Original Article

Success rates of a skeletal anchorage system in orthodontics: *A retrospective analysis*

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ABSTRACT

Objectives: To evaluate the premise that skeletal anchorage with SAS miniplates are highly successful and predictable for a range of complex orthodontic movements.

Materials and Methods: This retrospective cross-sectional analysis consisted of 421 bone plates placed by one clinician in 163 patients (95 female, 68 male, mean age 29.4 years $\pm$ 12.02). Simple descriptive statistics were performed for a wide range of malocclusions and desired movements to obtain success, complication, and failure rates.

Results: The success rate of skeletal anchorage system miniplates was 98.6%, where approximately 40% of cases experienced mild complications. The most common complication was soft tissue inflammation, which was amenable to focused oral hygiene and antiseptic rinses. Infection occurred in approximately 15% of patients where there was a statistically significant correlation with poor oral hygiene. The most common movements were distalization and intrusion of teeth. More than a third of the cases involved complex movements in more than one plane of space.

Conclusions: The success rate of skeletal anchorage system miniplates is high and predictable for a wide range of complex orthodontic movements. (*Angle Orthod.* 2018;88:27–34.)

KEY WORDS: Orthodontic anchorage; Bone plate; Skeletal anchorage; Miniplate

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INTRODUCTION

Temporary skeletal anchors have become a routine component of the contemporary orthodontists' clinical armamentarium. The clinician can use them to develop force systems directly from the device and/or prevent unwanted side effects by indirectly connecting the device to dental anchor units. The range of force application has extended beyond historical antero-posterior movements to include more complex vertical and transverse movements previously considered problematic. In addition, these devices do not rely on patient compliance and do not affect aesthetics, which is a major disadvantage with the traditional headgear or facemask. The stability of these devices makes it possible to obtain complete anchorage to address the wide range of reciprocal forces in orthodontic mechanotherapy.

Historically, temporary anchors were first documented in the early 1980s by placing a surgical fixation screw in the maxillary alveolus to support direct force to the dentition.[1] Similarly, Roberts et al.[2] demonstrated the application of osseointegrated implants as indirect anchorage to protract posterior teeth in the mandible. Following these reports, numerous applications of osseointegrated fixtures were demonstrated.[3] Notably, Konomi[4] reported intrusion of anterior teeth using an osseointegrated mini bone screw 1.2 mm in diameter and 6 mm in length.[4] This generated great interest in small microscrews as a source of orthodontic anchorage.

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Figure 1. Placement of a skeletal anchorage system (Y type) bone plate in the zygoma. The bone plate can be prebent and adapted to the contours of the bone prior to fixation.

Rapid progress in the development of these micro-screws, otherwise referred to as temporary anchorage devices (TADS), in both animal and human models resulted in more detailed comprehension of the bony microstructural implications in anchorage.[3,5,6] Subsequently, the scope of application has been expanded to support a wide array of tooth movements in three dimensions, including anchorage preservation during space closure,[7] protraction and retraction,[8,9] and intrusion and extrusion[10–11] and to assist in dento-facial orthopedics.[12,13]

The increased acceptance of TADS relates to the clinical advantages in addressing malocclusions because of the relative ease of placement, low cost, and minimal need for patient compliance during active tooth movement. Despite the interest, few studies stood up to scientific scrutiny and it was difficult to make valid comparisons.[14,15] As such, it is not surprising that success rates in TAD devices ranged from 37% to 94%.[11,16,17] Notwithstanding, the general trend indicates that TADS were versatile and predictable and were at least as effective as conventional techniques.

However, a number of complications have been reported including screw loosening, fracture, infection, and damage to adjacent structures. Screw fracture is one of the most undesirable effects of TADS and is related to insertion torque and bone quality.[18,19] Although damage to soft tissues during placement is generally transient, there is a risk of irreversible damage to the teeth and periodontium.[18] Relating to this, it was reported that screw–root proximity was a major risk factor for screw failure with the potential to induce pain, infection, and root resorption.[18] The success rate of screws in close proximity to the lamina dura has been reported to be reduced by as much as one third.[18,19] This finding was verified by numerous studies using three-dimensional computed tomography.[18,20] Some authors have reported techniques to diverge roots prior to screw placement in the initial stage of fixed-appliance therapy to minimize this complication.[21] Many studies emphasize the significance of cortical bone thickness for initial stability. Unfortunately, there are not many areas in the alveolar bone where there is sufficient bone quality to guarantee successful placement.[22]

These limitations prompted research to explore other means of skeletal anchorage such as miniplates.[22–24] One such system is the skeletal anchorage system (SAS) developed by Sugawara and Nishimura.[25] This system consists of a titanium bone plate (miniplate) fixed into cortical bone by several self-threaded titanium screws (Figures 1 and 2). Although numbers vary, there is a body of evidence indicating the comparatively high success rate of these miniplate anchors. Despite the need for surgery, one major advantage of miniplates is that placement is generally in areas of more predicable bone quality such as the zygomatic buttress,[23] retromolar pad,[22] and along the mandibular body.[22]

Although the SAS offers several distinct advantages, it is not a commonly used method in anchorage reinforcement. A recent survey of orthodontists indicated that they infrequently considered skeletal anchorage, with many citing a lack of clinical guidelines and/or skepticism of the evidence.[26] Many operators desire information on success rates, risk factors, and possible adverse effects of their treatment. With this in mind, the aim of this retrospective study was to evaluate the premise that skeletal anchorage with the

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Figure 2. The muco-periosteal flap is subsequently approximated with the head of the plate exposed. At 1-week review, there is typically some minor inflammation that can be addressed with conservative measures.

SAS miniplates is highly successful and predicable for a range of complex orthodontic tooth movements.

MATERIALS AND METHODS

Ethics approval for the study was obtained from the Human Research Ethics Committee from The University of Western Australia.

This study consisted of a retrospective cross sectional analysis of private practice records from specialist clinicians (orthodontists and one oral surgeon). Each specialist in the study had more than 10 years' experience with board-registrable qualifications in Australia. Patients receiving SAS bone plates as part of their orthodontic treatment were identified in each clinic. Clinical records for these patients were viewed in their respective practices where pertinent data such as age, gender, medical history, malocclusion, failure, complication, and type of orthodontic movement were noted. Data were stored in a separate electronic device where each patient was nonidentified.

These data formed the basis of this study, which consisted of 163 consecutive patients with a total of 421 bone plates placed. There were no specific exclusion criteria, and any patients receiving bone plates were considered. All patients received the standard SAS bone plate, Super Mini Anchor Plate® (Dentsply Sankin, Tokyo, Japan), which consisted either of the T,Y, or I plate and Osteomed Screws (Osteomed, 3885 Arapaho Rd, Addison, TX, USA), (5-mm length, 2-mm diameter). The choice of plate was determined by the oral surgeon, and placement was performed under general anesthesia. Data were managed with Microsoft Excel 2013 (Microsoft Corp., Redmond, Wash) with simple statistics using IBM SPSS version 23 (IBM Corp., Armonk, New York, 10504-1722, USA). The chi-square test was used to compare proportions between the independent nominal variables and consideration of the Pearson chi-square statistic at 5% significance.

In this study, *failure* was defined as an undesirable side effect of using a bone plate that either required replacement or removal for mechanical or biological reasons, had fallen out, or failed to achieve satisfactory orthodontic outcomes. Likewise, *complication* was defined as managing a side effect of a bone plate that did not affect its functionality or require replacement and had not jeopardized the outcome. A complication score was only recorded for cases where there was a specific postoperative complaint or if the clinician thought a condition was necessary for a dedicated review or additional measures as a result of poor oral hygiene, noncompliance, habits, or trauma. This did not include mild inflammation or swelling expected from routine surgery. Success was considered as a plate in function and performing its role until its intentional or elective removal without compromising treatment objectives. All clinicians adhered to the Australian guidelines when considering the need to prescribe medications.[27] In the category "presence of medical condition," this score was reserved for conditions that required the orthodontist to seek a specialist medical or dental opinion for nontooth or periodontal-related conditions considered as complex and benefiting from a second opinion. This included consulting with a medical specialist (ie, rheumatologist or psychiatrist) for an opinion on the systemic impact of various conditions on orthodontic treatment or a dental specialist (ie, oral medicine specialist) to assess conditions such as parafunction or temporomandibular dysfunction. Trivial medical conditions not requiring specialist management were not included in this score.

RESULTS

In 163 patients (95 female, 68 male, mean age 29.4 years $\pm$ 12.02) with a variety of malocclusions, 421 SAS plates were placed with a success rate of 98.6% (Table 1). Approximately 40% of patients experienced complications during the course of treatment, with a majority of cases successfully managed.

A total of six bone plates failed in four patients. One patient had two bone plate failures as a result of infection. Unfortunately, this patient's oral hygiene deteriorated as a result of depression associated with the loss of a family member. Another patient experienced fascial space infection when undergoing "surgery first" orthognathics. One bone plate fractured as a result of the dislodgement of food between the bone plate and soft tissue. Only two incidences of bone plate mobility (peri-implantitis) were noted, and this occurred in the same patient.

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Table 1. Success Rates and Orthodontic Characteristics of Skeletal Anchorage System Patients

		Total		Performance	
	Characteristic	N	%	No. Fail	Success Rate
Gender	Male	68	41.7%		
	Female	95	58.3%		
	Total Number of Patients	163			
	Total Number of Bone Plates	421			
Age	Over 18 years	127	77.9%		
	18 years of less	36	22.1%		
Presence medical condition		22	13.5%		
Dental Malocclusion	Angle Class I	29	18%	0	100%
	Angle Class II Div 1	84	52%	2	98%
	Angle Class II Div 2	22	13%	0	100%
	Angle Class III	28	17%	2	93%
Approximate Location of bone plate head	Maxillary Canine	4	1.8%	0	100%
	Maxillary Premolar	4	1.8%	0	100%
	Maxillary First Molar	88	38.8%	2	98%
	Maxillary Second Molar	21	9.3%	1	95%
	Mandibular Canine	16	7.0%	0	100%
	Mandibular Premolar	6	2.6%	0	100%
	Mandibular First Molar	76	33.5%	0	100%
	Mandibular Second Molar	12	5.3%	1	92%
Surgical Cases	Total Surgical Patients	19	11.7%	1	95%
	Proportion of Surgical First	8	42.1%	1	88%
	Proportion of Eventual Surgery	11	57.9%	0	100%
Types of Orthodontic Movements	Distal driving for crowding	41	18.5%	1	98%
	Distal driving for class II correction	71	32.0%	0	100%
	Distal driving for class III correction	9	4.1%	0	100%
	Distal driving for surgery first compensation	9	4.1%	1	89%
	Molar intrusion for closure anterior open bite	27	12.2%	1	96%
	Molar protraction	31	14.0%	0	100%
	Lower anterior retraction	14	6.3%	0	100%
	Molar intrusion	19	8.6%	1	95%
	Molar extrusion	1	0.5%	0	100%
	Movement in more than one plane of space	58	35.6%		
Complications during function	Soft Tissue Inflammation	63	38.7%		
	Bone Plate Modification Required	15	9.2%		
	Bone Plate Loosening/Mobility	0	0.0%		
	Bone Plate Fracture	1	0.6%		
	Infection (Antibiotics Prescribed)	24	14.7%		
	Total Number of Patients with complications	67	41.1%		
Bone Plate Failure	Fracture	1	0.24%		
	Infection	3	0.71%		
	Mobility	2	0.48%		
	Total Number	6	1.43%		
Bone Plate Success Rate	Total Number	421		6	98.57%

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Table 2. Summary Statistics of Infected and Noninfected Plates

		No. Infected	Total No.	%	χ^2	ρ value
Gender	Male	7	68	10%		
	Female	17	95	18%	1.823	0.17
Malocclusion	Class I	3	29	10.3%		
	Class II Div I	17	84	20.2%		
	Class II Div II	1	22	4.5%	4.651	0.19
	Class III	3	28	10.7%		
Orthodontic Movement	Distal driving for crowding	5	41	12.2%		
	Distal driving for class II correction	14	71	19.7%		
	Distal driving for class III correction	0	9	0.0%		
	Distal driving for surgery first compensation	2	9	22.2%		
	Molar intrusion for closure AOB	5	27	18.5%	7.251	0.51
	Molar protraction	2	31	6.5%		
	Lower anterior retraction	7	14	50.0%		
	Molar intrusion	4	19	21.1%		
	Molar extrusion	0	1	0.0%		
Bone Plate Location	Maxillary Canine	0	4	0.0%		
	Maxillary Premolar	0	4	0.0%		
	Maxillary First Molar	9	88	10.2%		
	Maxillary Second Molar	2	21	9.5%	8.406	0.29
	Mandibular Canine	1	16	6.3%		
	Mandibular Premolar	1	6	16.7%		
	Mandibular First Molar	9	76	11.8%		
	Mandibular Second Molar	2	12	16.7%		
Oral Hygeine	Satisfactory	5	106	4.7%	28.991	<0.01
	Poor	19	52	36.5%		

No significant complications (fracture, sinus perforation, nerve damage, lack of primary stability, allergy, and/or significant hemorrhage) occurred during the surgical placement of the SAS plates. Soft tissue infections (fascial space, suppuration, peri-mucositis) and the prescription of antibiotics occurred in approximately 15% of patients. The only statistically significant factor related to infected SAS plates was poor oral hygiene ($\chi^2 = 28.991$, $P < .01$; Table 2). Although soft tissue inflammation was the most common complica-

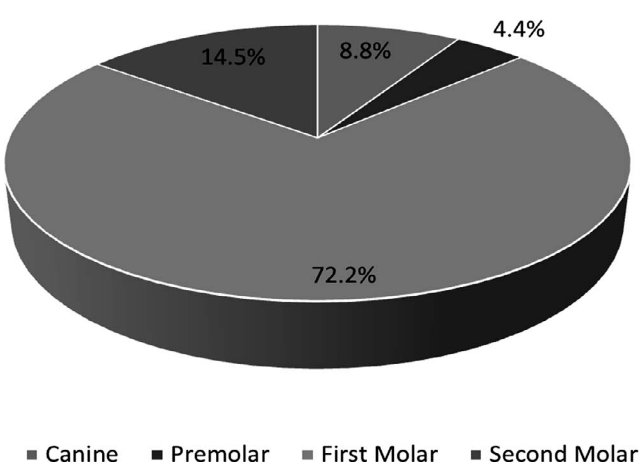

Figure 3. Approximate location of bone plate head.

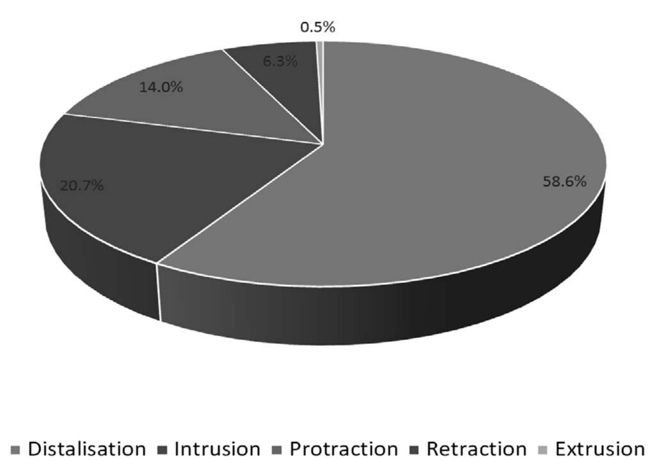

Figure 4. Types of orthodontic movements.

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tion, most occurrences were manageable with conservative measures such as focused cleaning and antiseptic rinses.

The most common movement was distalization of the posterior teeth followed by molar intrusion achieved by placing the SAS plates either in the zygoma (Y plate) or mandibular body (T plate; Figures 3 and 4). More than a third of the cases involved the movement of teeth in more than one plane of space, such as molar distalization and simultaneous intrusion, to correct a class II anterior open bite.

Apart from the four patients experiencing failures, there were no other reports of individualized treatment goals not being achieved with the use of SAS plates.

DISCUSSION

This study demonstrated that temporary anchors in the form of SAS plates are predictable and highly successful for a range of complex orthodontic movements. This was consistent with reports in the literature assessing miniplate outcomes.[28,29] A systematic review by Schätzle et al.[30] reported that the average failure rates for different anchorage devices were 7.3% for miniplates, 10.5% for palatal implants, and 16.4% for miniscrews. By comparison, the success rate for this study was 98.6%. It is important to note that even though studies report clinical success, there are often complications such as swelling, soft tissue hyperplasia, nerve damage, sinus perforation, or infection that are not always quantified. As such, this study considered it important to also quantify the types of complications encountered. With this in mind, it is important to note that although the SAS plates had a high success rate, approximately 40% of cases had complications that clinicians had to address or take particular caution. The difference in success rates between studies may be influenced by operator experience. In this particular study, all clinicians were highly experienced, and bone plates were placed by the same specialist surgeon with a keen interest in this field.

When considering success rates, it is necessary to appreciate the types of movements required to address malocclusions. Many studies reporting success rates do not provide such information, making it hard to determine anchorage demand. This study showed that SAS plates allow the predictable three-dimensional positioning of teeth, either individually or en-masse, with any combination of movements, including distalization, protraction, intrusion, and/or extrusion. In contrast, it is difficult to intrude molars with traditional orthodontic mechanotherapy. The ability to distalize molars enables the correction of cross-bites, incisor crowding, and asymmetries without the need to extract teeth in most instances. In skeletal class II patients, with SAS plates it was possible to achieve bimaxillary simultaneous intrusion and distalization of posterior teeth. Open-bite patients were able to have their molars both intruded and distalized. Cases requiring unilateral or bilateral protraction of molars necessitate placing anchorage at the canine. For TADS, this can be problematic because the only radicular spaces in the mandible of adequate bone are often mesial to the second premolar.[31] In this situation, the SAS may be preferred because its placement is more apical along the mandibular body, where bone quality is adequate. The range of movements in this study supports the arguments put forward that the SAS provides more reliable anchorage when reciprocal forces are higher.[32,33]

In comparison to TADS, the SAS offers several distinct advantages. Although the size of TADS allows an expansion of their clinical application, there are limitations. These limitations are often dictated by the quality and quantity of the surrounding bone. The placement of TADS between roots is possible but requires smaller diameter screws to avoid the lamina dura and/or an additional procedure to diverge the roots of adjacent teeth to create space. It is worthwhile noting that smaller size screws exhibit increased torsional strength and increased risk of fracture. In comparison, the SAS plates are not subjected to the risk of screw-root proximity because placement is more apical to the dentition where bone is more favorable. However, the placement of the SAS necessitates raising a flap during placement and more complicated removal that might involve fibrous tissue release and bone removal when compared to screws. Despite this, incisional access to the site of placement enables greater control and assessment of initial stability, depth, and placement of the SAS. It is difficult to predict the degree of engagement of TADS in bone with overlying soft tissue. When the placement of TADS is difficult because of inadequate bone dentistry or quantity, root proximity, or when TADS repeatedly fail and limit alternative locations, the SAS plates should be a strong consideration.[22,25]

One limitation with the SAS is that it requires surgery. As with any surgical procedure, patients will experience some discomfort and swelling. The placement of the SAS is more compelling in situations in which patients are already undergoing surgery such as during removal of impacted wisdom teeth or through "surgery first" orthognathic procedures. Bone plates can be simultaneously placed during this time, negating the need for a dedicated appointment. However, they do require an additional surgical procedure for removal. Although complications may be experienced with surgery, a majority of risks and complications are transient in an otherwise safe and predictable proce-

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dure. On the flip side, the benefits afforded by the SAS plates such as increased orthodontic control and scope of movement as well as avoiding the extraction of sound teeth are compelling indications for their consideration. A recent Cochrane review compared surgically implanted anchorage devices to conventional anchors and concluded that the former offered better stabilization and prevention of unwanted tooth movement during orthodontic treatment.[34]

As a retrospective cross-sectional study, there were limitations in the data. The observation time and time required to achieve the desired tooth movements varied with each case. In many patients, plates remained in situ for a period of time after the completion of active orthodontic treatment. This study also assumed that prescribing patterns were consistent among clinicians. Because of the small number of failures, there was insufficient statistical power to determine if any factor was significantly associated in the six plates that failed.

CONCLUSIONS

- The success rate of the SAS miniplates was high and predictable (98.6%) for a wide range of complex orthodontic movements.
- Despite its reliability in addressing many malocclusions, approximately 40% of cases experienced complications during treatment.
- Bone plate infections occurred in approximately 15% of patients, with the only significant risk factor being poor oral hygiene.
- Experience in treatment planning, placement, and managing any complication during treatment is necessary to ensure favorable outcomes of the SAS plates.

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