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INTRODUCTION

Dentofacial and maxillofacial deformities are common in the general population, ranging from mild abnormalities of the teeth to extensive and widespread deformities involving the entire face and skull. Reconstruction of congenital, post tumor oblation and post traumatic defects aims to replace or regenerate tissues and to restore human functions. Although many of the facial discrepancies can be corrected by a single specialist, more extensive deformities require a multidisciplinary approach, often involving maxillofacial surgeons.

Perhaps there is no other area in reconstructive medicine and surgery that demands as outstanding aesthetic and functional results than the treatment of dentofacial and maxillofacial deformities. Several methods have been developed to improve facial appearance and function in different medical fields including esthetic dentistry, orthodontics, plastic and reconsctructive surgery.

This thesis focuses on three revolutionary techniques in the correction of the facial skeleton. The first two belong to a new orthodontic method, skeletal anchorage, which has opened up a new avenue in the management of some dentofacial deformities. Movements of teeth that were previously thought difficult - if not impossible - might now be feasible by this technique. The first chapter of the thesis reports on severe skeletal anterior open bite closure with skeletal anchorage that offers an alternative to orthognathic surgery. The second chapter presents a detailed overview of impacted canine management with orthodontic screws. The diagnosis of ankylosis can be excluded with this method and the orthodontic alignment of an impacted canine tooth should be considered even in adult patients. The third chapter deals with reconstruction surgery. Although vascularized fibula flap transfer is widely recognized as an effective technique for mandibular and maxillary reconstruction, the debate over the necessity of preoperative angiography as well as over the postoperative monitoring techniques of the flap circulation is still ongoing. The results of this study show the need for preoperative donor site vascular imaging studies and demonstrate that color Doppler ultrasound is an excellent diagnostic tool for controlling the flap circulation following transplantation.

1. SKELETAL ANCHORAGE

The goal of any orthodontic treatment is to achieve successful tooth movement with a minimum number of undesirable side effects. In conventional orthodontic treatment, moving teeth against other teeth has its own limitations, as even a small reactive force can cause undesirable movements. Absolute or infinite anchorage is defined as no movement of the anchorage unit as a consequence to the reaction forces applied to move teeth. Such an anchorage can only be obtained by using ankylosed teeth or devices fixed to bone.

Skeletal anchorage devices are gaining popularity in the orthodontic practice. These are indicated when a large amount of tooth movement is required or dental anchorage is insufficient due to absent teeth or periodontal loss. They are used where the forces on the reactive unit would generate adverse side effects. These devices may also be useful in asymmetric tooth movements, intrusive mechanics, intermaxillary and orthopedic traction. During the past few years, the application of skeletal anchorage devices has been expanded to include a wide array of cases, including the correction of deep overbite, closure of extraction spaces, correction of a canted occlusal plane, alignment of dental midlines, distalization and mesialization of molar teeth, en-masse retraction of anterior teeth, and upper third molar alignment. The use of skeletal anchorage has increased the envelope of orthodontic treatment, occasionally providing an alternative to orthognathic surgery.

The following two studies offer further indications for skeletal anchorage as new treatment modalities in the correction of dentofacial deformities.

1.1 Closure of severe skeletal anterior open bite with zygomatic anchorage

1.1.1 Introduction

An open bite is commonly one of the main symptoms of an overall dentofacial deformity. Most cases of anterior open bite are characterized by overeruption of the maxillary molars. In young patients, the vertical maxillary growth can be controlled with a high-pull headgear or a functional appliance with bite blocks. Once excessive vertical development of the posterior maxilla has occurred, only two treatment options are available for the correction of an open bite. Elongation of the anterior teeth leaves the skeletal component of the deformity unchanged. When orthodontic or surgical intrusion of the overerupted maxillary teeth is performed, the mandible rotates closed at rest and in function, resulting in open bite closure. Intrusion of the molar teeth with traditional orthodontic methods is hardly possible. Multiloop edgewise archwire has been recommended for open bite closure in non-growing

patients, but with this approach the correction was achieved mainly through extrusion of the incisors without skeletal changes.

Until recently, there was no orthodontic approach for the predictable intrusion of molar teeth in non-growing patients, there was therefore no real alternative to a combined orthodontic and surgical approach. Skeletal anchorage has recently been suggested for the orthodontic movement of teeth.

The aim of the this study was to evaluate the role of titanium reconstruction miniplates as temporary skeletal anchorage in the management of severe anterior open bites.

1.1.2 Patients and methods

Seven patients (4 women and 3 men) with severe anterior open bites who applied for orthodontic treatment were selected. The average age of the patients at the beginning of treatment was 21 years (range 15-29 years). In all cases, the deformity was due to overeruption of the maxillary molars. The mean anterior open bite measured between the edges of the incisors in the vertical plane was 6 mm (range 4-11 mm). Four patients exhibited Class I occlusion, while 2 individuals presented with a Class II and one with a Class III malocclusion.

Surgical procedure

A 2-cm horizontal mucoperiosteal incision was made, extending from the second premolar to the second molar over the attached gingiva. With a periosteal elevator, a full-thickness mucoperiosteal flap was reflected superiorly to expose the zygomatic process of the maxilla. A 4-hole I-shaped miniplate was adjusted to fit the contour of the zygomatic process. The plates were fixed with monocortical screws. The mucoperiosteal flap was repositioned and the surgical wound was sutured, with the last hole of the anchor plate exposed intraorally.

Orthodontics

To provide continuous light forces, nickel-titanium coil springs or elastic bands were placed bilaterally between the exposed hole of the miniplate and a hook on the segmental wire between the molar buccal tubes. When only one molar tooth was intruded, the spring was attached to the molar tube. To avoid buccal tipping, the molars were connected with transpalatal arches.

The intrusion was terminated when the open bite had been visually corrected. The molars were stabilized with vertical wire ligation between the molar tubes and the miniplates. Following this, traditional fixed bracket therapy was completed.

1.1.3 Results

All patients displayed true intrusion of the maxillary molars. Open-bite closure was achieved for all of them. In consequence of the autorotation of the mandible, the mandibular plane closed by an average of 3.1 degrees; point B rotated anteriorly and upward. In all cases, the anterior facial height decreased and the facial profile improved significantly. No signs or symptoms of a temporomandibular dysfunction were observed, and no miniplate movement was detected during the treatment There was no significant root resorption. All the intruded teeth remained vital. There were some slight inflammatory changes around the anchor sites in one patient, but these improved following further instructions concerning oral hygiene.

1.1.4 Discussion

Skeletal open bite is one of the most difficult malocclusions to treat. The most frequently performed procedures for anterior open-bite correction are superior repositioning of the maxilla via Le Fort I osteotomy, posterior maxillary osteotomy, and vertical ramus osteotomy. Fear of surgery or general anesthesia may lead a significant proportion of patients to refuse surgery. Patients may prefer a less invasive surgical procedure with little risk and morbidity. A gradual change in the facial appearance may be more acceptable for some patients than an immediate change.

Titanium miniplates implanted in the zygomatic buttress area were recently introduced as absolute anchorage for maxillary molar intrusion. Predictable intrusion of the molars can be achieved with this method that results in open-bite closure. Complications with plate placement or removal are extremely rare.

Post-treatment stability is one of the most important issues after a dentofacial deformity correction. As maxillary molar intrusion for an open-bite closure with a skeletal anchorage is a new treatment approach, long-term results have yet to be published. If, according to the equilibrium theory, the forces of occlusion prevent the reeruption of molars and thus the relapse of an open bite, no special retaining methods may be necessary.

Ambulatory surgery done with local anaesthesia or day case surgery with general anaesthesia reduces the cost and the time of the treatment.

1.1.5 Conclusions

a. Skeletal anterior open bites due to posterior maxillary dentoalveolar hyperplasia can be closed without orthognathic surgery.

b. Titanium miniplates are recommended for temporary skeletal anchorage.

c. Both the placement and the removal of the plates are minimally invasive procedures with only slight discomfort to the patient and with no serious side-effects.

d. The dense cortical bone of the zygomatic buttress area is an ideal miniplate anchorage site for maxillary molar intrusion.

e. This method is a safe, quick and less expensive alternative to orthognathic surgery.

f. Well-planned studies with greater numbers of patients and long-term follow-ups are demanded to establish the precise indications, and the desirable surgical and orthodontic techniques and procedures.

1.2 Orthodontic screws to improve the initial angulation of impacted maxillary canines

1.2.1 Introduction

The impaction of maxillary canines remains one of the most frequently encountered surgical-orthodontic problems. The standard procedure is surgical exposure and forced orthodontic eruption, the duration of this orthodontic treatment varying from 12 to 36 months. Amongst the most significant factors associated with the prognosis and the duration of the forced eruption are the patient's age and extent of cooperation, crowding, the angulation and bucco-palatal position of the tooth and its distance from the occlusal plane. The prognosis is worse in older patients than in young ones. The upper limits suggested for successful alignment of an unerupted canine include 16 and 20 years of age.

The aim of this study was to establish the absence of ankylosis and to improve the initial angulation of impacted canine teeth.

1.2.2 Patients and methods

The present series comprises 63 consecutive patients with a total of 69 impacted maxillary canines, treated between 2004 and 2009. Fifty-seven cases were impacted unilaterally, and bilateral impactions were present in 6 cases. The 27 males and 36 females ranged in age from 14 to 49 years, with a mean of 22.7 years. Twenty-one of the 69 maxillary canines were situated buccally, while 48 were impacted palatally.

The canine was surgically exposed and an attachment was bonded. In all patients mini-screws were inserted into the alveolar bone and were used as anchorage for the initial traction of the embedded tooth.

For the buccally impacted canines the mini-screw was inserted on the buccal side, between the second premolar and the first molar. When the canine was impacted palatally, the screw was placed either between the second premolar and first molar or between the two molars. Stainless steel, 1.5 mm in diameter and 8-10 mm long mini-screws were inserted. Following soft tissue healing around the explored tooth, mechanical traction was activated with a nickel-titanium closed-coil spring. When the canine had reached its normal eruption pathway, the mini-screw was removed, and conventional fixed bracket therapy was completed.

1.2.3 Results

Sixty-one of the 69 canines (88.41 %) were successfully guided into occlusion. The active traction with mini-screw anchorage lasted 4-10 (average 6.8) months. Seven cases failed due to ankylosis. In one patient, the mini-screw was removed due to inflammation and severe pain before the beginning of the orthodontic traction. Six implants worked loose and had to be removed before the end of the treatment. In 4 cases, impingement of the screw head led to inflammatory reactions of the mucosa, which necessitated premature removal of the screws. In the latter 10 cases, radiological examinations had already proved the initial movement of the teeth, and the treatments were therefore finished by fixed bracket therapy. One screw broke during insertion. No root resorption or devitalization of the neighboring teeth was noted.

1.2.4 Discussion

Although guiding an impacted canine into occlusion is considered a routine orthodontic task, various complications and problems may arise during assessment and treatment. These teeth are frequently discovered at a later age, when the treatment duration is longer and the prognosis is worse. With the increased demand for orthodontic treatment, some individuals who oppose the extrusion of an impacted tooth in adolescence reconsider it later as adults. Both patients and clinicians need to know the expected duration of treatment and the predictable level of success. As these cases are relatively rare in adulthood, the limited experience of most orthodontists in this field means that these questions are difficult to answer.

Ankylosis, one of the major complications associated with impacted canines, may result in years of frustration for both patient and orthodontist. Patients over 40 years of age are particularly susceptible to this condition, but younger patients too can be affected. Orthodontically-assisted eruption of these teeth may cause intrusion or displacement of the adjacent anchoring teeth. The diagnosis of ankylosis can rarely be established on the basis of clinical and conventional radiographic examinations.

If the patient refuses orthodontic treatment or the extrusion fails, prosthetic replacement of a missing canine raises further questions. From a physiological point of view, orthodontically-assisted forced eruption of an impacted tooth would be the best option if the outcome were predictable.

If a mini-screw is placed in the alveolar process and used as an anchorage for orthodontic traction, the angulation of the impacted tooth can be corrected. Once the initial movement has occurred, the diagnosis of ankylosis can be excluded. Although the clinical benefits of orthodontic mini-implants are increasingly recognized, their safe surgical placement is still a matter of concern. Insertion is a relatively minor procedure that is atraumatic and painless and requires minimal anesthesia. As we use flapless surgery, postoperative swelling, bleeding and pain are minimal. Potential complications include root injury and sinus injury therefore all precautions should be taken to avoid hitting roots during drilling or screw insertion. In a tooth-bearing area, mini-screws with a smaller diameter are used to prevent damage to the dental roots.

1.2.5 Conclusions

a. Adults with an impacted canine are highly susceptible to ankylosis.
b. Mini-screws implanted in the alveolar bone proved to be reliable and convenient skeletal anchorage devices in the management of unerupted canines.
c. Because of the high incidence of ankylosis this method is strongly recommended for the treatment of adults.
d. This method may decrease the degree of disappointment and frustration when an ankylosed tooth is treated.
e. Although complications may occur, they are rare and usually not severe.
f. As the miniscrew is not osseointegrated, removal is easy and can be performed without anesthesia.
g. Additional research is necessary to establish clear indications and contraindications, and also precise treatment protocols.

2. PRE- AND POSTOPERATIVE MONITORING OF FIBULA FREE FLAP CIRCULATION IN OROFACIAL RECONSTRUCTION

2.1 Introduction

Although the use of vascularized fibular grafts has been established as a reliable method for oromandibular reconstruction, the debate over preoperative vascular imaging is ongoing. Vascular disease or variation in the blood supply of the leg and the foot may prevent the harvest of the fibula. Numerous previous investigators have advocated the routine use of donor site angiography. Some authors have recommended the selective use of preoperative imaging. The first aim of this study was to investigate whether the routine use of preoperative donor site imaging is necessary. Once the transplantation of the fibula occurred, monitoring of the flap viability is essential. Vascular insufficiency is a serious complication as this may cause necrosis of the flap. The second aim of this study was to evaluate color Doppler ultrasound for postoperative monitoring of fibula flaps.

2.2 Patients and methods

This series comprises of 45 consecutive patients between 1993 and 2010 who underwent angiography before planned fibula transfer for mandibular or maxillary reconstruction. There were 37 men and 8 women whose ages ranged from 16 to 68 years, with a mean of 45 years. Thirty six patients were to have primary or secondary reconstruction after tumor resection. Six patients were to undergo reconstruction of posttraumatic mandibular or maxillary defects (shotgun injury or explosion). Three patients required reconstruction of mandibular osteoradionecrosis.

Only the right leg was examined in the first three patients with digital subtraction angiography (DSA), but subsequently DSA was also performed on the left side when vascular anomaly contraindicated the harvest of the right-sided fibula or could cause technical difficulties during the procedure. Later in the series both legs were routinely examined. One patient underwent computed tomographic angiography and 2 other had magnetic resonance angiography when these modalities became available. A total of 78 lower extremities were imaged in the 45 patients.

In the second part of the study 9 patients following fibula free flap transplantation were examined by color Doppler ultrasonography during the early postoperative period. The facial or superior thyroid artery and the external jugular or facial veins were the recipient vessels. The anastomoses were positioned superficially under the platysma. The exact

situation of the vessels was indicated by marker pen. During the examination the patient was placed in a recumbent position. The head was rotated laterally so that the skin in the upper third of the neck was smoothed and tensed. The transducer was placed on the skin and the vessels of the transplant were identified and followed through the flap until they reached the angle of the mandible or divided into small branches.

In 8 cases our aim was to control the blood circulation of the transplant on the 2nd-4th postoperative day. In one case unexpected acute incident required urgent examination. In this case occlusion of the supplying vessels was suspected that would have required urgent surgical exploration.

2.3 Results

The incidence of anomalous blood supply to the foot was 14.1% (11 of 78 extremities). One patient was found to have a unilateral hypoplastic peroneal artery. The absence of either the anterior tibial or the posterior tibial artery occurred in one and two extremities, respectively. In one case both the anterior and posterior tibial arteries were missing and the peroneal arteria magna supplied the entire pedal circulation. In one extremity arteriovenous shunting was detected between the posterior tibial artery and its concomitant vein. Angiography revealed arterial fibromuscular dysplasia in one case. In one case significant dilatation of the concomitant veins of the peroneal artery prevented the harvest of the fibula. The fibula transfer was not performed in three cases due to the presence of significant atherosclerotic stenosis or the occlusion of the anterior tibial artery.

All postoperative color Doppler ultrasound examinations revealed patent arterial and venous anastomoses and vessels of wide caliber with good flow were evident. In the case when occlusion of the supplying vessels was suspected a hematoma was identified and satisfactory flap circulation was detected.

2.4 Discussion

Knowledge of normal vascular anatomy and variations is essential when planning fibula flap transfer. The arterial blood supply of the lower extremity below the knee joint originates from the anterior tibial, the posterior tibial and the peroneal arteries. The fibula is vascularized from the peroneal artery via periosteal and nutrient vessels. The peroneal artery provides the entire periosteal blood circulation and it is harvested with the graft. In 5 to 8% of the population the peroneal artery plays dominant role in the blood supply to the foot and harvesting the artery with the flap would endanger the pedal circulation.

There are four important variants of the three major vessels that prevent the harvest of the fibula:

1. Absence or hypoplasia of the anterior tibial artery occurs in 1.6–6%.
2. The incidence of aplastic-hypoplastic posterior tibial artery is 0.9–5%. In these situations harvesting the peroneal artery with the fibula would put the foot at the risk of ischemia.
3. Both the anterior and posterior tibial arteries are aplastic-hypoplastic. The peroneal artery (peroneal arteria magna) supplies the entire circulation of the foot (0,2–2%). Harvesting the artery with the flap would cause catastrophic complications.
4. Congenital absence of the peroneal artery is rare (less than 0.1%). In this situation vascular flap can not be harvested.

Most of the congenital and some of the acquired vascular diseases are undetectable by physical examination. Palpation of the pulses may be unreliable even by experienced surgeons, especially in case of the posterior tibial pulse. The peroneal artery normally communicates with the posterior tibial artery and gives off a perforating branch to the dorsalis pedis artery above the ankle joint. Due to these anastomoses the posterior tibial and dorsalis pedis pulses can be palpable even if the tibial arteries are absent or hypoplastic. The absence of the peroneal artery cannot be detected by clinical examination. Orofacial reconstruction is mainly performed for oncologic defects. More than 50% of our patients with oral malignancy were heavy smokers and over 50 years old. This group of patients is at increased risk of vascular diseases. Clinically undetectable but already significant atherosclerotic disease constitutes a contraindication to the use of the fibula as a free flap. An arterio-venous fistula can be acquired or congenital. Due to the shortcut in the circulation the blood supply of the distal areas is compromised. If the shunt were to be part of the flap it would have to be identified and ligated. Harvest of the contralateral fibula is recommended if that is anatomically more favorable. Fibromuscular dysplasia or dilatation of the concomitant veins may cause technical difficulties during the procedure. Preoperative vascular mapping identifies those vascular anomalies and peripheral vascular diseases that would compromise the flap or the limb circulation or may result in unexpected intraoperative difficulties. Knowledge of the vascular anatomy helps the surgeon to decrease the dissection time.

Following the transplantation, inadequate blood circulation is likely to compromise the vitality of surgical flaps. Vascular insufficiency results from arterial or venous obstruction. The most frequent reasons for obstruction are thrombosis and compression (e.g. hematoma).

Flap compromise requires urgent surgical intervention to carry out decompression or thrombectomy and reanastomosis. Early diagnosis of vascular insufficiency is essential.

If the ischemia time is no longer than six hours, the flap may remain vital. If longer, the flap survival rate decreases significantly. The clinical signs of the compromised flap are usually evident when the flap is positioned at an exposed site for example the face, neck or oral cavity. In cases where there is arterial occlusion, the flap is pale, cool, and without capillary refill. In contrast venous occlusion is characterized by a cyanotic, swollen flap. Clinical signs are not always reliable and therefore monitoring of the flap circulation by technical instrumentation may be valuable. When the flap is covered by other soft tissues (e.g. osseous free flap for mandible reconstruction), direct clinical monitoring is not possible; therefore one needs to rely on the use of instruments.

Color Doppler is one of the many tools that can assess tissue perforation. Its strength is a precise and quantitative characterization of inflow and outflow. Although it is not designed to provide continuous monitoring, it is an excellent method for examining free-tissue transfers for possible postoperative complications.

2.5 Conclusions

a. The results of this study demonstrate the need for preoperative donor site vascular imaging studies in patients undergoing fibula free flap transfer to evaluate the role of the three major vessels in the blood supply of the leg.

b. Angiography has been found to provide information about the continuity of the three lower leg vessels, the level of the bifurcation of the tibiofibular trunk and about arteriosclerotic plaques.

c. Performing angiography on both lower extremities offers the possibility of choosing the anatomically more favorable donor site.

d. Digital subtraction angiography is accurate, reliable, safe techniques for preoperative donor site vascular imaging.

e. Color Doppler ultrasound is an excellent diagnostic tool for controlling the flap circulation following transplantation.

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