The Present and Future of the Skeletal Anchorage System (SAS) Using Miniplates for the Treatment and Management of Jaw Deformities

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Abstract: The SAS using miniplates is a most reliable, effective, and predictable modality. We can remodel the dentoalveolar complex beyond the limits of traditional mechanics through tooth movements with SAS mechanics. Additionally, the miniplate can transfer the orthopedic forces directly to the facial skeleton for bone repositioning and growth modification. Patients with jaw deformities have various complicated dentoalveolar problems according to the degree of skeletal discrepancies. Since the emergence of SAS, comprehensive orthodontic treatment plans have become more extensive and complex than traditional orthodontics, while surgical plans have become simpler and less invasive for patients. Nowadays, non-extraction and non-surgical treatment options are available through SAS for molar intrusion and/or distalization. Additionally, SAS makes it possible to reduce total treatment time and to correct minor surgical inaccuracies and relapse tendencies after orthognathic surgery. Therefore, the application of SAS or other miniplate anchorage devices can improve the quality of surgical orthodontics.

Introduction

Anchorage has long been one of the greatest problems in the field of orthodontics. Many devices and techniques have been developed over the decades to assist or reinforce tooth-borne anchorage. In 1983, Creekmore and Eklund first suggested the possibility of skeletal anchorage using a vitallium bone screw for intrusion of the maxillary central incisors. In 1985, Jenner and Fitzpatrick reported on the use of a bone plate as an orthodontic anchorage to retract lower molars. Titanium miniplates and miniscrews were frequently used as osteosynthesis devices in orthognathic surgery. In 1992, Sugawara et al. first applied a titanium miniplate on one side and a miniscrew on the other as an orthodontic anchorage to correct a severe crossbite in view of the lack of molar anchorage in the lower arch. In 1998, Sugawara et al. subsequently developed the skeletal anchorage system (SAS) utilizing titanium miniplates for correction of Class III malocclusions by lower molar distalization. In 1999, Umemori et al. described techniques for open bite correction by intruding lower molars with SAS. Experience using osteosynthesis miniplates has been in line with their intended use at the design stage as orthodontic temporary anchorage devices (TADs). With orthodontic miniplates, multiple fixation screws can be fixed away from the tooth roots, allowing for undisturbed tooth movement in any direction, and heavier and more dynamic forces to be used. At present, patients with skeletal discrepancies benefit from SAS mechanics to compensate for malocclusions that cannot be corrected using traditional orthodontics.

This paper discusses the current status and future prospects for SAS utilizing titanium miniplates for the treatment and management of jaw deformities based on nearly 20 years of experience.

Features of orthodontic miniplates and screws

Various osteosynthesis miniplates have been shown to be effective TADs. Many authors showed that miniplates are associated with fewer failures.
than orthodontic miniscrews\textsuperscript{15,16}. The use of locking miniplates with self-drilling screws was also reported to provide higher stability for anchorage in the maxilla\textsuperscript{17}. However, the shape of these osteosynthesis miniplates was not ideal for use as orthodontic anchors\textsuperscript{6-8,18-20}.

The SAS (Dentsply-Sankin K.K., Tokyo, Japan) is comprised of miniplates and fixation miniscrews designed specifically for orthodontic purposes. These implants are made of commercially pure titanium, which is biocompatible and suitable for osseointegration.

The orthodontic miniplate consists of three components: the head, the arm, and the body (Fig. 1A). The head component is intraorally exposed and has three continuous hooks for the application of various orthodontic force vectors by connecting wires, springs, and elastics. Orthodontic tubes or brackets can be bonded onto the head when more complicated mechanics are required. The arm component is transmucosal and is available in three different lengths to accommodate individual morphological differences. The body component is positioned subperiosteally and is available in three different configurations: the T-plate, the Y-plate, and the I-plate. The T-plate can be converted to the L-plate by cutting off one side of the body portion.

The fixation miniscrews, 2.0 mm in diameter and 5.0 or 7.0 mm in length, are monocortically inserted through the holes in the miniplate. The surgical site requires at least 2 mm of cortical bone thickness to fix the miniplate, and accordingly a pilot hole is drilled before the insertion of each screw. The screw has a self-tapping threaded body with an internal-tapered square head.

**Sites for miniplate placement**

In the maxilla, the anterior sinus wall is too thin to fix the miniplate with monocortical screws; the placement sites allowing screw fixation are limited to the piriform rim and zygomatic buttress. The cortical bone of these regions is almost always thick enough to secure the miniplate with multiple fixation screws. At the piriform rim, the I-plate is usually placed for the intrusion and protraction of upper molars (Fig. 1B). At the zygomatic buttress, the Y-plate is usually placed to intrude and distalize upper molars (Fig. 1B). Predrilling can result in minor perforations of the sinus membrane, which may not be a concern. To increase the primary stability of fixation screws in the maxilla, the use of a self-drilling screw without creating a pilot hole is advantageous\textsuperscript{27}.

In the mandible, screw fixation is possible on the lateral cortical bone in most locations except for the
area adjacent to the mental foramen. The T-plate or the L-plate is usually placed in the mandibular body to intrude, protract, or distalize the lower molars (Fig. 1B). Placement of the L-plate at the anterior border of the mandibular ramus can assist the extrusion of impacted molars (Fig. 1B). In cases where the miniplate is positioned directly over the mandibular canal or near the mental foramen, monocortical screws should be used to avoid injury to the inferior alveolar neurovascular bundle. The density and thickness of the mandibular cortical bone may cause the screw to fracture when using a self-drilling screw\(^\text{15, 21}\). Therefore, it is essential to create a pilot hole for use with both self-tapping and self-drilling fixation screws.

**Preparation for surgery**

SAS treatment is performed by a team approach with orthodontists and oral surgeons, much like orthognathic surgery. The treatment goals are planned based on cephalometric, photographic, and setup model predictions. Prior to surgery, the orthodontist makes a prescription, in which the proposed tooth movements, the exact location of the head, the length of the arm, and the shape of the body are illustrated and relayed to the surgeon via panoramic radiograph. The surgeon must evaluate whether or not any anatomical limitations or pathological problems exist at the sites through clinical and radiographic examinations as well as check the patient’s general status. Careful surgical planning and consideration of the risk factors are important to optimize the final treatment options for the patient and the implantation site. For SAS treatment to be successful, patients must be in good general health, have sufficient quality bone to accept the devices, and also have reasonable oral hygiene. Absolute contraindications include patients with hypersensitivities, titanium allergies, localized active infection, irradiated bone, metabolic bone disorders, bone pathologies, cardiovascular disease, blood dyscrasias, current/previous bisphosphonate therapy, or psychosomatic disease. Relative contraindications are poor oral hygiene, inadequate patient compliance, parafunctional habits, and the use of drugs, tobacco, or alcohol, depending on whether the condition can be resolved or eliminated before surgery. Younger patients are at a significantly greater risk of failure because of limitations in primary stability of fixation screws\(^\text{15, 18}\).

Informed consent must always be obtained from each patient before surgery.

Since miniplates must be placed exactly at the time when anchorage control is needed, the time for miniplate placement is decided after orthodontic brackets have been bonded and archwires put in place. This is done to ensure utmost patient comfort, guarantee early loading, and avoid loosening of the miniplates before orthodontic loading. In addition, treatment with SAS should begin after the adolescent growth period, following extraction of the third molars if indicated. Presence of the third molars may prevent distalization and intrusion of the first and second molars. It is recommended to avoid combining miniplate placement with extractions in the same area in order to reduce the risk of infection at the surgical site.

**Miniplate placement procedure**

The surgical procedure is usually performed under local anesthesia, but combination with intravenous sedation may be performed depending on the specific surgical plan, the number of miniplates being placed, and patient preference\(^\text{18, 19}\).

Initially, a first horizontal incision of approximately 5 mm length is made at the mucogingival junction or within 1 mm of the attached gingiva\(^\text{20, 21}\), where the miniplate head is to be exposed. Next, a second horizontal incision about 15 mm in length is made in the buccal vestibule and parallel to the first incision. To tunnel between these incisions, the mucosa is undermined subperiosteally. The mucoperiosteal flap is elevated to expose the bone surface through the second incision. Depending on the distance between the dentition and the implantation site, an appropriate miniplate is selected. The miniplate is then carefully adjusted to fit the contour of the bone surface at the site. The miniplate head is inserted through the second incision subperiosteally to the first incision and exposed to the oral cavity\(^\text{20}\). Emergence of the miniplate at the mucogingival junction or within the attached gingiva is essential for good soft tissue healing and management\(^\text{18, 18}\). Exposure of the miniplate through the mobile mucosa may result in increased irritation, inflammation, infection, and soft tissue overgrowth around the miniplate\(^\text{20, 21}\). Once the miniplate has been appropriately contoured and positioned, the first pilot hole is drilled and a self-tapping monocortical screw is
inserted. The remaining screws are inserted to secure the miniplate on the bone surface (Fig. 1C–D). Self-drilling screws without the creation of a pilot hole may be more appropriate for miniplate placement in the maxilla. Finally, the surgical wound is closed with resorbable sutures.

The implantation surgery takes approximately 10 minutes per miniplate. As with all surgical techniques, there seems to be a learning curve. However, since the vast majority of orthodontists have little or no experience with surgical procedures or perioperative management of bone surgery, consultation with an oral surgeon is advisable.

Postoperative management

Immediate postoperative radiographs should be taken to confirm the positions of the implanted miniplates relative to the surrounding anatomic structures. A panoramic radiograph is usually adequate.

Analgesics and antibiotics are prescribed for three to five days after surgery. Ice packs should be applied during the first 24 hours to the sides of the face where surgery was performed. The day after surgery, the sutured areas and heads of the miniplates are irrigated with saline solution. The patient is instructed to gently clean the transmucosal portions of the miniplates with a soft single-tuft brush and to use a chlorhexidine oral rinse for two weeks after surgery.

Postoperative discomfort (e.g., pain, bleeding, trismus, numbness, fever, diet) is minimal except for mild or moderate facial swelling. Swelling is the body’s normal reaction to surgery and eventual repair, but it is the most significant problem for implant-orthodontic patients. Efforts to control postoperative swelling are advisable to reduce negative perceptions of miniplate placement. The systematic use of perioperative anti-inflammatories and the immediate application of ice packs may minimize swelling. The patient should be instructed preoperatively that swelling is most marked within the first several days after surgery and may take a week to disappear.

Orthodontic force application is usually delayed for a few weeks after surgery to allow for the resolution of postoperative facial swelling, soft tissue healing, and the reinstitution of oral hygiene procedures, although immediate loading is possible.

Orthodontic mechanics with SAS

Presently the most significant advantage of SAS is its achievement of predictable threedimensional molar movement without the need for patient compliance. Miniplates are extremely stable and they are placed outside of the dental arches, allowing for molar distalization, intrusion, protraction, extrusion, and

Fig. 2 Orthodontic biomechanics with the SAS. A, Distalization of upper molars; B, Intrusion of upper molars; C, Protraction of upper molars; D, Expansion of upper molars; E, Distalization of lower molars; F, Intrusion of lower molars; G, Protraction of lower molars; H, Expansion of lower molars.
transverse movements, either independently or combined (Fig. 2A-H). To date, distalization and intrusion of the molars has been performed in approximately 85% of all patients treated with SAS. The use of SAS mechanics not only results in a dramatic change in how far teeth can be moved, but also offers more treatment options to patients with dental and skeletal malocclusions.\textsuperscript{7,8}

1. Molar distalization

While molar distalization has always been considered difficult even with headgear, and especially so in adult patients, it is now possible by placing a miniplate anchorage at the zygomatic buttress (Fig. 2A), or at the posterior mandibular body (Fig. 2E). Traditional mechanotherapies were limited to single molar distalization. With the development of SAS mechanics, en-masse movement of the posterior molars can be achieved, considerably reducing treatment time. The magnitude of orthodontic force can be up to 400-500 g on each side. Before SAS treatment, extraction of the third molars is usually necessary to make space for molar distalization.

Upper molar distalization is indicated for patients with anterior crowding in the upper dentition, Class II dentition, asymmetrical upper dentition, and decompensation of the upper incisors in skeletal Class III cases requiring orthognathic surgery. On the other hand, indications for lower molar distalization are patients with anterior crowding in the lower dentition, asymmetrical lower dentition, anterior crossbite with Class III denture, and decompensation of the lower incisors in skeletal Class II cases requiring orthognathic surgery.

2. Molar intrusion

Because it is extremely difficult to intrude the molars with traditional orthodontic mechanics, open bite patients had to undergo orthognathic surgery for posterior maxillary impaction. It has been almost impossible to impact the posterior mandibular alveolar segment because of the high risk of injuring the inferior alveolar neurovascular bundle. Orthodontic intrusion of the molars is now possible using a miniplate anchorage placed at the zygomatic buttress (Fig. 2B), or at the posterior mandibular body (Fig. 2F). Following the engagement of a rigid rectangular archwire in the buccal side and a transpalatal arch (TPA) in the maxilla or a lingual arch (LA) in the mandible, an elastic intrusive force will be provided from the miniplate anchorage. The magnitude of intrusive force can be up to 400-500 g on each side. The purpose of the TPA or LA is to prevent the buccal flaring of molars.

Molar intrusion provides counterclockwise rotation of the mandible, and subsequent closure of anterior open bite. Upper molar intrusion is indicated for patients with anterior open bite, vertical posterior maxillary excess, and a skeletal Class I to moderate Class II jaw relationship. On the other hand, indications for lower molar intrusion are patients with anterior open bite, lower molar height excess, and a skeletal Class I to mild Class III jaw relationship.

3. Molar protraction

Protraction of the molars is easy using a miniplate anchorage placed at the piritform rim (Fig. 2C) or at the anterior mandibular body (Fig. 2G). About 200-400 g of protractive force can be applied unilaterally.

Upper molar protraction is indicated for patients who have an anterior crossbite caused by maxillary deficiency, congenitally missing upper teeth, particularly lateral incisors or second bicuspids, asymmetrical upper dentition, or Class III molar relationship. On the other hand, lower molar protraction is usually needed in patients with diastemas of lower dentition, congenitally missing lower second bicuspids, asymmetrical lower dentition, Class II molar relationship, or decompensation of the lower incisors in skeletal Class III patients requiring orthognathic surgery.

Miniplate removal procedure

Immediately after the completion of orthodontic treatment, all miniplates and screws are routinely removed under local anesthesia. Initially, a short mucoperiosteal incision is made to expose the miniplate body and fixation screws. It is not uncommon for bone to overgrow the miniplate due to increased osseointegration with time.\textsuperscript{7,8} Bony overgrowth often complicates access to the screws, but resistance of the screws themselves is not a problem.\textsuperscript{10} After careful removal of the excess bone, the screws can be turned in reverse with a hand driver. The miniplate and residual bony overgrowth can be easily removed from the bone surface with a periosteal elevator. Curettage of residual inflammatory tissues in the surgical site is necessary to
facilitate soft tissue healing. Lastly, the surgical wound is closed with resorbable sutures. Analgesics, antibiotics and oral rinse solution are prescribed as necessary. Control of postoperative swelling and infection are advisable similar to post-implantation surgery.

**Miniplate failure and other complications**

In 210 consecutive patients (41 males, 169 females), 551 miniplates (Dentsply-Sankin K.K., Tokyo, Japan) were implanted in the first three years after development of the SAS. The mean age of patients at implantation was 24 ± 8 years (range, 9–46 years). All miniplates were removed after completion of orthodontic treatment with the SAS. The mean duration of miniplate implantation was 618 ± 244 days (range, 56–1279 days). A total of nine miniplates were removed prematurely and replaced. Failure criteria included miniplate mobility (7) and fracture of the head (2). The failure rate was 1.7% (Fig. 3, Table). The main advantage of orthodontic miniplates is their very low failure rate compared with miniscrews.\(^{15,16}\)

The failure rate due to miniplate mobility in the mandible was 2.8% (6 miniplates), which was much higher than that in the maxilla (0.3%, 1 miniplate). Two of 6 mandibular mobile miniplates had been combined with extraction of the impacted lower third molars near the implantation site. Inflammation or infection around the extraction socket might have interfered with bone and soft tissue healing.\(^{19}\) Four other mobile miniplates were severely fixed on the posterior mandibular cortex, but they showed mobility before or immediately after orthodontic loading (Fig. 3A). These failures might have been induced by progressive compression necrosis of the bone around the screws and repeated excessive impact during mastication. Increased incidence of failures in the mandible was also found in other studies\(^{15,16}\). Only one maxillary miniplate showed mobility immediately after orthodontic loading. At this site, primary stability of the miniplate was not completely obtained despite insertion of three self-tapping screws because of excessive sinus pneumatization. This failed miniplate was replaced with a long Y-type miniplate using three self-drilling fixation screws on the zygomatic process. Four of 7 mobile miniplates occurred in growing or adolescent patients. Younger age increases the risk of failure because of lower bone density, thin cortical bone and their relations to poor primary stability of the fixation screws.\(^{15}\) Special caution is needed to lessen the increased probability of failure, especially immediately after miniplate placement in young patients.

<table>
<thead>
<tr>
<th>Complications</th>
<th>Maxilla</th>
<th>Mandible</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection</td>
<td>27 /331</td>
<td>16 /220</td>
<td>43 /551</td>
</tr>
<tr>
<td>Miniplate mobility*</td>
<td>1 /331</td>
<td>6 /220</td>
<td>7 /551</td>
</tr>
<tr>
<td>Miniplate fracture*</td>
<td>1 /331</td>
<td>1 /220</td>
<td>2 /551</td>
</tr>
<tr>
<td>Mucosa covering</td>
<td>0 /331</td>
<td>1 /220</td>
<td>1 /551</td>
</tr>
<tr>
<td>Numbness</td>
<td>0 /331</td>
<td>1 /220</td>
<td>1 /551</td>
</tr>
<tr>
<td>Total</td>
<td>29 /331</td>
<td>25 /220</td>
<td>54 /551</td>
</tr>
</tbody>
</table>

*Failure rate of miniplates: 1.7%*
Two miniplates fractured after the head portion had been excessively bent by the orthodontist (Fig. 3B), and were replaced with new ones. The orthodontist should take care when manipulating the three continuous hooks of the miniplate.

The most common complication was acute infection, with clinical evidence of pain, swelling, and pus production around the miniplate. Such infection occurred in about 8% of miniplate implantation sites. Mild infections were controlled by irrigation, careful brushing technique, and antiseptic mouthwash. In more severe cases, antibiotics were required. Once an infection was resolved, the miniplate could be used again without premature removal. To prevent infection during treatment, it is important to emphasize oral home care with a single tufted brush. Also, professional cleaning of the miniplate and surrounding mucosa at all routine orthodontic appointments greatly reduces incidence of infection. Significant inflammation or infection may result if the mucosa surrounding the miniplate is mobile. The miniplate should emerge at the mucogingival junction or within the attached mucosa when possible.

Other potential complications including mucosa covering the miniplate and numbness in the implantation site were very rare. Mucosal coverage occurred at one miniplate placed in the retromolar region, which was intended to upright a mesioangulated second mandibular molar. Repeated surgical uncovering around the miniplate head was necessary. Numbness
occurred at one miniplate placement site adjacent to the mental foramen, which spontaneously recovered one month after surgery.

Clinical applications of SAS

1. Non-surgical camouflage treatment

SAS has been used in combination with multibracketed appliances to move molars individually or the entire dentition in three dimensions. Its mechanics for molar intrusion and distalization have been shown to be highly predictable. The use of a miniplate anchorage subsequently involved a number of camouflage or compensation techniques for a variety of skeletal problems that traditionally would have required orthognathic surgery, such as class III deformity and anterior open bite⁴⁻¹³.

A 41-year-old man was diagnosed with a severe crossbite due to a hyperplastic mandible (Fig. 4A). L-type miniplates were implanted bilaterally at the mandibular body to distalize posterior mandibular teeth (Fig. 4B). By debonding, correction of his total crossbite was achieved through non-surgical and non-extraction treatment with SAS (Fig. 4C). After five years of retention, a slight relapse was observed, but he was extremely pleased with his outcome (Fig. 4D). Evaluation of the cephalometric superimpositions revealed that his skeletal frames did not change, but the lower molars were distalized by a total of 6 mm (Fig. 4E).

A 16-year-old girl was diagnosed with a large anterior open bite due to a hypoplastic mandible with a short ramus (Fig. 4F). In order to intrude the upper and lower molars simultaneously, Y-type miniplates were placed bilaterally at the zygomatic buttress, and L-type miniplates were fixed bilaterally on the mandibular body (Fig. 4G). At debonding, a good occlusion had been obtained without orthognathic surgery and with avoidance of bicuspid extraction (Fig. 4H). After five years of retention, her occlusion had remained stable and favorable (Fig. 4I). Evaluation of the cephalometric superimpositions revealed a dramatic correction of her open bite resulting from radical intrusion of her posterior teeth and distalization of her upper dentition (Fig. 4J). Her vertical facial proportion and interlabial gap also improved because of counterclockwise rotation of the mandible.

SAS has proven useful as camouflage treatment for those patients who cannot or will not undergo orthognathic surgery, and for those patients who have failed orthodontic treatment. Miniplates can provide continuous anchorage support required for large tooth movement beyond the limit of traditional orthodontic mechanics alone. Miniplates have a significantly higher success rate than other orthodontic TADs, and they do not disturb any kind of tooth movement. As a result, predictable orthodontic treatment outcomes based on a goal-oriented approach can be achieved. However, the long-term reaction of the teeth and surrounding tissues to excessive orthodontic intrusion and distalization beyond anatomical boundaries of the dental- alveolar process remains unknown.

2. New approaches using miniplate skeletal anchorage

The use of titanium miniplates as stable anchorage is not confined to orthodontic tooth movements but also extends to orthopedic bone movements. Now, various types of miniplates have been developed and adapted to fit a variety of clinical situations⁷,⁸,¹⁸,¹⁹,²⁰. The role of miniplate anchorage is expected to increase orthodontic efficiency, minimize the need for orthognathic surgery, accelerate orthognathic surgery when needed, and achieve orthopedic growth modification. Several new treatment approaches using miniplates have been introduced²²⁻²⁴. Some methods may warrant consideration or caution because long-term data are not yet available²⁵.

1) Speedy orthodontics

Chung et al.²² reported a new approach of corticotom y-assisted orthodontic treatment called speedy orthodontics, which allows faster movements of the dental segments using miniplate anchorage. The author developed the C-tube²⁰ miniplates to allow for attachment to the orthodontic appliance. Two-stage peri-segmental corticotomy is performed to outline a block of bone around the anterior or posterior maxillary teeth under local anesthesia. An interval of two weeks is the optimal latency between the labial and palatal corticotomy. Miniplate anchorage allows 500–900 g of orthopedic forces per side to be applied to the corticotomized segment. Successful alveolar bone bending can be obtained in cases of adult protrusion or open bite. This technique is powerful, easy to apply, and provides a significant adjunct to traditional surgical
orthodontics.

2) “Surgery First” orthognathics

Nagasaka et al.20 reported the new treatment approach on “Surgery First” orthognathics with the SAS for the correction of skeletal Class III deformity. The principle of “Surgery First” is to first correct the skeletal disharmony and then decompenstnate the dentition. The SAS7,8 is an indispensable modality for intermaxillary fixation and postsurgical orthodontics, since predictable three-dimensional movement of the entire dentition is required. This sequence in surgical orthodontics has two significant advantages: rapid improvement of the facial profile and a shorter treatment time. Due to the application of SAS, a stable and functional occlusion can be obtained without bicuspid extraction or segmental maxillary osteotomy. This technique may well represent a paradigm shift in surgical orthodontics.

3) Maxillary orthopedic traction

De Clerk et al.21 reported an innovative treatment technique of maxillary orthopedic traction with miniplate anchorage. The author developed the Bollard miniplates with a locking fixation screw to allow traction hooks to be used. Four miniplates are placed at the infrazygomatic crests and between the lower canine and lateral incisor, on both sides. Three weeks after surgery, orthopedic forces of 100 g per side initially, and later, 200 g per side, are applied with Class III intermaxillary elastics on miniplates. With this procedure, no extraoral appliance is required, dental compensations can be avoided, and facial esthetics can be improved before the onset of puberty.

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References

4) JSPTIJ/"("4","


