is an important factor in obtaining good treatment results. Stable anchorage is a pre-requisite for orthodontic treatment with fixed appliances. Traditional appliances for reinforcement of anchorage have included headgear and intraoral elastics. However, it is difficult to obtain stable anchorage with such appliances, even with the full cooperation of the patient.

Dental implants, mini-plates and mini/micro-screws are excellent alternative orthodontic skeletal anchorage devices. These devices provide stable anchorage for various tooth movements and do not require patient cooperation[15]. Dental implants have high success rates[5,6] and are strong enough to resist the reciprocal forces of various orthodontic tooth movements[16].

Jenner and Fitzpatrick[17] first reported the use of an osteotomy mini-plate for orthodontic anchorage in 1985. In 1992, Umemori *et al.*[39] used mini-plates in the mandible and the maxilla to assist in correcting skeletal open-bite deformities in adult patients. Mini-plates for orthodontic anchorage have also been used in patients with super-erupted posterior teeth to distalize molars. Furthermore, Kanomi[19] first described a temporarily placed micro-screw for orthodontic anchorage in 1997. The following years brought greater refinement of screw design. Micro- and mini-screws with diameters of 1.0–2.3 mm have now become established as orthodontic anchorage devices.

The aim of this retrospective study was to analyze the success rates and determine potential factors in complications with temporary anchorage devices (TADs) used for orthodontic anchorage.

Materials and Methods

1. Patients

A total of 455 consecutive patients requiring skeletal anchorage for orthodontic treatment were included in this retrospective study. A total of 904 implants were used in these 455 patients (97 male, 358 female, Fig. 1). Clinical diagnoses for which orthodontic treatment was planned were as follows: malocclusion, jaw deformity, various syndromes, cleft lip and palate and impacted tooth. All patients subsequently underwent surgery at Tokyo Dental College Chiba Hospital between November 2000 and June 2009. The mean age of the patients was 25.7 ± 9.8 years (male, 23.8 ± 9.2 years; female, 26.2 ± 9.9 years, Fig. 2).

2. Pre-operative planning

All patients underwent the standard pretreatment tests, which consisted of facial and intraoral photography, dental model analysis, radiography and cephalography. The orthodontists and surgeons involved subsequently established indications for implant anchorage devices. Positioning of the implant in each patient was determined based on

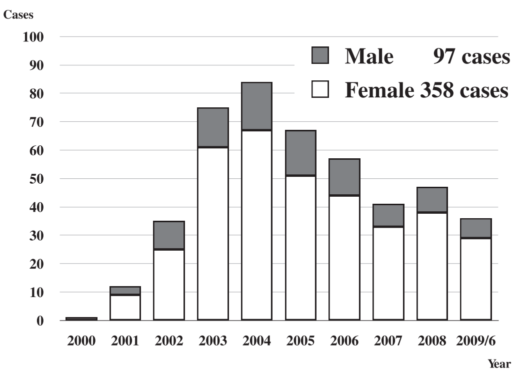


Fig. 1 Number of patients
455 patients underwent surgery between November 2000 and June 2009.

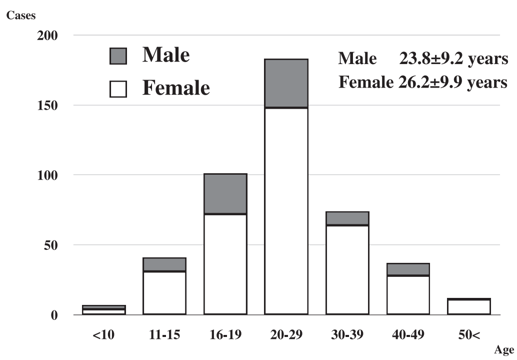


Fig. 2 Age of patients
Mean age, 25.7 ± 9.8 years.

orthodontic need. All procedures were performed depending on the availability of bone and dental conditions at the predetermined site for implantation. Cone Beam CT (CBCT)[20] and the multidimensional DICOM imaging software OsiriX were used to assist in this process[30].

3. Surgical procedure

Two different self-drilling titanium mini-screw implant systems (Dualtop autoscrew®, Jeil Medical Corp., Korea; OSAS®, DEWIMED Co. Ltd., Germany), one pre-drilling micro-implant system (K1 system®, Dentsply-Sankin, Japan) and a palatal implant anchorage system (PIAS®, Tokyo Dental College, Japan) were investigated. Mini-plates (SAS system®, Dentsply-Sankin, Japan) fixed with 2 or 3 screws were also used for skeletal anchorage (Fig. 3). Treatment plan and choice of implant were determined by an orthodontist; the mechanics of insertion were determined on the basis of an anatomical diagnosis made by the surgeon. Informed consent was obtained from each patient before surgery. The study protocol was approved by the Ethical Review Board of the Tokyo Dental College Chiba Hospital.

Placement of the implants was performed under local anesthesia. Micro- and mini-implants were inserted into the gingiva or palate. Local anesthesia (2% lidocaine with 0.0125 mg/ml epinephrine and xylocain/adrenaline, Dentsply-Sankin, Japan) was injected at the insertion site. The screws, plates and implants were then placed according to their manufacturers' protocols.

Implants should not be immediately subjected to orthodontic forces. Therefore, we waited for a period of approximately one month after implant placement before allowing application of orthodontic force.

4. Outcome evaluation

All patients were seen the day after implant placement and instructed on how to clean the implants with a single-tuft brush by a dental hygienist. Patients were given monthly

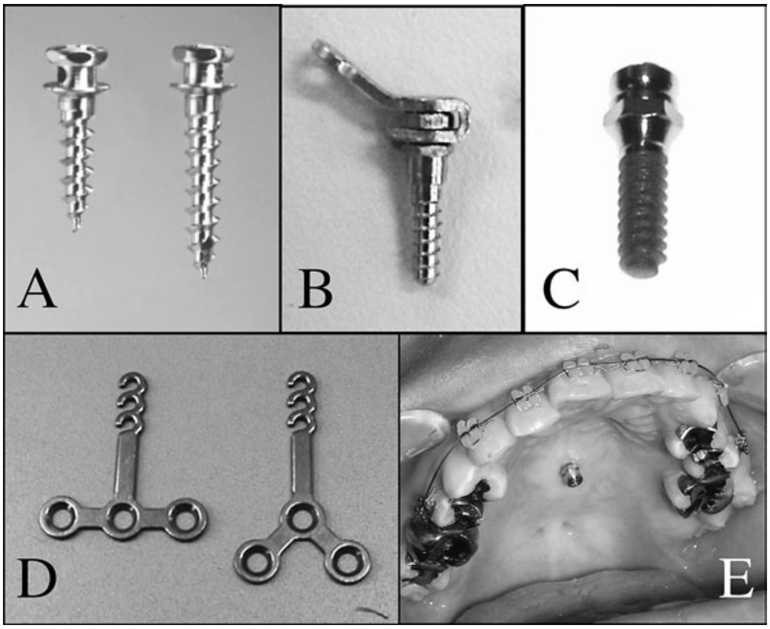


Fig. 3 Implants for orthodontic anchorage
A: Dualtop autoscrew®; B: K1 system®; C: PIAS®; D: SAS system®; E: implant placement of PIAS®

maintenance over a 3-month period after implant placement. The clinical condition of the patients was evaluated during orthodontic treatment. Criteria determining the success of the implants were as follows: presence of inflammation; clinically detectable mobility for orthodontic treatment. Peri-implant infection was defined as swelling of the tissue surrounding the implant requiring analgesics and antibiotics for relief. Failure was defined as implant mobility or implant loss.

Results

A total of 904 implants were used in 455 patients (97, male; 358, female, Fig. 1). The largest number of implant procedures in any one year was greatest in 2004, followed by almost the same number in 2007. Female patients received the largest number of implants in each year observed. Age ranged from 8 to 68 years, with mean age at 25.7 ± 9.8 years (male, 23.8 ± 9.2 years; female, 26.2 ± 9.9 years, Fig. 2).

Of the total number of patients, 95 received orthodontic treatment for pre/post-surgical jaw deformity, 333 for malocclusion, 18 for impacted teeth, 4 for cleft lip and palate and one for crouzon syndrome (Fig. 4).

Treatment mechanics were as follows: plate-type occupied 49% and screw-type 51%. A pre-drilling micro-screw (K1 system®) was used in 83 implants; a self-drilling mini-screw (Dualtop autoscrew®, OSAS®) in 225 implants; a palatal screw (PIAS®) in 152 implants; and a mini-plate type (SAS®) in 444 implants (Fig. 5).

Almost all of the patients felt well after surgery and during the orthodontic treatment period. No symptoms of tooth disturbance (pain, loss of vitality) were reported. Tooth movements were mostly successfully performed in all cases where implants remained immobile.

Implant mobility or implant loss was observed in 62 implants. Both screw- and

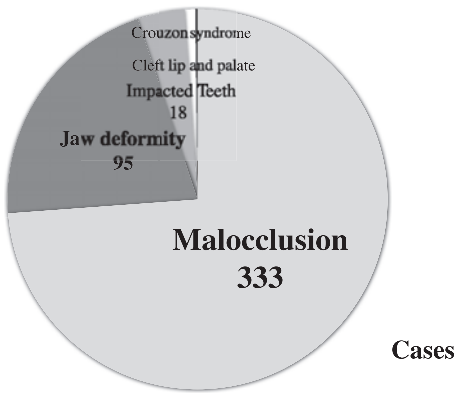
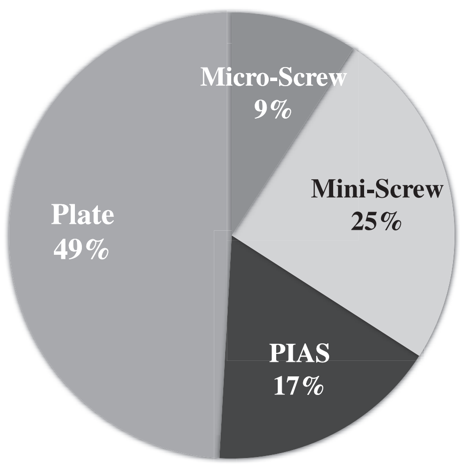


Fig. 4 Clinical diagnoses



Implant	Female	Male	Total
Micro-Screw	67	16	83
Mini-Screw	183	42	225
PIAS	122	30	152
Plate	343	101	444
Total	715	189	904

Micro-Screw:K1 system®
Mini-Screw:Dualtop autoscrew®
PIAS:Palatal Implant Anchorage System®
Plate:SAS system®

Fig. 5 Numbers of orthodontic implants

plate-type implants had a high success rate. Failure rates for the screw-type were follows: pre-drilling micro-screw, 7%; self-drilling mini-screw, 6%; and palatal screw, 11%. Plate-type implant loss was 6%. The results according to type of TAD are shown in Tables 1, 2, 3 and 4.

1. Micro-screw implant (Table 1)

The majority of the micro-screw implants were placed in the anterior alveolar region of the maxilla (34/83). The next most common location was the posterior alveolar region of the maxilla (12/83) and retro-molar region of the mandible (12/83). Insertion of implants into the median suture of the maxilla was performed less commonly (2/83). A 100% success rate was shown in the anterior alveolar region, external oblique ridge, retro-molar region of the maxilla and posterior alveolar palate region of the mandible. The anterior (94%) and posterior alveolar region (92%) of the mandible had a higher success rate than the posterior alveolar region of the mandible (75%). However, the median suture area showed the lowest success rate (0%).

2. Mini-screw implant (Table 2)

The majority of the mini-screw implants were placed in the posterior alveolar region of the maxilla (92/225). The next most common location was the posterior alveolar region of the mandible (58/225). Implant insertion into the median suture and zygomatic buttress of the maxilla was performed less commonly

Table 1 Implant location and success rates of micro-screw

Implant location		Numbers of implant	Failure	Failure rate	Success	Success rate
Mandible	Anterior alveolar region	8		0%	8	100%
	Posterior alveolar region	4	1	25%	3	75%
	External oblique ridge	3		0%	3	100%
	Retro-molar region	12		0%	12	100%
Maxilla	Anterior alveolar region	34	2	6%	32	94%
	Posterior alveolar region	12	1	8%	11	92%
	Posterior alveolar palate region	8		0%	8	100%
	Median suture	2	2	100%		0%
Total		83	6	7%	77	93%

Table 2 Implant location and success rates of mini-screw

Implant location		Numbers of implant	Failure	Failure rate	Success	Success rate
Mandible	Anterior alveolar region	21	2	10%	19	90%
	Posterior alveolar region	58	2	3%	56	97%
	External oblique ridge	11		0%	11	100%
	Retro-molar region	8	1	12%	7	88%
Maxilla	Anterior alveolar region	16	1	6%	15	94%
	Posterior alveolar region	92	7	8%	85	92%
	Posterior alveolar palate region	8	1	12%	7	88%
	Median suture	1		0%	1	100%
	Paramedian suture	9		0%	9	100%
	Maxillary zygomatic buttress	1		0%	1	100%
Total		225	14	6%	211	94%

(1/225). A 100% success rate was shown in the median suture, paramedian suture, maxillary zygomatic buttress and external oblique ridge of the mandible. The anterior alveolar (94%) and posterior alveolar regions (92%) of the maxilla and the anterior alveolar (90%) and posterior alveolar regions (97%) of the mandible had higher success rates than either the posterior alveolar palate region of the maxilla (88%) or the retro-molar region of the mandible (88%).

3. Palatal implant anchorage system (Table 3, Fig. 6)

The majority of the palatal implant anchorage systems (PIAS®) were placed in the median suture region of the maxilla (129/152). The next most common location was the paramedian suture region of the maxilla (19/152). Insertion of implants into the posterior alveolar and retro-molar regions of the mandible and anterior alveolar region of the maxilla was performed less commonly (4/152). A 100% success rate was achieved in the posterior alveolar and retro-molar regions of the mandible and anterior alveolar region of the maxilla. The median suture region of the maxilla (90%) had a higher success rate than the paramedian suture region (84%) of the maxilla. Furthermore, implant loosening occurred at the median suture and paramedian suture regions of the palate in younger patients. When we classified the patients into two groups according to age, the failure rates were 36% for the median suture in the under-15-years group and 50% for the paramedian suture in the over-16-years group.

4. Plate type implant (Table 4)

The majority of the plate-type implants (SAS®) were placed in the zygomatic buttress region of the maxilla (304/444). The next most common location was the mandibular body region (137/444). Placement of implants in the nasomaxillary buttress region and median suture region of the maxilla was performed less commonly (3/444). Placement of plate-type implants in the median suture

Table 3 Implant location and success rates of PIAS®

Implant location		Numbers of implant	Failure	Failure rate	Success	Success rate
Mandible	Posterior alveolar region	2		0%	2	100%
	Retro-molar region	1		0%	1	100%
Maxilla	Anterior alveolar region	1		0%	1	100%
	Median suture	129	13	10%	116	90%
	Paramedian suture	19	3	16%	16	84%
Total		152	16	11%	136	89%

Table 4 Implant location and success rates of plates

Implant location		Numbers of implant	Failure	Failure rate	Success	Success rate
Mandible	Mandible body	137	21	15%	116	85%
Maxilla	Median suture*	1		0%	1	100%
	Nasomaxillary buttress	2		0%	2	100%
	Maxillary zygomatic buttress	304	5	2%	299	98%
Total		444	26	6%	418	94%

* Locking plate system was used at median suture region.

region was carried out to obtain bone fixation by use of a locking plate. A 100% success rate for SAS® was only shown in the nasomaxillary buttress region. The zygomatic buttress region of the maxilla (98%) showed a higher success rate than the mandibular body region (85%).

5. Postoperative complications (Table 5)

Inflammation was classified as acute inflammation or chronic inflammation of the soft tissue surrounding the implant. Inflammation occurred at a higher rate with plate-type (7.6%) than screw-type implants. Acute inflammation occurred in 0% of patients with predrilling micro-screws, 1.3% with self-drilling mini-screws and 2.5% with palatal screws. Chronic inflammation accompanying the formation of granulation tissue occurred in 6.9% of patients with screw-type implants, but only in 0.9% with plate-type. However, the ratio was highest (5.7%) with the micro-screw type implants. With self-drilling mini-screws, it was 0% and with palatal screws 0.6%.

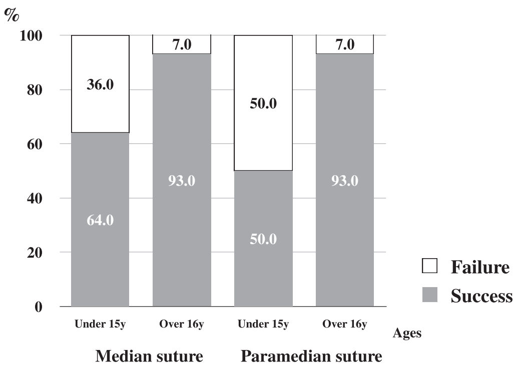


Fig. 6 Success rates of palatal implants (PIAS®)

Discussion

Obtaining anchorage of tooth moment has long been a standard problem in orthodontic treatment, and one that remains so, even after the introduction of temporary anchorage devices. The development of intraoral and extradental anchorage systems by traditional methods has been welcomed. However, none of these methods has led to a comprehensive solution to the problem.

Various types of anchorage device have been used in orthodontics[15,28]. Turley *et al.*[38] and Roberts *et al.*[29] reported conventional osseointegrated implants. Costa *et al.*[10] and Freudenthaler *et al.*[14] reported mini- and micro-implants and Wehrbein *et al.*[41–43] reported palatal implants. Screw-type mini- and micro-implants offer the advantage of lower cost, simpler surgical placement and higher versatility than plate-type implants. The number of publications on implants in the orthodontic literature is increasing exponentially. Recently, a number of human studies have investigated factors associated with stability of orthodontic temporary anchorage screw type implants. One paper by Crismani *et al.*[12] reviewed clinical trials reported before September 2007 and included at least 30 mini screws. All 14 articles described success rates sufficient for orthodontic treatment. These 14 clinical trials included 452 patients and 1,519 screws. The mean overall success rate

Table 5 Inflammation, granulation tissue and numbers of implants

	Inflammation		Granulation tissue	
	Number of implant	%	Number of implant	%
Micro-screw (K1)	0	0	5	5.7
Mini-screw (DTA)	3	1.3	0	0
PIAS	4	2.5	1	0.6
Plate (SAS)	33	7.6	4	0.9

was 83.8%. Screw diameters of 1.0–1.1 mm yielded significantly lower success rates than those of 1.5–2.3 mm.

In this study, titanium pre-drilling micro-screws of 1.2 mm in diameter, titanium alloy self-drilling mini-screws of more than 1.4 mm in diameter, pre-drilling palatal screws tapered to 1.9–2.2 mm in diameter and mini-plates were used as orthodontic anchorages. The success rate of the mini-plates and all screws at the majority of placement sites was more than 90%.

Park *et al.*[26] reported 222 micro-screws 1.2 mm in diameter. The overall success rate was 89.1%. They also identified local host factors. Screw implants placed in the maxilla showed a higher success rate at 96% than those placed in the mandible at 86.4%. In a report by Chen *et al.*[7], 59 micro-implants 1.2 mm in diameter were placed in 29 patients as orthodontic anchorages. Nine of these micro-implants were later removed and the overall success rate was 84.7%. With respect to location, the success rate was 87.5% in the maxillary anterior teeth, 85.7% in the maxillary posterior teeth and 81.3% in the mandibular posterior teeth. The success rate in the mandible was lower than in the maxilla. This was due to occlusal stress and food impaction force causing loosening of the micro-implants in the mandible.

In this study, we placed 58 titanium micro-screws measuring 1.2 mm in diameter in the alveolar region with pre-drilling and obtained a success rate of 75–100%. Success rates decreased depending on location in the following order: the anterior alveolar region (94%) and posterior alveolar region (92%) in the maxilla; the anterior alveolar region (100%) and posterior alveolar region (75%) in the mandible. The success rate was higher in the posterior alveolar region of the maxilla than in the posterior alveolar region of the mandible, which was similar to the earlier reports of Park and Chen. The mandible has thicker, denser cortical bone than the maxilla. However, this result may also have been due to overheating of the bone by high-speed drilling. Because the mandible has denser bone, there is a greater chance of generating heat of above 47°C, which is the critical temperature for causing bone damage[13,35]. In addition, screw implants placed in the posterior region of the mandible can easily be irritated by food during chewing. These factors might negatively affect the clinical success of screw-type implants. Furthermore, we believe we were able to prevent possible ossification of the peri-implant alveolar bone by setting a waiting period after implant placement before allowing application of orthodontic force.

Lim *et al.*[24] conducted a review of their charts and reported a total of 378 mini-screws in 154 patients. They reported an overall success rate of 83.6%. They showed that the midpalatal and maxillary buccal molar areas (85.9%) had a higher success rate than the mandibular buccal molar (71.4%) and mandibular buccal canine areas (80.0%). Tseng *et al.*[37] reported an overall success rate of 91.1%. They investigated risk factors for failure of mini-implants. They showed that location was the only significant risk factor for failure of mini-implants. Their success rates were 100% in the anterior teeth of the maxilla, 95% in the posterior teeth of the maxilla, 100% in the anterior teeth of the mandible, 85.7% in the posterior teeth of the mandible and 60% in the ramus. Cheng *et al.*[8] obtained the same result for survival rate. In a Japanese report, Kuroda *et al.*[22] reported that mini-screws had a high success rate of approximately 90%. In terms of location, this was maxillary premolar at 95.6%, maxillary molar at 66.7%, palatal molar at 90.0%, mandibular premolar at 88.9% and mandibular molar at 66.7%. They concluded that the reason the success rate in the molar region was lower than in the premolar region was the greater likelihood of root contact and invasion of the maxillary sinus. In another report by the same team[23], screws had a high success rate of 80% in approximately 216 titanium screws in 110 patients. The proximity of a mini-screw to the root is a major risk factor for failure of screw anchorage.

More recent investigations involving a healing period before application of load found success rates of above 90% and failure was associated with implant location[40]. Wu *et al.*[44] reported 414 mini-implants of 4 types with diameters ranging from 1.2–2.0 mm in 166 patients. The overall success rate was 89.9% (42 failures among 414 screws). The failure rates for the over 1.4 mm type mini-implant were 13.2% in the maxilla and 2.7% in the mandible. In the maxilla, they recommended an implant diameter of equal to or less than 1.4 mm. In the mandible, an implant diameter of greater than 1.4 mm is suggested for better orthodontic anchorage.

In this study, success rates for the self-drilling mini-screw were 88–100% in the maxilla and 88–100% in the mandible. These results were similar to those of earlier reports. The posterior alveolar region of the mandible (97%) showed the highest success rate, followed by the anterior alveolar region of the maxilla (94%), the posterior alveolar region of the maxilla (92%) and the anterior alveolar region of the mandible (90%). In most of these patients, diagnosis and planning were based on the results of CBCT. We selected implant diameter and planned surgical direction and placement 3-dimensionally with the computer software OsiriX[30]. This may account for the high success rate achieved in placement of both micro- and mini-implants within narrow confines between roots.

The palatal region is suitable for placement of orthodontic anchorage devices because the palate has sufficient cortical bone and gingiva. The palatal implant anchorage system (PIAS®) used in this study was a 3-piece titanium implant specifically designed for use in the median or paramedian palatal region, which was developed by Takaki and Nishii. To utilize this anchorage, the mid-palatal implant is connected to the anchor teeth *via* a trans-palatal arch.

Bernhart *et al.*[3] reported a survival rate of 84.8% using 21 short implants in the paramedian region for improvement of orthodontic anchorage. Three implants were lost after the start of orthodontic loading, which was delayed for 4 months after implant placement. Asscherickx *et al.*[1] reported that the success rate of palatal implants was 91%. Thirty-four palatal implants were placed in 33 patients in their study. In the adult group (median placement), the success rate was 88.8%. In the adolescent group (paramedian placement), the success rate was 92%. Three implants failed early; they were lost during the healing phase within 12 weeks after placement. Crismani *et al.*[11] reported a success rate of 90% in their study, in which 20 palatal implants were placed in 20 patients. Bantleon *et al.*[2] reported a 92% success rate. Three of 40 implants were lost within 2 to 3 months after placement. Wehrbein *et al.*[41] investigated, prospectively, 9 palatal implants placed in the median palatal suture for anchorage reinforcement of the posterior teeth in adults. The mean unloaded implant healing period was 12 weeks. All implants showed primary stability directly after placement and were successfully used for anchorage purposes throughout the examination period, and the success rate was 100%. These reports showed a high success rate of over 90% for the palatal region. In this study, we had a success rate of 90% for palatal implants placed in the median palatal suture and 84% for those in the paramedian region. The success rates observed in our study were similar to those observed in these earlier studies.

In terms of palatal placement, Jung *et al.*[18] reported 30 implants placed at the median region of the anterior palate in patients aged 12–41 years. After placement, all implants (30/30) were stable, but during the 8-week healing phase 2 (6.7%) were lost and 28 (93.3%) became osseointegrated. They reported that these were lost early in the healing phase in patients aged 13 and 18 years. Although somewhat speculative, one might claim parafunctional activity of the tongue was responsible for these implant losses. Kim *et al.*[21] reported that younger patients, especially those less than 15 years of age, had a higher failure rate than did older age groups in 128 cases. The results of this study are in agreement with those of these earlier studies. This may have been due to differences in bone density, because calcification of bone is not completed in adolescents, or differences in area, as mini-screws are usually placed in the parapalatal area in adolescents. Some authors have suggested placing implants laterally to the mid-line to avoid this problem[4,36]. This may be a valid option in young patients with a patent mid-palatal suture, although appropriate surgical and radiological planning is essential. In a recent study, Schlegel *et al.*[32] examined cadavers and concluded that suture ossification began no earlier than 17 years of age, which means that implant failure rate may be higher in patients under this age. In this study, we used our custom-made PIAS® implant and obtained a success rate similar to that seen in earlier reports. In terms of age distribution in this study, the success rates were 64% for the median suture and 50% for the paramedian suture in patients aged under 15 years, while patients aged over 16 years showed a success rate of 93% for both regions. A patent mid-palatal suture may also be problematical in younger patients and contribute to failure. In this study, we examined the palatal region with CBCT before placement implant, and most of the implants were placed in the mid-palatal area between the second premolars and first molars. In this study, 16 implants did not integrate, although the reason for these failures is not clear. One reason may be that the bone of the palate tends to be of poor quality and not as dense as that of the mandible. Furthermore, the surgeon commented on the variability of bone density between patients and in some patients bone density was lower, which may have contributed to implant failure.

The skeletal anchorage system (SAS®), a plate-type implant developed by Sugawara, is an orthodontic anchorage modality utilizing titanium mini-plates and monocortical screws that are temporarily fixed in the maxilla and mandible for absolute orthodontic anchorage[34]. This modality enables predictable intrusion, distalization and a non-extraction approach to treatment involving the maxillary and mandibular molars. In this study, this plate-type implant was placed primarily at the zygomatic buttress in the maxilla with a Y-plate and in the lateral cortex in the mandible with a T-plate.

Sugawara[33] reported plate loosening in only 1% of their cases. Nagasaka *et al.*[25] evaluated the efficacy of utilizing transmucosal mini-plates as temporary orthodontic anchorages in 55 patients. A total of 107 mini-plates were anchored to the jaws by two or more monocortical screws, with the long arm exposed to the buccal vestibule. Three of these mini-plates were replaced by new ones and screw loosening only occurred in 2 cases due to mobility during the unloaded healing period. The failure rate was 2.8%. Orthodontic force was applied to each mini-plate at approximately one month after implantation. All mini-plates remained stable during the force application period. Choi *et al.*[9] reported a total of 68 mini-plates in 17 patients. The post-treatment clinical examination showed that 5 mini-plates, all in the mandible, failed before the end of treatment (a failure rate of 7%).

In this study, loosening of the plate-type implant occurred in 21 plates in the lateral cortex of the mandible and in 5 plates in the zygomatic buttress of the maxilla. The failure rate in this study was 2% for the maxilla and 15% for the mandible. These rates were lower than those of earlier reports, but similar in terms of location. In JCO interviews, Sugawara[33] noted that loosening sometimes occurs, but that is not due to elastic force. There are three features of SAS placement that must be controlled to prevent movement of the mini-plates: bite force, bone alignment and implantation technique. In some of our earlier patients, occlusion interfered with the mini-plates, causing some loosening. However, we are now careful to avoid this. Furthermore, when bone and mini-plates are in good alignment, there are fewer problems.

In this study, most loosening occurred in the mandibular body region. We believe that the low success rate in this region was primarily due to surgical procedure-mediated stress such as burning of bone due to drilling or incompatibility of the plate contour with that of the bone; a secondary cause may have been the environment of the implant location.

One potential problem that may occur during surgical procedures is osteonecrosis under the plate due to blood flow inhibition in the cortical bone through excessive compression of the rib surface of the plate. Perren *et al.*[27] reported that the stability of conventional bone plating systems is achieved when the head of the screw compresses the fixation plate to the bone as the screw is tightened. Invariably, over time, the cortex of bone adjacent to the plate will resorb. Unfortunately, if the plate is not contoured precisely and is not in intimate contact with the bone, or if the host is compromised, the "race" between fracture healing and cortex resorption will be lost, resulting in unstable fixation. In this study, although inflammatory frequency was lower than that in previous reports, there were many cases that required re-fixation due to instability of the plate during the waiting period. Furthermore, there is the possibility that bone healing was inhibited due to masticatory pressure where the plate was exposed to the buccal oral cavity.

It is important to thoroughly educate patients in oral care; it is also advisable to professionally clean the orally exposed part of the anchor screws and plates, which greatly reduces postoperative infection. In addition, oral hygiene control is sometimes poor in the posterior maxilla, and the risk of peri-implant inflammation with plate-type is higher than that with screw-type implants.

Sugawara and Nishimura[34] reported that infection occurs in about 10% of patients. Mild infections can be controlled by antiseptic mouthwash and careful brushing techniques. In more severe cases, antibiotics are required. In our study, we identified two types inflammation: acute inflammation and chronic inflammation of the soft tissue surrounding the implant. Inflammation occurred in 7.6% with the plate-type, which was higher than with the mini-screw type (1.3%) or palatal screw type (2.5%) implants. When severe infection occurs with plate-type implants, we administer antibiotics as necessary.

Chronic inflammation accompanied by formation of granulation tissue occurred in 6.9% of patients with the screw-type implants, which was higher than that with the plate-type (0.9%). The micro-screw type showed the highest ratio (5.7%) among screw-type implants. In this study, most of the micro-screw type implants were placed in the anterior alveolar region of the maxilla. It was inferred that chronic inflammation was high due to persistent stimulation by wire penetrating the mucosa in this region.

Sato *et al.*[31] suggests that the environment in crevices around titanium orthodontic anchor plates is anaerobic and supports anaerobic growth of bacteria, which may trigger inflammation in the tissue around the plates. Therefore, orthodontic treatment with titanium anchor plates requires strict self care and regular professional plaque control in order to prevent infection. We have adopted oral hygiene instruction by a dental hygienist from an early stage in orthodontic treatment involving temporary anchorage devices. We believe that this may have been responsible for the low rate of complications such as inflammation seen in this study.

Conclusions

We reviewed 904 orthodontic implants in 455 patients over a period of 10 years. Implant devices used comprised micro-screws (83), mini-screws (225), PIAS® for the palate (152) and plate-type implants (SAS®, 444). Success rates were over about 90%. Success rates were 94% for mini-plates, 93% for micro-screws, 94% for mini-screws and 89% for palatal screws. The highest failure rate occurred at the mid-palatal region with PIAS® in young patients, which was the same as that with mini-screws placed in the alveolar region of the mandible generally. Inflammation rate of soft tissue surrounding orthodontic implants was highest with plate-type implants (acute inflammation), followed by palatal implants and mini-screws. Chronic inflammation mostly occurred with placement of micro-screws in the anterior alveolar region of the maxilla. Both plate- and screw-type orthodontic implants yielded excellent clinical results.

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