PH.D. THESIS

MODERN THERAPEUTIC APPROACHES IN THE CORRECTION OF DENTOFACIAL AND MAXILLOFACIAL DEFORMITIES

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CONTENTS

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 fibular flap transfer is widely recognized as an effective technique for mandibular and maxillary reconstruction, the debate over the necessity of preoperative angiography is still ongoing. The results of this study demonstrate the need for preoperative donor site vascular imaging studies.

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. Anchorage, defined as a resistance to unwanted tooth movement, is a fundamental part of orthodontics. Orthodontists have long searched for the perfect anchorage to minimize undesired tooth movements *[Wahl 2008]*. Absolute or infinite anchorage means that there is no movement of the anchorage unit as a consequence to the reaction forces applied to move teeth *[Daskalogiannakis 2001]*. Such an anchorage can only be obtained by using ankylosed teeth or devices fixed to bone.

Skeletal anchorage, as this concept is called, evolved from two lines. One category originated as osseointegrated dental implants *[Kokich 2000]*, which have a solid scientific base of clinical, biomechanical, and histologic studies *[Matthews 1993]*. Rigid osseous fixation (osseointegration) is a relative term, because even well-integrated endosseus implants demonstrate some flexure relative to supporting bone. In effect, osseointegration is physiologically similar to severe ankylosis *[Roberts et al. 2006]*.

Osseointegrated implants can be used as restorative abutments following orthodontics. Patients, who do not need prosthetic rehabilitation, would benefit from a removable skeletal anchoring device that can be placed outside the dentition. To achieve optimal treatment goals this device should:

-be biocompatible

-be easy to adjust and to place

-not interfere with tooth movement

-not cause the patient much discomfort

-remain stable in long term after orthodontic force application

-be easy to remove

-be cost effective.

This second category of skeletal anchorage devices developed from surgical miniimplants, which have been used by oral surgeons for decades and are highly predictable. This group can be subdivided according to whether the screw or plate components are the principal design elements. These all use osseous physical engagement for stability and are effective anchorages that offer a wide range of orthodontic applications.

Screws are classified as pretapped screws, self-tapping screws, or self-drilling screws, according to the method of insertion. Pretapped screws are used in harder, less compressible materials, such as cortical bone. These devices require the use of a tap to precut the thread. Pretapped screws are not suitable for low-density bone, such as the maxilla. Self-tapping screws are used in softer, less compressible materials and form threads by compressing and cutting the surrounding tissues. They have a fluted leading edge and require only a predrilling procedure. Self-drilling screws have a corkscrew-like tip, therefore, neither predrilling nor tapping are needed *[Lee et al. 2007]*.

Manufacturers have produced several anchorage systems with a confusing array of names including mini-implants, micro-implants, mini-screws, orthodontic screws or pins, temporary or bone anchorage devices *[Prabhu et al. 2006]*.

Historical background

The concept of skeletal anchorage has a history of more than 60 years. In 1945, research into the concept of using a pin or a screw attachment to the ramus was initiated not only for moving teeth, but also for "exerting a pull on the mandible" *[Gainsforth et al. 1945]*. Their attempt failed, as did most of the implants of that era, because the vitallium screw used was not conducive to osseointegration. Although Branemark introduced the concept of osseointegration using pure titanium implants in 1969, only a few clinicians envisaged the use of these in orthodontics at that time *[Branemark et al. 1969]*.

Linkow was among the first to propose use of the blade implant as anchorage for class II elastics *[Linkow 1970]*. In 1983, Creekmore and Eklund reported the placement of a screw, resembling a bone-plating screw, in the anterior nasal spine region. This was loaded after 10 days for successful intrusion of the upper incisors *[Creekmore et al. 1983]*. This early loading of an implant, without the usual wait for osseointegration, was to become a major feature of the later use of mini-screws.

In 1984, Roberts investigated the tissue response to orthodontic forces applied to restorative implants and concluded that continuously loaded implants remained stable with 100 g force after a 6-week healing period *[Roberts et al. 1984]*. Further research by Turley et al. also recommended endosseous implants for anchorage *[Turley et al. 1988]*. Ödman used osseointegrated titanium implants in several orthodontic patients *[Ödman et al. 1988]*. Conventional osseointegrated implants have since become a standard part of multidisciplinary care involving orthodontics, but their use is limited to a minority of cases. The reason for this is that they can only be placed in those positions in a dental arch where adequate bone is available, where orthodontic anchorage is necessary, and where a subsequent implant-supported restoration is required *[Paik et al. 2009]*.

In 1985, Jenner reported a clinical case where maxillofacial bone plates were used for orthodontic anchorage *[Jenner et al. 1985]*. Kanomi designed a two-stage miniature intraalveolar implant that achieves osseointegration *[Kanomi 1997]*.

Costa described a mini-implant with a bracket-like head specifically designed for orthodontic use *[Costa 1998]*. In 1999, Umemori et al. demonstrated effective intrusion of mandibular molars when L-shaped Leibinger mini-plates and screws were used as anchorage and coined the term "skeletal anchorage system" for titanium plates and screws *[Umemori et al. 1999]*. They suggested that, when compared with osseointegrated implants, these mini-plates provide stable anchorage with immediate loading.

The studies by Ohmae and Deguchi demonstrated with animal models that mini-screws can be loaded immediately or shortly after placement *[Ohmae et al. 2001; Deguchi et al. 2003]*.

Erverdi suggested the zygomatic buttress area as an anchorage site for maxillary molar intrusion *[Erverdi et al. 2002]* and reported closure of anterior open bites *[Erverdi et al. 2004]*. Sherwood intruded maxillary molars with miniplate anchorage *[Sherwood et al. 2002; 2003]*. Yao used a mini-implant system for the intrusion of overerupted maxillary molar teeth *[Yao et al. 2005]*.

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 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 *[Papadopoulos et al. 2007]*. 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 (Figure 1) *[Schudy 1965]*. In young patients, the vertical maxillary growth can be controlled with high-pull headgear or a functional appliance with bite blocks.

Figure 1.

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 *[Bell et al. 1980]*. 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 *[Kim 1987; Kim et al. 2000]*.

Carano recently reported rapid molar intrusion with an appliance consisting of two elastic modules *[Carano et al. 2005]*. Their initial clinical experience was promising but the number of treated non-growing patients was not reported. Further, the rapid molar intrusion device reportedly tended to undergo permanent deformation, and the replacement of these modules complicates the treatment procedure.

Until recently there was no orthodontic approach that would predictably intrude molar teeth in non-growing patients. The aim of the present 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, 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 and ranged from 15 to 29 years. In all cases the deformity was due to the overeruption of the maxillary molars. The mean anterior open bite measured between the edges of the incisors in the vertical plane was 6 mms, and the range varied from 4 to 11 mms. Four patients had Class I occlusion, 2 individuals presented with Class II and one with Class III malocclusion.

Sequence of treatment planning

1. Dental and periodontal treatment
2. Banding of the molars and adaptation of the transpalatal arch (TPA)
3. Placement of skeletal anchorage, removal of wisdom teeeth - if necessary
4. Application of intrusive force
5. Extraction of premolars - if necessary
6. Fixed appliance therapy
7. Termination of intrusion, retention of intrusion
8. Removal of miniplates
9. Removal of fixed appliance - retention

Transpalatal arch

Before the implantation of the skeletal anchors, the molars were separated, and the molar bands were adapted. The intrusion of the molars by a force directed only apically to the buccal tooth attachment would result in adverse buccal tipping. To avoid this, the molars were connected with two TPAs. A Goshgarian-type transpalatal bar was bent from a 0.036-inch (0.9 mm) stainless steel wire so as to extend from the maxillary first molar, along the contour of the palate, to the maxillary first molar on the opposite side.

Another 5mm x 1 mm prefabricated cobalt-chrome-alloy TPA was soldered to the palatal aspects of the second molar bands (Figure 2). The soldered TPA prevented torque and tipping of the molars until the mesiodistal and orovestibular angulation could be corrected with the Goshgarian-type TPA during treatment. When only either the first or the second molars were intruded, the soldered TPA was used (Figure 3).

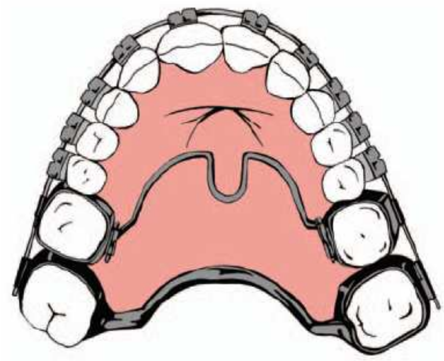


Figure 2.

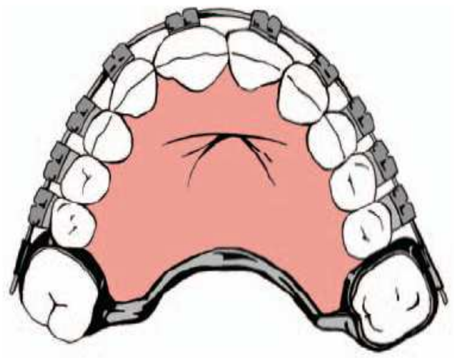


Figure 3.

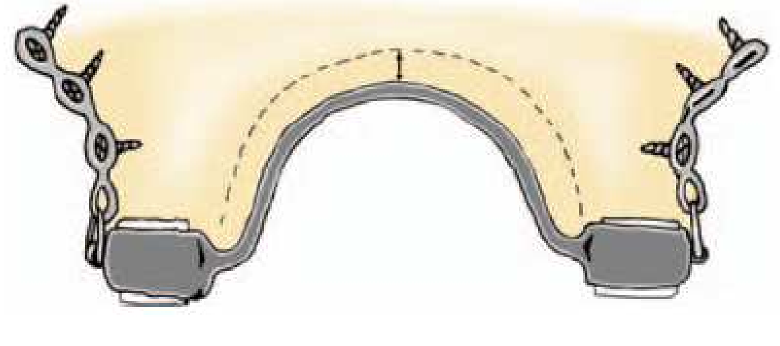


Figure 4.

During the intrusion, the TPAs move upward. Normally, the TPA lies 2 to 3 mm away from the palatal mucosa (Figure 4).

Figure 5.

In the event of intrusion this would result in impingement of the soft tissues (Figure 5). To avoid this, the distance of the planned intrusion was added to the normal TPA to palate distance. If a 3 mm intrusion of the molars was planned, the TPA to palate distance was at least 5-6 mm. TPAs have the extra advantage of adding the intermittent intrusive force of the tongue onto the molars. TPA adaptation could be performed following surgery, but the manipulation of orthodontic devices around an operation site would cause the patient more discomfort.

Surgical procedure

Both the placement and the removal of the plates were performed under standard operating room conditions on a day-case basis. Following infiltration of a local anesthetic with a vasoconstrictor at the height of the maxillary vestibule, 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. The mucoperiosteum inferior to the incision was left attached to the bone (Figures 6-7).

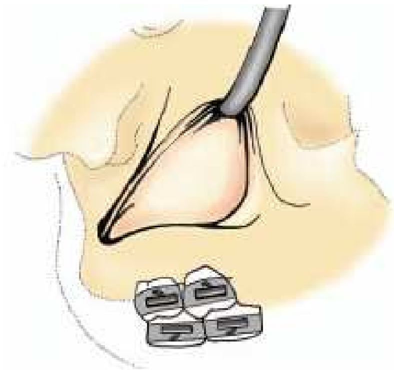


Figure 6.

Figure 7.

A 4-hole I-shaped miniplate (Synthes, Oberdorf, Switzerland) was adjusted to fit the contour of the zygomatic process. L, T, Y-shaped plates could also be used. The course of the zygomaticoalveolar crest and the position of the molar teeth in the arch are variable, but the dense cortical bone of the zygomatic buttress area gives flexibility in plate positioning (Figures 8-11).

Figure 8.

Figure 9.

Figure 10.

Figure 11.

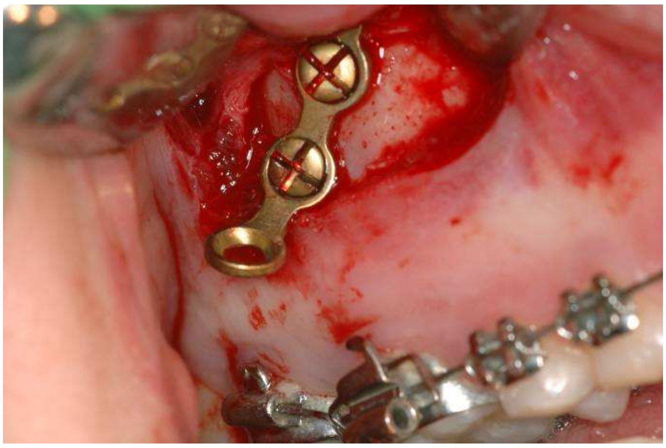


Figure 12.

The plates were fixed by three 4-mm monocortical screws (Figure 12). The proximal loop of the plate serves to attach a coil spring or an elastic band for intrusion. When the intrusion of both the first and the second molars is planned, the ideal position of the most proximal loop of the plate is between the roots of the teeth in order to prevent unfavorable mesiodistal angulation during the intrusion (Figures 13-14).

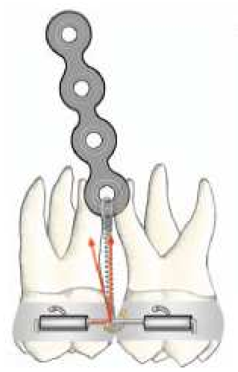


Figure 13.

Figure 14.

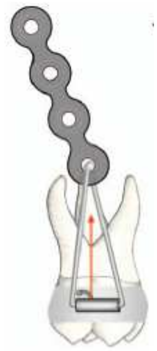


Figure 15.

Figure 16.

When only one molar is to be intruded, the last loop should be placed over the vertical axis of the tooth (Figures 15-16).

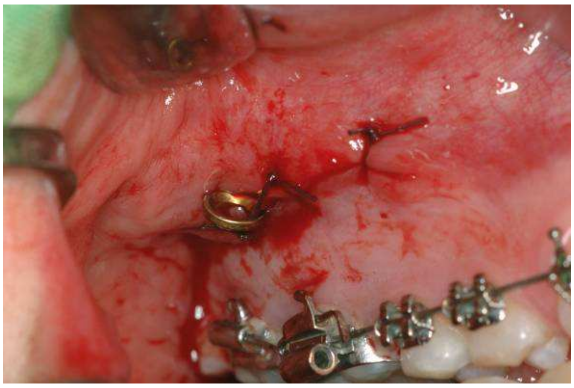


Figure 17.

The mucoperiosteal flap was repositioned and the surgical wound was sutured, with the last hole of the anchor plate exposed intraorally (Figure 17). Impacted wisdom teeth that could have interfered with the intrusion of the second molars were removed at the same time.

Figure 18.

Orthodontics

Orthodontic force could be applied immediately following the implantation, but we allowed 1-2 weeks for soft tissue healing with a view to minimizing patient discomfort. To provide continuous light forces of 100-120 g, 9 mm nickel-titanium closed coil springs (0.010 inch) were placed bilaterally between the exposed hole of the miniplate and a hook on the segmental wire between the molar buccal tubes (Figure 18). When only one molar tooth was intruded, the spring was attached to the molar tube.

After the intrusion force was delivered, the patient was seen at 3-week intervals. The following examinations and measurements were made:

1. The mobility of the molars.
2. The distance of the TPAs from the palatal soft tissues.
3. Unfavorable mesiodistal or orovestibular angulation.
4. Intrusion: the distance between the edge of the miniplate and the molar tubes.
5. Open bite closure: the vertical distance between the edges of the central incisors.

Three months after the application of the intrusive force, standardized periapical X-rays were taken to evaluate the change in the marginal bone level and the amount of root resorption. The intrusion was terminated when the open bite has been visually corrected.

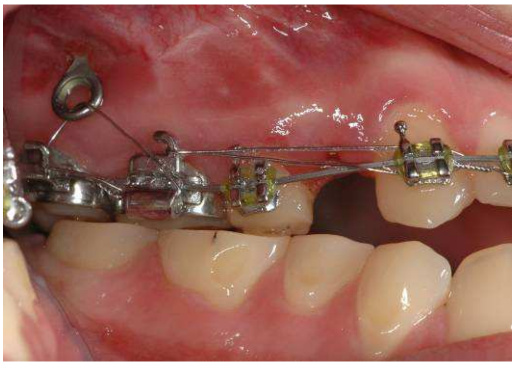


Figure 19.

The molars were stabilized with vertical wire ligation between the molar tubes and the miniplates (Figure 19). Lateral and anteroposterior cephalometric radiographs, orthopantomogram, and periapical x-rays were taken to assess the postintrusion status. Following this, traditional fixed bracket therapy was completed.

1.1.3 Results

All patients exhibited true intrusion of the maxillary molars. Open-bite closure was achieved for all patients. Due to the autorotation of the mandible, the mandibular plane closed by an average of 3.1 degrees, B point rotated anteriorly and upward. In all cases anterior facial heights decreased and the facial profile significantly improved. No signs or symptoms of a temporomandibular dysfunction were reported. No miniplate movement was detected during the treatment. There was no significant root resorption and although some periapical changes were observed, 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 on oral hygiene. None of the patients reported more than mild discomfort after surgery or during the orthodontic treatment period.

1.1.4 Case studies

Case 1

An 18-year-old man sought treatment to correct his open bite. He reported that the open bite seemed to have started to develop in late adolescence. Facial examination indicated symmetric facial features. The lower third of the face was excessively long. Lip closure was competent. On intraoral examination, a 7-mm anterior open bite was present. The front and the premolar teeth were not in contact. Only the distal occlusal surface of the first molars and the second molars occluded. Significant abrasion of the upper and lower molars and premolars was noted. Abrasion on the occlusal surface of the premolars revealed the previous contact between these teeth before the development of the open bite.

There was a Class III molar relationship, with mild crowding in both the upper and lower anterior regions. The lower incisors were lingually inclined. The oral health and jaw function were normal (Figures 20-23)

Figure 20.

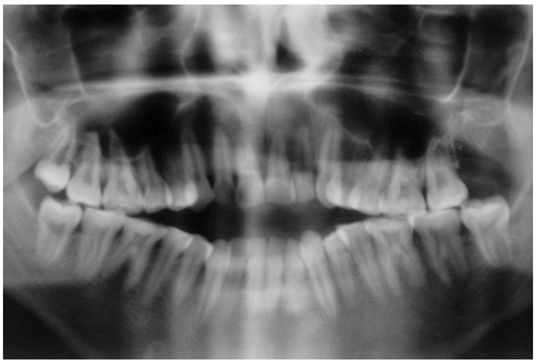


Figure 21.

Figure 22.

Figure 23.

Cephalometric evaluation indicated a skeletal Class III pattern with a steep mandibular plane and excessive vertical development of the maxillary alveolar process. The gonion angle was large. A high interincisor angle showed a dentoalveolar compensation for the skeletal form (Table 1). The diagnosis was an anterior open bite with a skeletal Class III jaw base relationship and lingual inclination of the mandibular incisors.

Treatment objectives:

1. Shortening of the lower anterior face height.
2. Closure of the anterior open bite.
3. A Class I canine and molar relationship.
4. Correction of the maxillary crowding.
5. Alignment of the lingually inclined lower incisors.

Treatment plan:

1. Intrusion of maxillary first and second molars with skeletal anchorage to allow autorotation of the mandible and closure of the open bite.
2. Extraction of the first maxillary premolars.

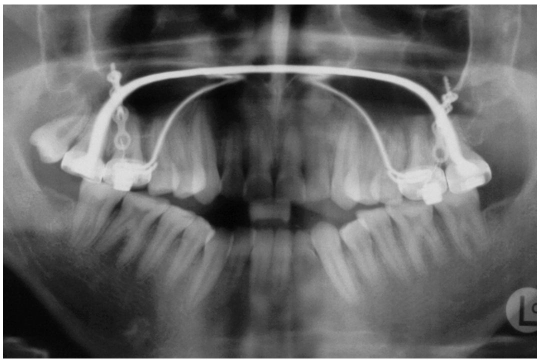
Table 1.

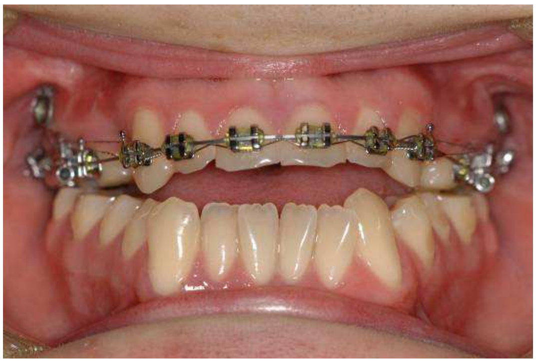
	Norm	Pre	Post
SNA	82	78	78
SNB	80	78	81
ANB	2	0	-3
SNPg	81	80	83
NSBa	130	130	130
Go angle	126	140	140
Mand.-NS plane	32	51	44
Pal-NS plane	8,5	9	9
Pal-Mand plane	23,5	42	35
N-Sp’ (mm)		57	57
Sp’-Gn (mm)		85	81
N-Sp’/ Sp’-Gn	79	67	70
Interincisal angle	131	121	118
l-NA (angle)	22	36	37
l-NB (angle)	25	22	21
l-NA (mm)	4	10	9
l-NB (mm)	4	6	5
Nasolabial angle	110	122	116

3. Orthodontic leveling and alignment of the arches; correction of the inclined mandibular incisors.
4. Posterior repositioning of the mandible and vertical reduction genioplasty.
5. A complete detailed alignment.

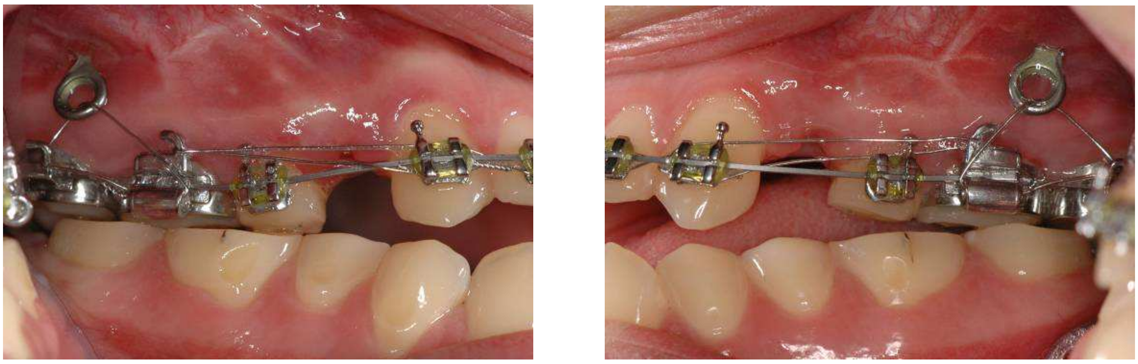
Treatment progress:

The patient exhibited true intrusion of the maxillary molars. The 7-mm open bite was corrected in 7 months (Figures 24-27). Due to the autorotation of the mandible, the mandibular plane closed by 7 degrees, while the B point rotated anteriorly and upwards (Table 1) (Figures 28-31). The facial profile improved significantly. No miniplate movement was observed during the treatment. There was no significant root resorption. All the intruded teeth remained vital. The patients did not report more than mild discomfort after surgery or during the orthodontic treatment period.

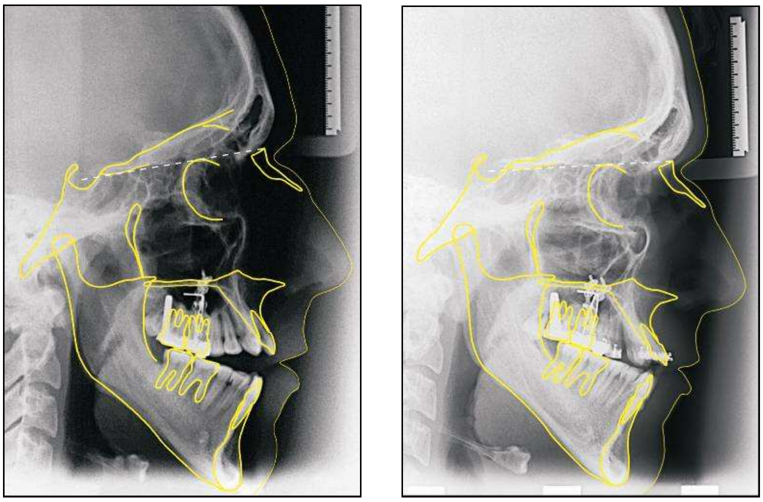




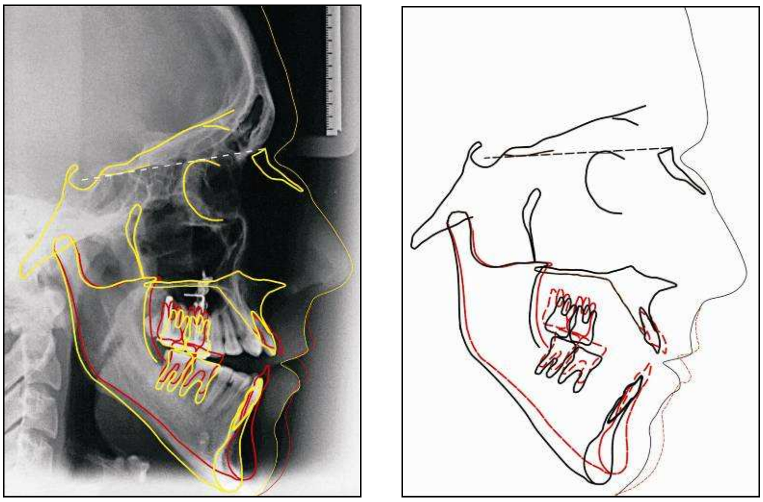
Figures 24-25. Postintrusion orthopantomograph and intraoral photograph. The space between the upper and lower second premolars disappeared.



Figures 26-27. Lateral intraoral views following intrusion.



Figures 28-29. Initial and final cephalometric radiograph of the patient.



Figures 30-31. Superimposition of initial and final cephalometric radiograph. Cephalometric superimposition from preintrusion (black) to postintrusion (red).

Case 2

A 16-year-old female patient presented with a symmetrical long-face appearance and lip incompetency. She sought treatment for her open bite and facial appearance. Her anamnesis was not significant. Intraoral examination revealed a Class I malocclusion with a 4.4 mm open bite. There was a “gummy” smile in the posterior region. The upper arch had moderate crowding with a palatally displaced right-sided second premolar and ectopic canines. Due to the hypertrophy of the lower lip, the upper incisors were labially inclined. The lower incisors were slightly intruded and lingually inclined (Figure 32).

Table 2.

	Norm	Pre	Post
SNA	82	83	82
SNB	80	77	79
ANB	2	5	3
SNPg	81	78	79
NSBa	130	124	124
Go angle	126	129	129
Mand.-NS.plane	32	42	38
Pal.-NS plane	8,5	3	4
Pal.-Mand. plane	23,5	39	34
N-Sp’ (mm)		52	52
Sp’-Gn (mm)		81	78
N-Sp’/ Sp’-Gn	79%	64	67
Interincisal angle	131	110	125
l-NA (angle)	22	34	24
l-NB (angle)	25	30	29
l-NA (mm)	4	6	5
l-NB (mm)	4	6	6
Nasolabial angle	110	122	119

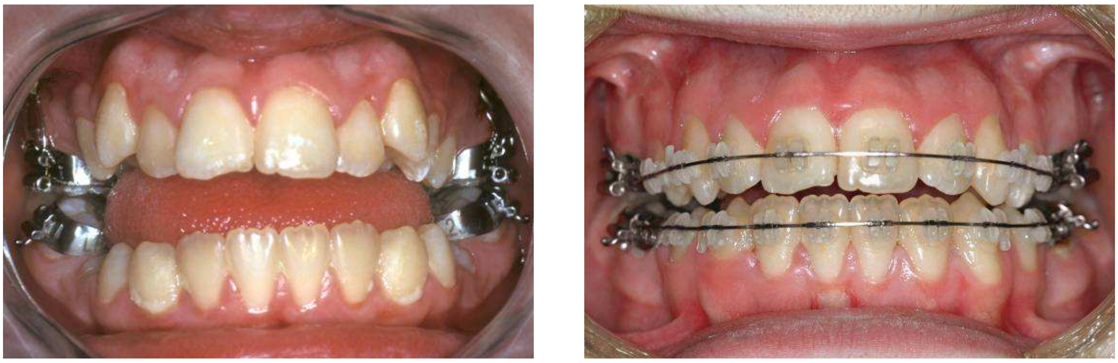
Cephalometric analysis revealed an obtuse mandibular plane angle, excessive vertical development of the posterior maxilla and a large lower third of the face (Table 2).

Treatment plan

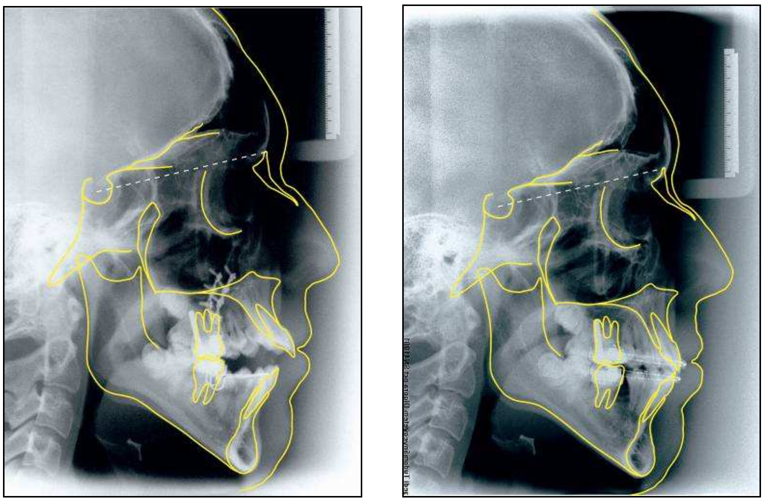
1. Skeletal anchorage in the zygomatic buttress area for intrusion of the first maxillary molars
2. Removal of all four second bicuspids to eliminate crowding
3. Minimal extrusion of the lower incisors
4. Palatal crown torque of the upper incisors
5. Alignment and leveling of the arches with fixed edgewise appliances

Treatment progress

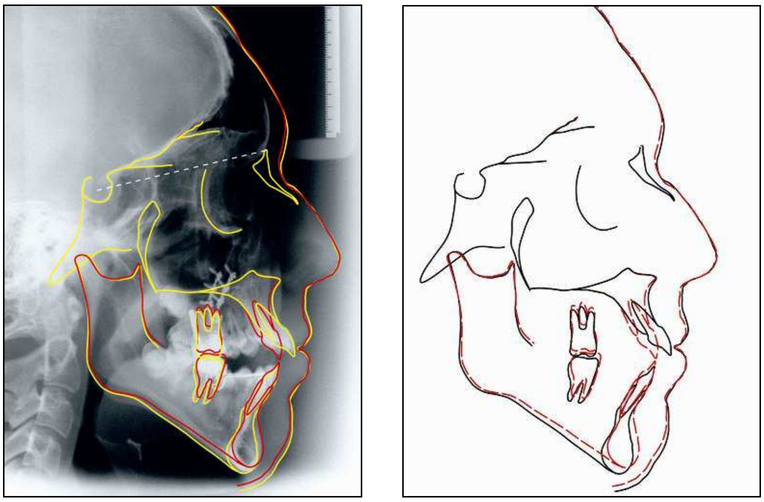
Six months following the application of the intrusive forces, the anterior open bite was reduced to 1 mm (Figure 33). The changes in the cephalometric measurements revealed a moderate intrusion of the first molars and anterior rotation of the mandible (Figures 34-37). The anterior facial height was reduced, and this was followed by counterclockwise rotation of the mandibular plane. This patient still exhibits some lip incompetence despite the closure of the anterior open bite.



Figures 32-33. Initial and postintrusion intraoral views.



Figures 34-35. Initial and final cephalometric radiograph of the patient.



Figures 36-37. Superimposition of initial and final cephalometric radiograph. Cephalometric superimposition from preintrusion (black) to postintrusion (red).

1.1.5 Discussion

Skeletal anterior open-bite is one of the most difficult malocclusions to treat. Due to the lack of a reliable orthodontic method for molar intrusion until recently there was no real alternative to a combined orthodontic and surgical approach. The most frequently performed surgical procedures for anterior open-bite correction are superior repositioning of the maxilla via Le Fort I osteotomy, posterior segmental maxillary osteotomy, and vertical ramus osteotomy. If the mandible does not rotate into the correct position after the maxilla is impacted, two-jaw surgery is required.

Fear of surgery or general anesthesia and other factors may lead a significant proportion of patients to refuse surgery. Bailey reported that fewer than half of the patients who seek orthodontic treatment for long-face problems accepted the recommended orthognathic surgery *[Bailey et al. 2001]*. Proffit suggested that a patient with a skeletal long-face problem who refuses surgical correction is better left untreated *[Proffit et al. 2003]*.

Patients would probably prefer a less invasive surgical procedure with little or no risk and less discomfort. A slow change in the facial appearance may be more acceptable for some patients than a sudden one. Local rather than general anesthesia, a decreased operation time and shorter hospitalization would reduce costs.

Skeletal anchorage has opened a new chapter in the management of some dentofacial deformities. In this study, pure titanium miniplates well known from maxillofacial trauma were used for temporary anchorage. These fixation devices are available in every operating room where maxillofacial trauma or orthognathic cases are operated on. Most oral and maxillofacial surgeons are familiar with their placement and removal. No special instrument is needed for the implantation and removal therefore no financial investment is necessary.

Initially, we used five-hole straight miniplates and 6 mm screws, but currently it is our experience, that a shorter plate fixed with fewer and shorter screws has sufficient stability against orthodontic forces. If the proximal edge of the plate is at least 1 cm from the molar tube then the screws are inserted well above the root tips so as to avoid root damage during drilling or interference with the intrusion.

Complications with plate placement or removal are extremely rare. Mild postsurgery pain and facial edema are often present but these usually subside rapidly. Abrasion of the mucosa of the lips from retraction may occur; attention must therefore be paid to soft tissue protection and moistening of the lips with vaseline cream.

When a tooth is intruded, attention has to be paid to apical root resorption, crestal bone height changes, periodontal tissue alterations, compromised blood supply to the pulp. Melsen in an animal model found that not only the bone, but also the soft supporting tissues will move vertically with the teeth during orthodontic intrusion *[Melsen et al. 1986]*.

Figure 38.

Figure 39.

Histologic analysis showed new cementum formation and connective tissue attachment on the intruded teeth, provided a healthy gingival enviroment was maintained through the tooth movement. Moderate apical root resorption following intrusion is common, but in most cases it has no clinical significance (Figures 38-39).

Sugawara found no significant changes in crestal bone heights, clinical crown length or root length following intrusion of mandibular molars *[Sugawara et al. 2002]*.

Daimaruya et al, using an animal model reported alveolar bone remodeling around the intruded molar roots *[Daimaruya et al. 2001]*. Their study also found some moderate root resorption and no remarkable changes of the pulp. Ari-Demirkaya reported minimal apical root resorption with no clinical significance after intrusion of maxillary first molars with zygomatic anchorage *[Ari-Demirkaya et al. 2005]*.

Good oral hygiene is essential. Soft tissue inflammation at the implant site due to plaque accumulation may occur. In our practice the patients are instructed on how to brush around the anchor site and to rinse with 0.2% aqueous chlorhexidine twice a day after surgery and throughout the orthodontic treatment. Every time a patient visits the orthodontic clinic during the intrusion, a periodontology appointment is given for professional cleansing.

Posttreatment stability is one of the most important issues in orthodontics. A minimal to moderate tendency to relapse has been observed in open-bite patients following surgery. Proffit reported that there is approximately a 10% chance of 2 to 4 mm relapse toward anterior open bite in long term following superior repositioning of the maxilla *[Proffit et al. 2000]*. Sugawara et al. reported 27.2% and 30.3% relapse rate at the first and second molars, respectively, after intrusion of mandibular molars but no significant change was observed of the mandibular autorotation or of the anterior facial height *[Sugawara et al. 2002]*. Kuroda et al. reported an open bite case where little relapse was observed after a 1-year retention period, although molars in both jaws had been intruded approximately 3 mm *[Kuroda et al. 2004]*. Greenlee et al. compared the stability of surgical and non-surgical open bite cases in a meta-analysis of 105 abstracts and 21 articles. Pooled results indicated reasonable stability of both the surgical (82%) and non-surgical (75%) treatments at 12 or more months after the treatment interventions *[Greenlee et al. 2011]*. As maxillary molar intrusion for open bite closure with skeletal anchorage is a new treatment approach, long-term results have not been published as yet.

Both long-term follow-ups of ongoing treatments and future studies will furnish more information on relapse rates. If according to the equilibrium theory, the forces of occlusion prevent the re-eruption of molars and thus the relapse of open bite, no special retaining methods may be necessary *[Proffit et al. 1978]*.

1.1.6 Conclusions

1. Skeletal anterior open bites due to posterior maxillary dentoalveolar hyperplasia can be closed without orthognathic surgery (Figure 40).

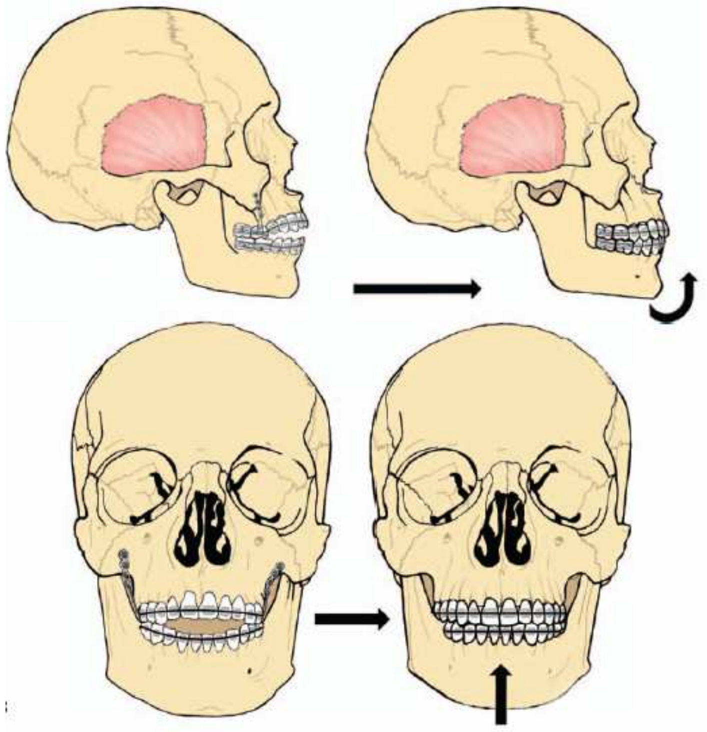


Figure 40.

2. Titanium miniplates are recommended for temporary skeletal anchorage.
3. 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.The dense cortical bone of the zygomatic buttress area is an ideal miniplate anchorage site for maxillary molar intrusion.
4. This method is a safe, quick and less expensive alternative to orthognathic surgery.
5. 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 mini-screws for the management of impacted maxillary canines

1.2.1 Introduction

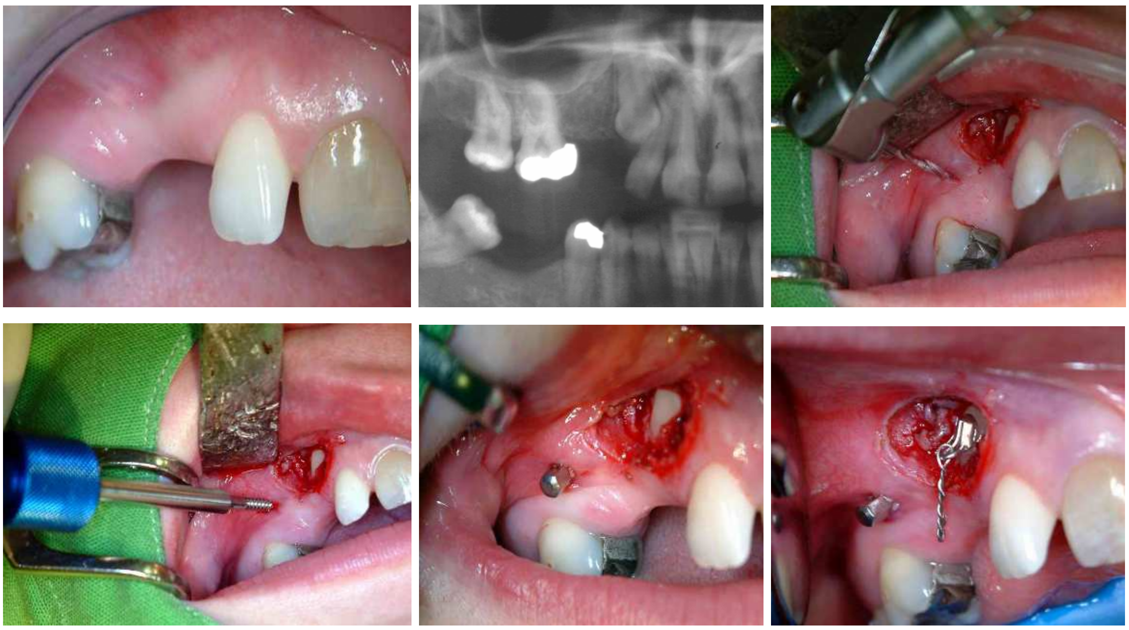
The impaction of maxillary canines remains one of the most frequently encountered surgical-orthodontic problems; with a reported incidence of between 0.9% and 2.2% for the general population *[Dachi et al. 1961, Ericson et al. 1986, Grover et al. 1985, Kramer et al. 1970]*. The alignment of an unerupted maxillary canine may necessitate complicated and prolonged treatment. The standard procedure is surgical exposure and forced orthodontic eruption *[Caminiti et al. 1998]*, the duration of this orthodontic treatment varying from 12 to 36 months. Patients' refusal to participate in long-term treatment or ankylosis of the impacted tooth results in various treatment difficulties. 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 *[Becker et al. 2003, Harzer et al. 1994, Stewart et al. 2001]*. The treatment time for bilateral impactions is longer than for unilateral ones. The prognosis is worse in older patients than in young ones and early diagnosis is therefore important *[Ericson et al. 1986]*. The upper limits suggested for successful alignment of an unerupted canine include 16 and 20 years of age *[McSherry 1996, Nordenram 1987]*.

The lengthy treatment with multiband appliances and the possibility of failure lead a number of patients to refuse orthodontics. The aim of this study was to establish the absence of ankylosis and to improve the initial angulation of impacted canine teeth. To achieve this, mini-screws were inserted into the alveolar bone and were used as anchorage for the initial traction of the embedded tooth.

Recently, numerous studies have offered mini-screws for rigid anchorage. Despite the great interest in anchorage control with these devices and the occasional difficulties in impacted canine treatment, to the best of our knowledge only a single paper has been published that presents two case reports when micro-implant were used as anchorages in the management of these teeth *[Park et al. 2004]*.

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. In all cases the diagnosis of an impacted canine was based on both clinical and radiographic examinations. Panoramic, periapical and anterior occlusal radiographs were taken. Twenty-one of the 69 maxillary canines were situated buccally, while 48 were impacted palatally. All surgical procedures were performed under local anesthesia. After a chlorhexidine mouthwash, the canine was surgically exposed and an attachment was bonded. 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. At each implant site, a pilot drill with a low-speed contra-angle hand piece was used to penetrate the attached gingiva and the cortex at a distance of 5-6 mm from the alveolar crest. Stainless steel, 1.5 mm in diameter and 8-10 mm long mini-screws (Leone, Florence, Italy) with an endosseous body and intraoral neck section were inserted. (Figures 41-46) The procedure was performed without a surgical stent.



Figures 41-46. Exploration, bracketing of an impacted canine. Predrilling, insertion of the mini-screw in a 21-year-old-woman.

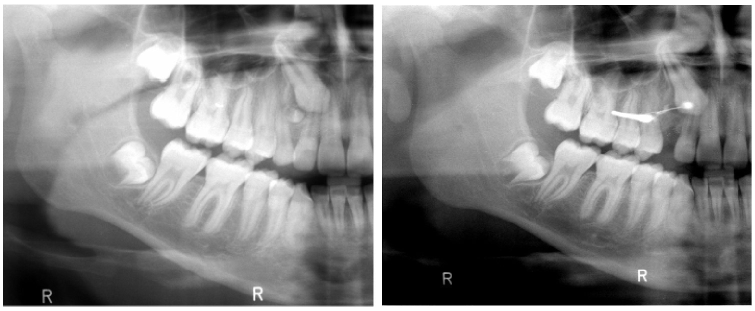
Pre- or postoperative antibiotics were not given routinely. Following soft tissue healing around the explored tooth, mechanical traction was activated with a nickel-titanium closed-coil spring exerting 50-80 g of force. Following that, the patient was seen at 4-week intervals. Anterior occlusal radiographs and periapical X-rays were taken at every second visit. 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

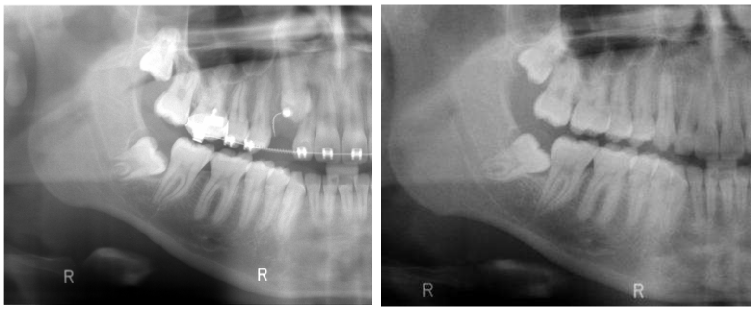
Sixty-one of the 69 canines (88.41%) were successfully guided into occlusion (Figures 47-57). The active traction with mini-screw anchorage lasted 4-10 (average 6.8) months. Seven cases failed due to ankylosis. In one patient, the mini-screw was removed due to inflammation and severe pain before the beginning of the orthodontic traction. None of the other patients complained of any significant discomfort. 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.

Figures 47-49. Beginning of the orthodontic treatment. 10 months later.

Figures 50-51. Uprighting of the canine in a 14-year-old girl



Figures 52-53. Supernumerary tooth preventing the eruption of a canine in a 16-year-old boy. Following the removal of the supernumerary tooth extrusion of the canine was initiated.



Figures 53-54. Six months later the angulation was corrected.
The canine at the end of the treatment.

Figures 55-57. Extrusion of a palatally impacted canine in a 35-year-old patient. Temporary replacement of the extracted primary canine with fiber-reinforced composite. The canine at the end of the treatment.

1.2.4 Discussion

Although guiding an impacted canine into occlusion is considered a routine orthodontic task, several complications and problems may arise during assessment and treatment. As this disorder is often associated with only a minor malocclusion, these teeth are frequently discovered at a later age when treatment duration is longer and the prognosis is worse. With the increased demand for orthodontic treatment, some adults who opposed the extrusion of the impacted tooth in adolescence reconsider it later.

Patients and clinicians need to know the expected treatment duration and the predictable level of success. Due to the limited experience of most orthodontists in this field, these questions can be hardly answered.

Ankylosis is one of the major complications associated with impacted canines that may result in years of frustration for both the patient and the orthodontist. Patients over 40 years of age are particularly susceptible to this condition, but younger patients can be affected, too *[Stafne et al. 1945]*. Orthodontically-assisted eruption of these teeth may intrude or displace the adjacent anchoring teeth resulting in a skeletal deformity. *[Tiwana et al. 2005]* (Figures 58-59).

Figure 58.

Figure 59.

The diagnosis of ankylosis can be rarely established on the basis of clinical and conventional radiographic examinations. The periodontal space that is depicted on the periapical or occlusal X-ray represents only one portion of the surface of the root. Although axial CT scans display the entire root surface, its resolution is insufficient to detect minor resorptions *[Korbendau et al. 2006]*.

If the patient refuses orthodontic treatment or the extrusion fails, prosthetic replacement of a missing canine raises further questions. Grinding the adjacent, usually healthy teeth for a standard, fixed bridge is far from optimal. Placement of an implant requires the removal of the impacted tooth, but this creates a bony defect that has to be bone grafted. Orthodontic closure of the gap results in asymmetry in unilateral cases and the removal of the buried tooth is unavoidable, too. From physiological point of view, orthodontically-assisted forced eruption of the impacted tooth would be the best option if the outcome was predictable.

If a mini-screw is placed in the alveolar process and used as an anchorage for orthodontic traction then the angulation of the impacted tooth can be corrected. We use gentle forces of 50-80 g to prevent an overly rapid movement that would impair the periodontal tissues. This traction force coincides with the suggestion of Dalstra. et al. They used finite element analysis to calculate the strain developed in various cortical thicknesses and densities of trabecular bone *[Dalstra et al. 2004]*. When a load of 50 g was placed perpendicular to the long axis of a 2 mm-diameter mini-implant, they found that with thin cortical bone and low-density trabecular bone, the strain values may exceed the level of microfractures and thus lead to screw loosening. Therefore, immediate loading should be limited to about 50 g of force.

Once the initial movement of the impacted canine has occurred, the diagnosis of ankylosis can be excluded so the successful extrusion is guaranteed. Patients are happy to accept this method as the treatment duration with multiband appliances is significantly reduced.

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, painless and requires minimal anesthesia. As we use flapless surgery, postoperative swelling, bleeding and pain are minimal. Potential complications include the following *[Ludwig et al. 2011]*:

1. Root or periodontium injury
2. Maxillary sinus injury
3. Mini-implant fracture during placement
4. A loss rate as high as 25% *[Chen et al. 2008]*

Although complete root repair was reported after injury from mini-implant insertion in a histological animal study *[Asscherickx et al. 2005]*, all precautions should be taken to avoid hitting the roots during drilling or screw insertion. In a tooth-bearing area mini-screws with a smaller diameter are used to prevent damaging of the dental roots. A clinical study of the factors associated with mini-implant stability assessed fixtures with 1-2.3 mm diameters and 6, 11, 14 mm body lengths. It was found that implant mobility was associated with 1 mm body diameter, but it was not statistically associated with body length *[Prabhu et al. 2006]*. Hence, in terms of primary stability, the diameter is more important than body length.

Poggio studied the interradicular anatomy of 25 patients with volumetric tomographic imaging *[Poggio et al. 2006]*. On the palatal side, the greatest amount of mesiodistal bone was found between the second premolar and the first molar, at 5-mm depth. The interseptal distance is somewhat less but still sufficient between the two molars. These areas are also convenient for clinical application of a mini-screw when extrusion of a palatally impacted canine is planned. In the same study, mesiodistal measurements revealed the most available bone between the two premolars on the buccal side. There is less bone between the second premolar and the first molar where the mini-screw is placed in case of a buccally exposed canine. In this region the greatest interradicular distance was found between 5 to 8 mm from the alveolar crest.

Currently, there are no data available on how much bone is necessary between the dental root and the mini-screw that ensures both periodontal health and implant stability. Leone mini-implants have a diameter of 1.5 or 2 mms. We used 1.5 mm screws to minimize the risk of damaging the dental roots. Root resorption and the vitality of the adjacent teeth should be monitored regularly. In our study significant root resorption was not noted and devitalization of the neighboring teeth did not occur.

Figure 60.

Leone mini-implants are made of surgical grade stainless steel (Figure 60). The implant head has a hexagonal shape with a transverse hole in it to connect orthodontic traction auxiliaries. The self-tapping body design requires a pilot hole. This should be drilled at a slow speed with adequate cooling to minimize heat generation and thus prevent bone necrosis. When the implant stability is not satisfactory, we suggest that a different implant site should be chosen instead of using another screw with greater diameter.

Insertion of implants in the upper molar region above 8-11 mm from the bone crest has to be avoided due to the possible presence of the maxillary sinus. As we placed the mini-implants at 5-6 mm depth, we have not experienced sinus injury. Even if the maxillary sinus is opened, spontaneous closure is expected due to the small diameter of the injury.

There is a small risk of screw fracture during insertion or removal. In one case in this study the implant head broke off at the level of the mucosa. The removal of the remaining piece proved to be difficult due to the lack of available screw surface. Screw fracture during orthodontic traction did not occur.

Antibiotics were not provided routinely unless it was required for general medical reasons. One of our patients complained of unbearable pain 3 days following the insertion of the screw on the palatal side. The stability of the screw was fine. The adjacent teeth were not tender to percussion. X-ray was not specific. A discharging sinus was present buccally. Despite of the antibiotic therapy and daily irrigation with betadine the symptoms did not improve so the implant was removed. Following that the infection settled. In our opinion, this single case of infection does not indicate the usage of antibiotics in all cases.

Orthodontic force can be applied immediately following the implantation, however, we allow one week for soft tissue healing around the explored impacted tooth to minimize patient discomfort. Because mini-screws rely on mechanical retention rather than osseointegration for their anchorage, the orthodontic force should be perpendicular to the direction of screw placement.

One of the side effects of mini-screw insertion is soft tissue irritation. This can be avoided if the implant is placed through the attached gingiva rather than the alveolar mucosa. Soft tissue inflammation at the implant site due to plaque accumulation may occur so excellent oral hygiene is essential. In our practice the patients are instructed on how to brush around the anchor site and to rinse with chlorhexidine twice a day after implant placement and throughout the orthodontic treatment. In spite of this, 4 mini-screws had to be removed prematurely due to severe inflammation around the neck section. Further 6 screws got mobile without signs of inflammation. Fortunately, in these cases the angulation of the canines had already improved, so the treatments could be finished with traditional orthodontics.

As the mini-screw is not osseointegrated, removal is easy and can be performed without anesthesia. Soft tissue closure is not necessary; the implant bed is left to granulate. Mucosal coverage usually occurs within some days.

1.2.5 Conclusions

1. Adults with an impacted canine are highly susceptible to ankylosis.
2. Mini-screws implanted in the alveolar bone proved to be reliable and convenient skeletal anchorage devices in the management of unerupted canines.
3. Because of the high incidence of ankylosis this method is strongly recommended for the treatment of adults.
4. This method may decrease the degree of disappointment and frustration when an ankylosed tooth is treated.
5. Although complications may occur, they are rare and usually not severe.
6. As the mini-screw is not osseointegrated, removal is easy and can be performed without anesthesia.
7. 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

Composite orofacial defects have always posed a challenging problem to the maxillofacial surgeon. Such defects may be a result of trauma, tumor resection, infection, developmental disorder, radiotherapy and recently increasing number of bisphosphonate related osteonecrosis. Reconstructive surgery to repair the functional limitations and aesthetic concerns can be complex and extensive. Currently, autologous bone grafts are the “gold standard” method for surgical repair of a bony defect. Traditional, nonvascularized iliac crest graft has its limitations due to the high rate of infection and resorption.

The biological advantages of vascularized bone grafting over conventional grafts include more rapid and predictable union, less graft resorption and lower rate of infections. The use of vascularized fibular grafts for mandibular and maxillary reconstruction is increasing in popularity *[Hidalgo et al 1995]*. The advantages are numerous. There are no length limitations as the fibula offers up to 22-25 cm of bone. The fibula allows great versatility in reconstruction as multiple osteotomies can be performed because of the rich periosteal blood supply. The strong bicortical bone supports osseointegrated implants, allowing prosthetic rehabilitation. Large skin island is available for reconstruction of mucosal and skin defects. The long vascular pedicle offers flexibility in flap design even if recipient vessels from the contralateral side of the neck are used for anastomoses. The location of the donor site enables a two-team approach. Donor site morbidity is minimal.

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 (Figure 61).

The fibula is vascularized from the peroneal artery via periosteal and nutrient vessels. The nutrient artery, sometimes paired, usually enters the posterior surface of the fibula near its midpoint *[Taylor et al. 1988, Yoshimura et al. 1990]*. It does not need to

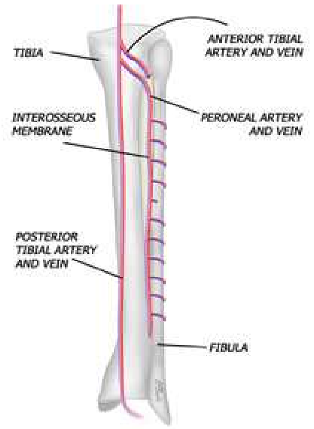


Figure 61.
(www.microsurgeon.org)

be identified and harvested with the flap, as most of the blood supply of the fibula is periosteal. The peroneal artery provides the entire periosteal blood circulation and it is harvested with the graft. In 5-8% of the population the peroneal artery plays dominant role in the blood supply to the foot *[Young et al. 1994, Carrol et al. 1996, Kim et al. 1989]* and harvesting the artery with the flap would endanger the pedal circulation. If there is a variant on one side the incidence of contralateral arterial variance is 50% *[Bardsley et al. 1970, Keen 1961]*.

Arterial variation in the blood supply of the leg and the foot have been investigated and classified extensively. Kim et al. *[Kim et al. 1989]* studied the branching patterns of the popliteal artery in 495 angiograms. Variant blood supply to the foot was found in overall 5.6% of the extremities. Mauro et al. *[Mauro et al. 1988]* reported aplasia or hypoplasia of the tibial arteries in 2.3% following the evaluation of 343 angiograms.

Taylor *[Taylor et al. 1988]* investigated the blood supply to the fibula in 66 cadaver limbs by India ink injection and radiographic studies (Figure 62). 100 angiograms were also evaluated revealing 21 limbs with anomalies. Yoshimura *[Yoshimura et al. 1990]* carried out an anatomic study of the peroneal artery and vein branching patterns on 80 cadaver legs with special attention to the cutaneous branches, communicating branches with the anterior and posterior tibial vessels and to the nutrient arteries of the fibula. Yamada *[Yamada et al. 1993]* studied the anatomic variations of pedal arteries in 30 cadaver limbs by performing anatomic dissection, arteriography and preparation of

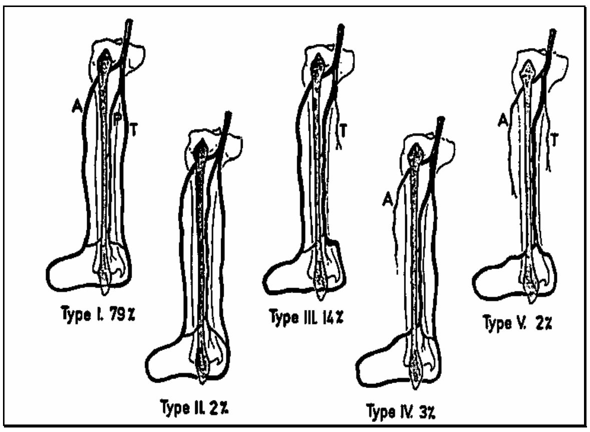


Figure 62.

corrosion cast models. The dorsalis pedis artery arose from the peroneal artery in 6.7% of the cases in this series.

The popliteal artery usually divides into the anterior tibial artery and the tibioperoneal trunk posteriorly to the inferior border of the popliteal muscle. The peroneal artery arises from the tibioperoneal trunk with an average of 3.9 cm below the bifurcation *[Kim et al. 1989]*. The longer the tibioperoneal trunk is the shorter vascular pedicle that can be harvested. The incidence of trifurcation when the three major arteries arise in close proximity to each other is 2%. High division of the popliteal artery occurs in 3-5% when the artery bifurcates proximal to the inferior border of the popliteal muscle, at or above the knee joint. These variations offer a long vascular pedicle if necessary.

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% *[Kim et al. 1989; Keen et al. 1961; Lippert et al. 1985]*.

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 ischaemia. In severe cases it will commence in the early postoperative period, in other cases it may arise as a late complication.

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%) *[Lippert et al. 1985]*. In this situation vascular flap can not be harvested.

The indication for preoperative vascular imaging and the best method of assessment remains controversial. 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. Numerous systems have been described for monitoring the viability of microsurgical free flaps *[Weiss et al. 1991; Dominici et al. 1995]*. Angiography, plethysmography *[Wu et al. 1995]*, laser Doppler *[Lorenzetti et al. 1999]*, transcutaneous or intravascular blood gas analysis *[Nagase et al. 1997; Reinert et al. 1991]*, fluorescence technique, scintigraphy, color duplex ultrasound *[Salmi et al. 1995; Hjortdal et al. 1994]* all have advantages and disadvantages.

Color Doppler ultrasound *[Khoury et al. 1990; Wheatley et al. 1996; Hidalgo et al. 1990; Picardi-Ami et al. 1990]* is a non-invasive, repeatable and objective diagnostic tool that is capable of separate examination of the arterial and venous blood flow (Figure 63). The second aim of this study was to evaluate color Doppler ultrasound for postoperative monitoring of fibula flaps.

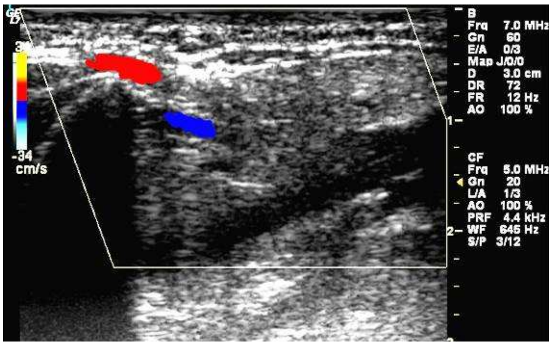


Figure 63. Parallel artery and vein displayed in different colours in a revascularized fibula flap

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 (Figure 64). DSA was performed with a Polytron 1000 VR unit (Siemens, Erlangen) using the Seldinger technique. A 4.5 French catheter was inserted into the popliteal, superficial femoral or the iliac artery and 5-20 mls of iodine-containing contrast material was administered intraarterially while X-rays were taken.

Figure 64. DSA revealed a normal anatomic pattern

One patient underwent computed tomographic angiography and two 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

(Figure 65). The absence of either the anterior tibial (Figure 66) or the posterior tibial artery (Figure 67) occurred in one and two extremities, respectively.

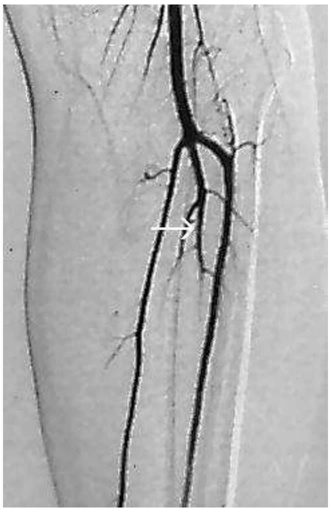
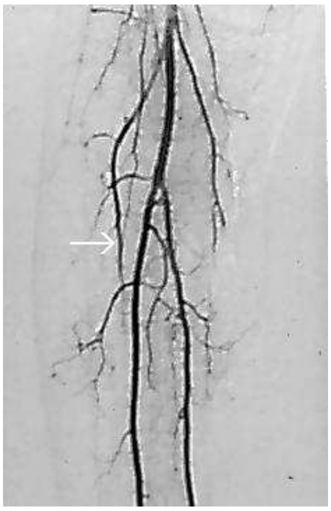
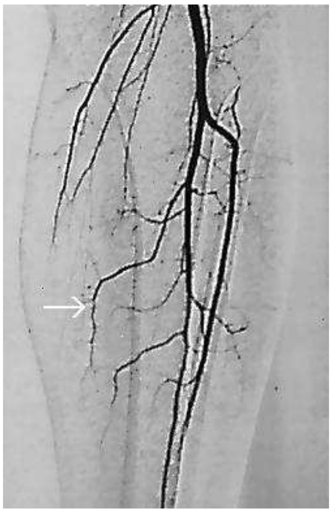




Figure 65. **Figure 66.** **Figure 67.**

In one case both the anterior and posterior tibial arteries were missing and the peroneal arteria magna (Figure 68) 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 (Figure 69).

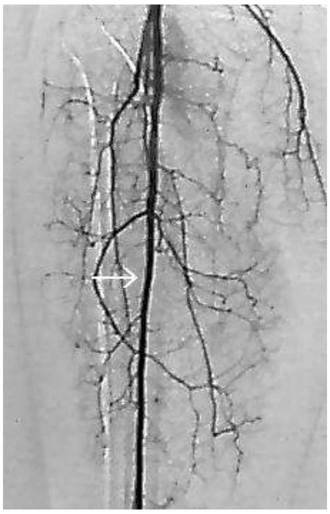
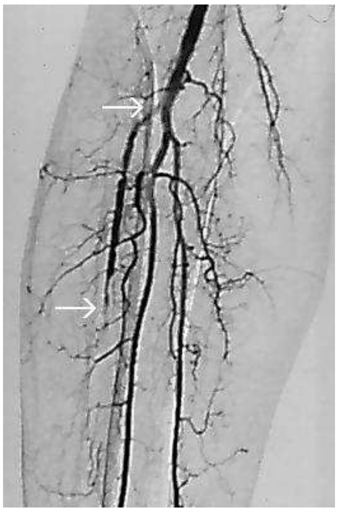



Figure 68. **Figure 69.**

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

The patency of the major vessels in the donor limb should be evaluated before the fibula is harvested because the blood supply can be inadequate to safely utilize the flap. Numerous previous investigators *[Manaster et al. 1990, Young et al. 1994, Carroll et al. 1996, Blackwell 1998, Futran et al. 1998]* have advocated the routine use of donor site angiography. The rarity of abnormalities in the lower limb vessels has led some clinicians to question the need for invasive angiography *[Moaghan et al. 2002]*. Some authors have recommended the selective use of preoperative imaging. Hidalgo *[Hidalgo et al. 1995]* did not suggest angiography unless there is evidence of advanced peripheral vascular disease. Disa *[Disa et al. 1998]* and Dublin *[Dublin et al. 1997]* considered arteriography necessary for patients with abnormal vascular physical examinations. Lutz *[Lutz et al. 1998, Lutz et al. 1999]* added previous severe lower extremity trauma to these indications (Figure 70). In their postal survey of fibula flap preoperative assessment, Clemenza et al. found that surprisingly, some 38% of respondents were happy to rely on clinical examination and ward Doppler studies alone *[Clemenza et al. 2000]*.

Figure 70. Donor site imaging of a polytraumatized patient before fibula transfer

History and clinical evaluation are essential in planning fibula free flap transfer. A history of peripheral or central vascular disease, diabetes, arterial hypertension and previous trauma to the leg should be noted. Physical examination may suggest peripheral vascular disease. Palpation of the dorsalis pedis and the posterior tibial pulses is an essential part of the clinical examination. In case of arterial or venous insufficiency an alternative method should be considered for mandibular reconstruction.

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 *[Brearley et al. 1992, Magee et al. 1992]*. 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.

Mandibular 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.

Digital subtraction angiography *[Ovitt et al. 1985]* is a reliable, repeatable imaging technique that can be safely performed even on an outpatient basis in most patients. The opponents of routine preoperative angiography emphasise the risks of the invasive procedure. Known complications of vascular access include hematoma, hemorrhage, thrombosis, and pseudoaneurysm. Contrast administration may cause arrhythmia, anaphylaxis or renal insufficiency *[Hessel et al. 1981]*. Due to recent technological advances smaller gauge catheters and a smaller volume of contrast media is required for the examination. Therefore, the incidence of vascular injury and general complications has been reduced. In this series there were no complications that required surgical intervention or caused permanent morbidity. Contrast-media related vasculitis may adversely affect the flap survival. Most of the examinations were performed 3-5 days before the planned operation. There were no intraoperative findings suggestive of macroscopically detectable vasculitis.

Although angiography is considered the “gold standard” method of assessment, magnetic resonance (MRA) *[Manaster et al. 1990; Manaster et al. 1990; Bretzman et al. 1994]* and CT angiography (CTA) *[Rieker et al. 1997; Rubin et al. 1999, Chow et al. 2005, Karanas et al. 2004]* (Figure 71), color Doppler *[Nzeh et al. 1998; Smith et al. 2003]* and duplex ultrasonography *[Moneta et al. 1992]* are alternative tools to evaluate the vascular status of the donor site. In an overview of 62 studies Smit et al. concluded that CTA and MRA are currently the best methods available to map the vasculature of the donor sites and that DSA appears to be fading out slowly *[Smit et al. 2010]*. Due to the low number of angiographies that were not performed by DSA, our study has not been suitable for comparison of these modalities.

Figure 71.

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 *[Furnas et al. 1991, Jones 1992]* and compression (e.g. hematoma). Flap compromise requires urgent surgical intervention to carry out decompression or thrombectomy *[Concannon et al. 1991]* and reanastomosis *[Goldberg et al. 1990]*. 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 need 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 *[Khalid et al. 2006]*. Although it is not designed to provide continuous monitoring, it is an excellent method for examining free-tissue transfers for possible postoperative complications.

Case report

A 66-year-old non-insulin-dependent diabetic man underwent surgery for gingival cancer. A right-sided composite resection and left-sided modified radical neck dissection were performed. A fibular flap was used for reconstruction. The vessels of the flap were anatomized to the preserved facial artery and external jugular vein on the right side of the neck. On the first postoperative day marked swelling approximately 5 centimeters in diameter arose at the right angle of the mandible over two hours but did not progress further. However the question of surgical exploration arose because of possible venous occlusion or hematoma due to a local hemorrhage. It was felt that hematoma may have compressed the vessels, predominantly the veins, and leading to thrombosis. Urgent ultrasound examination confirmed a hematoma. Color Doppler ultrasound revealed intact arterial and venous circulation so the re-exploration of the flap was not necessary (Figure 72). The patient recovered well and the hematoma resorbed completely over approximately ten days. In this case color Doppler ultrasound examination spared the patient of an unnecessary reoperation.

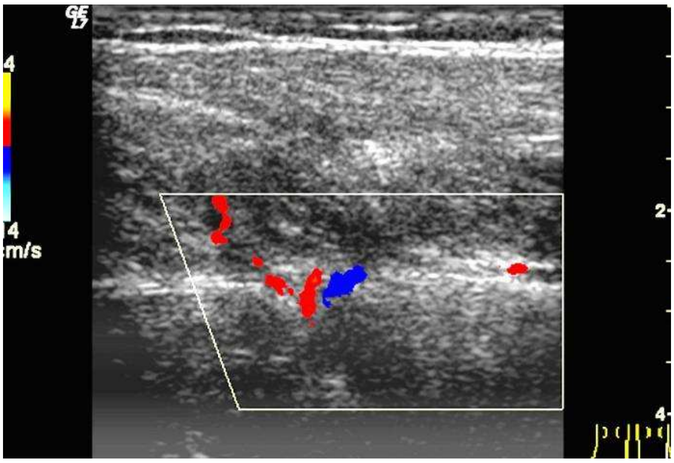


Figure 72. Periosteal arterial and venous blood supply in the fibula flap.

2.5 Conclusions

1. 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.
2. 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.
3. Performing angiography on both lower extremities offers the possibility of choosing the anatomically more favorable donor site.
4. Digital subtraction angiography is accurate, reliable, safe techniques for preoperative donor site vascular imaging.
5. Color Doppler ultrasound is an excellent diagnostic tool for controlling the flap circulation following transplantation.

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LIST OF PUBLICATIONS RELATED TO THE SUBJECT OF THE THESIS

<u>In extenso publications</u>

1. Borbély L, Császár J, Fehér Á, Halász J, **Seres L,** Roszik M. *Állkapocs- és lágyrészpótlás fibula osteo-septocutan lebennyel.* Magyar traumatológia, Orthopédia, Kézsebészet és Plasztikai sebészet 1998;41(3),155-60.
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<u>Book chapter</u>

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