Development of Reconstructive

Head and Neck Surgery

– Special Emphasis on

Novel Applications of Microsurgery

Annastiina Husso

ACADEMIC DISSERTATION

To be presented, with the permission of the Faculty of Medicine of the University of Helsinki, for public examination in the main Lecture Hall of Töölö Hospital, on June 29th 2018, at 12 noon.

Helsinki 2018
Supervised by
Docent Patrik Lassus
Department of Plastic Surgery
Helsinki University Hospital
University of Helsinki
Helsinki, Finland

and
Professor Antti Mäkitie
Department of Otorhinolaryngology
Helsinki University Hospital
University of Helsinki
Helsinki, Finland

Reviewed by
Docent Minna Kääriäinen
Tampere University Hospital
Department of Plastic Surgery
Tampere, Finland

and
Docent Paula Mustonen
Kuopio University Hospital
Department of Plastic Surgery
Kuopio, Finland

Official Opponent
Professor Juan Barret
Department of Plastic Surgery and Burns
University Hospital Vall d’Hebron
Universitat Autonoma de Barcelona
Barcelona, Spain

ISBN 978-951-51-4342-6 (PDF)
The world is changed by your example, not by your opinion.

-Paolo Coelho
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1. Original Publications

This thesis is based on the following original publications.


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### 2. Abbreviations

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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ALT</td>
<td>Anterolateral thigh flap</td>
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<tr>
<td>BCC</td>
<td>Basal cell carcinoma</td>
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<tr>
<td>CCI</td>
<td>Charlson Comorbidity Index</td>
</tr>
<tr>
<td>DCIA</td>
<td>Deep circumflex iliac artery flap / Iliac crest flap</td>
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<tr>
<td>DIEP</td>
<td>Deep inferior epigastric artery perforator flap</td>
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<tr>
<td>FOM</td>
<td>Floor of the mouth</td>
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<td>LD</td>
<td>Latissimus dorsi flap</td>
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<td>NL</td>
<td>Nasolabial</td>
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<td>OC</td>
<td>Osteocutaneous</td>
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<tr>
<td>RFA</td>
<td>Radial forearm flap</td>
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<tr>
<td>RXT</td>
<td>Radiation therapy</td>
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<tr>
<td>SAF</td>
<td>Submental artery flap</td>
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<tr>
<td>SCC</td>
<td>Squamous cell carcinoma</td>
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<tr>
<td>SLNB</td>
<td>Sentinel lymph node biopsy</td>
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<tr>
<td>ST</td>
<td>Superficial temporal</td>
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<tr>
<td>TAPAS</td>
<td>Temporal artery based posterior auricular skin flap</td>
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<tr>
<td>cTNM</td>
<td>Clinical TNM</td>
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<tr>
<td>pTNM</td>
<td>Pathological TNM</td>
</tr>
<tr>
<td>TRAM</td>
<td>Transverse rectus abdominis myocutaneous flap</td>
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<tr>
<td>VRAM</td>
<td>Vertical rectus abdominis myocutaneous flap</td>
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3. Abstract

3.1 Background

Managing extensive bone and soft tissue defects in the head and neck region remains a challenge for reconstructive surgeons. The aim of the reconstruction is not only to manage the three-dimensional tissue defect, but includes also preserving functions like swallowing, talking and breathing, and maintaining aesthetics. Modern microsurgical free tissue transfer practice is reported to be highly reliable. Still, when complications occur, they can be devastating. The heterogeneity of these surgical defects provides a constant challenge in choosing the most suitable management method and motivates development of new reconstructive methods. Understanding the advantages and disadvantages of the different reconstruction alternatives ensures the optimal choice of treatment.

3.2 Aims of the Study

This thesis comprises four studies of surgical practice and the different types of head and neck reconstructive modalities in the Helsinki Head and Neck Center.

1. To review and analyze the surgical management strategy and outcomes of head and neck reconstructions at our institution from 1995 to 2012. (Study I)
2. To compare the use of the three most frequently used composite free flaps of the head and neck region at our institution during the time period from 2000 to 2012; iliac crest, scapular and fibular flap. (Study II)
3. To evaluate the use of local pedicled submental artery flap as an alternative reconstructive option in oncological management of the head and neck area. (Study III)
4. To describe novel external ear-based alternatives in facial and head and neck microvascular reconstruction. (Study IV)
3.3 Patients and Methods

The first study included 541 patients receiving 594 free flaps of the head and neck region between the years 1995 and 2012 at the Department of Plastic Surgery, Helsinki University Hospital, Helsinki, Finland. The second study compared 163 patients with a scapular, fibular, or iliac crest flap for mandibular, maxillary or orbital reconstruction. The third study investigated the outcome of reconstruction with a submental artery flap in a series of 10 patients with early or locally advanced intraoral cancer who had not been candidates for free flap reconstruction. In the fourth study, 3 external ear-based free flaps in facial reconstruction were described in a series of 19 patients with 20 reconstructions with temporal artery posterior auricular skin (TAPAS), helix, or hemiauricular flaps.

3.4 Main Results

In Study I, the most commonly used free flap from 1995 to 2000 was the radial forearm flap (RFA). The invention and development of the anterolateral thigh flap (ALT) was early omitted at our center and it became the most commonly used free tissue flap between 2001 and 2012. Patients’ mean age increased from 53 to 56 years. The number of different flap types and combinations expanded from 15 during the first study trimester to 24 different flap types during the last trimester. The flap survival remained constant at 97%. The prevalence of surgical complications, including early major recipient-site complications decreased.

In Study II, the overall survival rate of scapular, fibular, and iliac crest flaps from 2000 to 2012 was 91%. The most reliable flap was scapular flap with a 100% survival, followed by the fibular with a 97% survival, and the least reliable was the iliac crest with an 85% survival. The fibula and scapula had fewer complications than the iliac crest, and the fibula also had the lowest perioperative blood loss. The prevalence of osteotomies in all free flaps was similar, but the fibula most often required several osteotomies. Regarding osteotomies or the number of dental implants the outcomes were similar in all three osseal flaps.

In Study III, two patients with a submental artery flap (SAF) reconstruction developed major complications, of which one involved total flap loss. The SAF was lifted in three cases in
combination with sentinel lymph node biopsy to rule out positive neck disease and in two cases with the combined nodal sampling technique. The follow-up showed no signs of metastatic neck disease, but six patients developed local recurrences. Three of these patients were treated primarily with palliative intent.

In Study IV, the free flaps lifted from the ear region included 12 helix flaps, 7 temporal artery posterior auricular skin (TAPAS) flaps, and one hemi-auricular flap. One helix flap was lost, making the overall flap survival 95%. Donor-sites healed uneventfully, and aesthetic and functional outcomes were good in all patients, although the majority of them underwent minor corrections.

3.5 Conclusions

Microsurgical practice in head and neck surgery was established in our institution during recent decades. The flap selection has been constantly expanding along with the increasing mean age of the patient population, without sacrificing outcome. The reconstructive ideology has been shifting towards a customized approach, evident in the increased number of chimeric and double flaps. In composite reconstructions, fibular, scapular, and DCIA flaps are all useful and reliable tools, with DCIA being least favorable in terms of flap survival and complications. With knowledge of and expertise in all three alternatives it is possible to select the most suitable and safe reconstructive option for every individual patient. Local flap reconstruction with a submental artery flap is an alternative tool in selective patients not suitable for conventional microvascular surgery and can be used with cautions in oncological purposes. Development of free flaps from the ear region has added a versatile and unique flap alternative in the armamentarium of facial reconstruction techniques.
4. Introduction

During the past decades surgical management of complex head and neck tissue defects has evolved hand in hand with microsurgical techniques (Brown et al. 2006, Thorwarth et al. 2008, Wu et al. 2014). Managing extensive bone and soft tissue defects after, for example, resection of a tumor or a trauma in this particular region presents surgical challenge. The complexity of the human upper aero-digestive tract provides additional challenges in oropharyngeal reconstruction, making it one of the most demanding tasks in the field of head and neck surgery. Successful reconstruction requires detailed knowledge of the normal anatomic and physiologic mechanisms of swallowing and breathing that exist in this area, in combination with the surgical expertise and insight to execute various techniques for a broad spectrum of defects. The aims of the reconstruction are not only to manage the defect, but also to preserve functions like swallowing, talking, and breathing without compromising oncological accuracy. The heterogeneity of this group of patients provides a constant challenge in choosing the best management method. Microvascular free flaps are established as the gold standard, but some patients with multiple co-morbidities may also benefit from local pedicled flap alternatives, which can provide shorter operation times and less donor-site morbidity (Kowalski et al. 1994, Zabrodsky et al. 2004). Modern microsurgical practice is highly reliable with success rates in both non-oncological and oncological population exceeding from 90 to 98%, but the complications are devastating and require expertise in further management (Wong and Wei 2010, Pohlenz et al. 2012). New flap alternatives and variations are constantly developed to reach better, safer, and functionally more precise reconstruction results in balance with an acceptable risk of flap failure and donor-site morbidity.
5. Review of the Literature

5.1 Brief History of Microsurgery

Paré had already described the first vascular ligature in 1552 and in 1759 a brachial artery wound was repaired with a suture by Hallowell (Paré and Dale 1974, Hallowell and Dale 1974). In 1902 a French-American surgeon, Alex Carrel, described the first microvascular anastomosis technique (Carrel 1902). He was later awarded the Nobel Prize (1912) based on his pioneering work on vascular sutures and the transplantation of organs, in which he experimented on dogs. Development of heparin played an important role in successful microvascular interventions in humans (Howell 1918, Charles et al. 1933). The monocular microscope for ear surgery was first used by otolaryngologist Nylén in 1921 (Nylén 1972). During the 1950s, development of the Zeiss operating microscope, microsurgical instrumentation and suture material had a significant impact in developments of microsurgical practice. In 1958, Onji and Tamai performed a historic replantation of an amputated extremity in Japan (Onji et al. 1963, Tamai 1964). Jacobson and Suarez were the first to perform microvascular anastomosis using an operative microscope in 1960 (Jacobson and Suarez 1960). In 1962, Chase and Schwartz demonstrated improved patency of microvascular anastomosis in less than 1.5mm vessels with interrupted vs. continuous technique (Chase and Schwartz 1962). Based on the development of the microsurgery, Japanese microsurgeon Tamai called the 1970s “the developing period”, the 1980’s “the fully matured period”, and the 1990’s “the turning point from autogenous tissue transplantation to allogeneic transplantation” (Tamai 2009). The latter has become reality also in head and neck microsurgery, when face transplantation was introduced to surgical practice in 2005 (Devauchelle et al. 2006).

5.1.1 Development of Free Flaps

Already by 1957 Seidenberg and colleagues had reconstructed the cervical esophagus with free jejunal segment in dogs (Seidenberg et al. 1959). In 1966, Buncke and colleagues performed a toe-to-hand transfer in a rhesus monkey, inspired by two-staged hallux-to-hand transplantation reported by Nicoladoni in 1900, and in 1968, Tamai and his colleagues
performed the first experimental free skeletal muscle transplantation on a dog (Nicoladoni 1900, Buncke, Buncke and Schultz 1966, Tamai et al. 1972). In 1968, Cobbet performed the first toe-to-hand transfers successfully in a human (Cobbet 1968) Taylor was the first in the world to successfully perform and describe a free flap transfer in a human (Taylor and Daniel 1973). In 1972, he performed a free groin flap (Taylor and Watson 1978). The free pectoralis flap soon followed it in 1973, done by Shanghai Replantation Group and the first free gracilis flap was performed in the same year by Harii to treat facial paralysis (Harii, Ohmori and Torii 1976). During the 1970’s the principles of microvascular surgery were popularized all over the developed world. Baudet et al introduced the term “musculocutaneous flap” in 1976, and the group also described the usefulness of the thoradorsal vessel-based latissimus dorsi flap (Baudet, Guimberteau, and Nascimento 1976).

Soon after success with the first free soft-tissue flaps, the idea of vascularized bone graft arose, especially because of the demand for bone reconstruction in pediatric orthopedic conditions such as extensive open fractures. The experimental work was done by Buncke and Tamai (Tamai 1964, Buncke and Schulz 1965). In 1972, the first vascularized fibula graft was performed by Taylor et al (Taylor, Miller and Ham 1975), and in 1976 Tamai performed the iliac osteocutaneous flap (Tamai 1979).

5.1.2 Angiosomes

Taylor et al found that a source artery of a specific skin area corresponds to deep tissues' anatomic territory of a source artery (Taylor and Palmer 1987). An angiosome is a composite block of tissue supplied anatomically by source vessels that span the skin and deeper tissues. The source vessels of these angiosomes supply branches to the overlying skin. Branches pass between the deep tissues or through the deep tissues, to pierce the deep fascia at fixed skin sites. An arterial road map presented by Taylor consists of an average of 374 major perforators found in one individual. With the help of the angiosome-map-approach, it is possible to define those tissues available for transfer.
5.1.3 Perforator Flaps

“Perforator flap” refers an area of skin and soft tissue which survives on a single vascular stalk called a perforator. The flap can be utilized both pedicled and in free fashion. The main difference between a classical flap and a perforator flap is that whereas classical flaps are connected to a source vessel under the muscle, a perforator flap is connected to vessels of the subdermal or subcutaneous plexus. In a true free perforator flap, an idea described by Koshima and Soeda in 1989, the flap is lifted with a perforator, which supplies only the area of the flap (Koshima and Soeda 1989). Ideally, this leaves the main vessels of the donor-site intact and allows optimal reconstruction with minimal donor-site morbidity. The perforator is traditionally dissected from distal to proximal orientation. Dissecting the perforator from the muscle and beneath can lengthen the vascular stalk of such a flap and this also allows a larger-caliber vessel to facilitate the vascular anastomosis. Perforator flaps are generally named after the artery, for example DIEP, the deep inferior epigastric perforator flap.

5.2 Considerations in Reconstructive Surgery

5.2.1 Indications

Malignancies are the main reason for reconstructions in head and neck region. The most common pathology of the tumors is squamous cell carcinoma, covering over half of the malignancies in head and neck (Zhang et al. 2015). Other head and neck malignancies include epidermoid cancers, sarcomas, and skin cancer melanoma and basalioma. In Finland, approximately 800 new cancers of head and neck area are diagnosed annually (Syöpärekisteri 2017). In general, head and neck cancers account for one in six new cancer diagnoses worldwide and are responsible for 200 000 deaths annually (Jemal et al. 2011). The prevalence of oral cancer, excluding lip cancer, is increasing (WHO 2017). Overall, during the last 30 years, the profile of head and neck cancer has changed dramatically. An increasing number of head and neck squamous cell cancers are associated to human papilloma virus, while the number of alcohol and tobacco associated diseases has decreased. It is suggested
that approximately 70-90% of new oropharyngeal cancers are related to HPV (Deschler et al. 2014).

Benign reasons for head and neck reconstructions include traumas and burn injuries, benign tumors and vascular malformations, congenital defects, and complications of prior surgery and radiotherapy. In addition, dysfunction after facial nerve paralysis can be restored with a functional free flap reconstruction. The most common benign tumour requiring extensive resections in the head and neck are ameloblastomas, giant cell tumors and odontogenic myxomas. Traumas affecting the head and neck area are most often high energy traffic injuries, or ballistic injuries, in non-warzone environment most often resulting from suicidal actions. Moreover, complications of prior surgical procedures in head and neck area often require reconstruction with microvascular flaps. Osteonecrosis of the jaw is a devastating complication of radiotherapy or medication occurring at an incidence of 1% to 15% in the oncological population and 0.001% to 0.01% in patients receiving bisphosphonates for osteoporosis (Khan et al. 2015).

5.2.2 Surgical Decision-making

Decision-making in head and neck surgery is influenced by several factors, including patient comorbidities, anatomy of the defect and surrounding tissues, anatomy of the planned donor-site, planned further oncological treatments, and life expectancy. The ideal reconstruction is typically performed in a single stage, should be reliable in terms of surgical survival, and should allow uneventful healing with non-inferior quality of life (Wehage and Fansa 2011). During the last four decades, head and neck reconstructive surgery has gone through several stages of development extending from local flaps to complex microsurgical free flaps (Thorwarth et al. 2008). Nowadays a full reconstructive armatorium is utilized, extending from simple secondary healing or primary closure, to more complicated local and pedicled flap alternatives, and at the other end to extremely complex anatomical free soft-tissue and composite flap reconstructions and whole tissue transplantation. It is often postulated that in reconstructive surgery the golden standard is to use the simplest method suitable. However, from our point of view, it should also state the most suitable method to achieve the best possible anatomical and functional reconstruction with careful consideration and with patient-related factors in mind.
The no-closure technique, as in secondary healing, is generally not advisable in the head and neck region because of the size and complexity of most defects. However, although it can serve in certain locations in some cases with small resections, its main disadvantages are contracture and tethering, when scar tissue develops. Primary closure can be applied when possible without tension, for example in small defects in a mobile tongue (McConnel, Teichgraeber and Adler 1987). In addition, a skin graft can be useful in small defects not amenable to primary closure. Local flap alternatives are limited in the head and neck, mostly because of the areas anatomical and functional complexity. Other significant factors are limitations in the arch of rotation and in cosmetic requirements.

When considering the optimal reconstructive method, the first priority concerns the patient’s overall medical condition. Attention should focus on other comorbidities such as peripheral vascular disease and diabetes, previous radiotherapy, and nutritional insufficiency, all being factors known affecting postoperative wound healing. The patient's ability to tolerate extensive surgery must be considered and comorbidities such as severe coronary artery disease, chronic obstructive pulmonary disease, or poor overall functional status or prognosis may contraindicate a complicated time-consuming reconstruction. Instead, a simpler reconstructive method should be chosen, to optimize the relationship between risks and benefits.

Several tools to analyze and classify comorbidities in surgery have been developed to assess the risk profile of developing complications. This thesis used the Charlson Comorbidity Index. The CCI in an index of general comorbidity predicting mortality. It was described by Charlson et al in 1987 (Charlson et al. 1987). This weighted index was takes into account the number and severity of comorbid disease of an individual patient. Factors affecting CCI are presented in the thesis’s supplement material.

Currently, a consensus exists to strive for the functionally and aesthetically superior reconstructive alternative, and these criteria are related to free tissue transfers. Despite the surgical challenges, free flap reconstructions have proven to be a safe and reliable method in head and neck reconstructions (Wei et al. 2001, Nakatsuka et al. 2003).
### 5.2.3 Reconstructive ladder

#### Technique

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<tr>
<td>Reconstructive Transplantation</td>
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<td>Free Flaps</td>
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<td>Pedicled Flaps</td>
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<td>Local Flaps</td>
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<td>Skin Grafts</td>
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<td>Primary Closure</td>
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<th>Simple</th>
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<td>Secondary Healing</td>
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5.3 Local and Pedicled Flaps

5.3.1 Local Flaps

In the head and neck area, local flaps have not gained popularity, mostly because of the poor availability of extra tissue. However, in selective reconstructive cases, local flaps can be used as a lighter, less time-consuming, and less-invasive method. The major advantage of local flaps is the similar color and texture when reconstructing defects including skin (Blackwell 1998). In addition, the surgical procedure is simple and well tolerated, and pliability and thickness of the flap are favorable. Even though successful development of the microsurgical techniques has dominated the field, the local flaps should not be abandoned and the interest in the development and appropriate usage of local alternatives has increased among the microsurgeons during the last years (Bianchi et al. 2009).

5.3.1.1 Facial Skin Flaps

There are multiple local flap alternatives available for reconstruction of smaller facial defects. The main advantage of these flaps, besides minor invasiveness, is the local cosmetic tissue match. Local flap types can be classified into advancement flaps; single pedicle, bipedicile and V-Y-flaps, and pivotal flaps; rotation flaps, transposition flaps, interpolation flaps and rhomboid flaps. Disadvantages include, in addition to tissue shortage, scarring and eventual compromises in resection. A good example of a local interpolation flap used in subtotal nose reconstruction is the paramedial forehead flap. The flap is harvested in 3 layers and rotated to cover the defect. It is based on the supratrochlear artery and provides an excellent texture match.

5.3.1.2 Oropharyngeal Local Flaps

In oropharyngeal reconstruction, the palatal island flap and uvulopalatal island flap might be considered as alternatives. The palatal island flap consists of hard palatal mucoperiosteum which is rotated based on a single greater palatine artery to fill the defect. The donor-site in the hard palate is left to remucosalize. The uvulopalatal flap is best used for
a limited lateral soft palatal defect when the uvula and contralateral soft palate remain intact. The uvula is denuded of mucosa and rotated to fill the defect. In addition, other local flap alternatives are inferior and superior pharyngeal flaps and the superior-constrictor advancement flap, but the clinical applications of these flaps are limited.

Figure 1. Alternative for flap classification utilizing the donor-site location

5.3.2 Pedicled Flaps

A pedicled flap is a partially isolated segment of vascularized tissue perfused with its own blood supply (pedicle) and transferred to another location. The optimal flap for a specific reconstruction site is defined by pedicle length. Like free flaps, pedicled flaps may consist of skin, subcutaneous tissue, bone, or viscera.
5.3.2.1 Pectoralis Major Flap

Ariyan presented the pectoralis major flap for head and neck reconstruction in 1979 (Ariyan 1979). It became the workhorse of head and neck reconstructions in many institutions during the 1980s and 1990s (Sabri 2003, Vartanian et al. 2004). The limitations of the flap are related to its nature; the locoregional flaps can result in unsatisfactory cosmetic and functional results, such as long-term fibrotic retraction, of the donor area. Limitations of arch rotation might also compromise the reconstruction.

5.3.2.2 Deltopectoral Flap

Aymard already had described the first shoulder region fasciocutaneous flap in the 1917 (Aymard 1917). The concept was refined, and a regional medial deltopectoral flap was developed in the 1960s and presented by Bakamjian in 1968. This flap is best used in superficial cervical and thoracic wall reconstructions. When lifted as a lateral flap, it gets its blood supply from the thoracodorsal artery and lateral thoracic arteries (Bakamjian 1968).

5.3.2.3 Pedicled Latissimus Dorsi Flap

Schneider et al were the first to use the pedicled latissimus dorsi flap in 1972 (Schneider, Hill and Brown 1977). It was primarily used for breast reconstruction, where it provides reliable reconstruction especially suitable for women with small breasts. In the head and neck area the length of the pedicle can form a challenge, but the LD pedicle is longer than the pedicle of the pectoralis major or the trapezius flap. The flap can be bulky, but this can be avoided with trimming of the proximal part of the muscle. Unlike other pedicular flaps in the head and neck region, it is also favorable for post-laryngopharyngectomy when muscular and cutaneous layers can be anastomosed and sutured separately to avoid leakage (Wilkman et al. 2014).
5.3.2.4 Trapezius Flap

The trapezius flap is a myocutaneous island flap first presented in 1979 by Demergasso (Demergasso and Piazza 1979). It is a thin and pliable flap based on scapular and dorsal scapular vessels. Its usefulness in head and neck reconstruction has often been discouraged by reports of failure rates (Can et al. 2014). Its disadvantages consist of a need for repositioning the patient and the unreliability of the vascular pedicle after level-V neck dissection.

Regional flaps still play an important role in reconstruction of larger defects, especially in centers where microvascular surgical expertise is unavailable or when other options are unsuitable.
5.4 Free flaps

A free flap is defined as tissue which can be transferred to another anatomical location with its free vascular pedicle. Free flaps can be classified according to their constituents into fasciocutaneous flaps (skin, fat, fascia), muscle flaps (muscle), osseous flaps (bone), or combinations such as osteocutaneous, myocutaneous or osteomusculocutaneous. In addition, nerve, omentum or intestine can be used for a free flap. The free flaps can also be classified according to their vascular anatomy. The Mathes-Nahai Classification divides free flaps into 5 categories; I – one vascular pedicle, II- dominant pedicle(s) and minor pedicle(s), III – two dominant pedicles, IV – segmental vascular pedicles and V – one dominant pedicle (Mathes and Nahai 1981).

Figure 2. Mathes-Nahai Classification.
5.4.1 Soft Tissue Flaps

5.4.1.1 Radial Forearm Flap

One of the very first free flaps described was the radial forearm flap, which was originally developed in the late 1970’s in China (Yang, Chen and Gao 1981). Soutar reintroduced it for head and neck reconstruction in 1983 and Urken et al succeeded in neurocutaneous use of the flap in 1989 (Soutar and Widdowson 1986, Urken et al. 1990). Over the years, it’s been described in large series by multiple authors and can be with no doubt entitled as the main workhorse of head and neck microsurgery. It is extremely reliable, offers sufficient soft tissue stock for oromaxillofacial reconstruction and carries low donor-site morbidity. Its major advantages are the rich vascular pedicle and the tissue alternatives it provides. It is a thin, pliable, and versatile flap and could be elevated with part of the radius and palmaris tendon for composite reconstruction. In case of extensive head and neck defects, though, the tissue amount might not be sufficient for reconstruction. The pedicle consists of the radial vessels and constant perforators arising from the radial artery, making its vascular venous system. The pedicle is also rather long and there is a double superficial and deep venous system. The standard is to test upper limb circulation with Allen’s test and Doppler ultrasound prior to the surgery (Soutar and Widdowson 1986, Vaughan 1990, Evans et al. 1994).

5.4.1.2 Anterolateral Thigh Flap

The anterolateral thigh flap is a versatile perforator flap, which can be lifted as a subcutaneous, fasciocutaneous, myocutaneous, or adipofascial flap. It is usually based on septocutaneous perforators, and at times on musculocutaneous perforators of the circumflex femoral artery. It was first described by Song et al. 1984 (Song, Chen and Song 1984). The harvesting of this flap is straightforward, despite the wide anatomical variation in the perforators. It carries a low complication profile at both donor- and recipient-sites (Valentini et al. 2008, Shaw et al. 2010, Liu et al. 2011). The low donor- and reconstruction-site morbidity, suitability for a western population, easy accessibility, and versatile skin and tissue
stock have guaranteed its role as one of the main workhorses in head and neck reconstructive surgery (Wei et al. 2001, Mäkitie et al. 2003, Lin, Coppit and Burkey 2004, Helmiö et al. 2010).

5.4.1.3 Latissimus Dorsi Flap

A decade after presentation of the pedicled latissimus dorsi flap, the concept of the musculocutaneous LD flap was described by Baudet in 1976 and performed by Watson in 1979 (Baudet et al. 1976, Watson, Craig and Orton 1979). In the Helsinki University Hospital Department of plastic surgery, Asko-Seljavaara and colleagues used the LD flap in microvascular head and neck reconstructions as soon as in the very early 1980’s (Asko-Seljavaara, Ryynänen and Sundell 1982). Nowadays, the LD is known as a versatile and reliable reconstructive method and is widely used in reconstructive surgery, not depending on the reconstruction site (Kim et al. 2015). The flap gets its blood supply from the thoracodorsal vessels, which form the pedicle of the flap, and medially from segmental perforating branches of the intercostal and lumbar arteries. The LD offers a good stock of reconstructive tissue and a long pedicle, which is unlikely to become affected by the atherosclerotic disease. It’s possible to harvest separate skin pedicles, which could be useful, for example, in orofacial defects.

5.4.1.4 Gracilis Flap

The free gracilis flap was first used in facial reanimation by Harii in 1976, and soon after it was introduced also in functional limb reconstructions, for example in the traumatic brachial plexus injuries and Volkmann’s contracture (Harii et al. 1976, Manktelow and McKee 1978, Ikuta, Yoshioka and Tsuge 1979). The blood supply is via a single arterial branch and two venae comitantes arising from the adductor branch of the profund femoral vessels or the medial circumflex femoral vessels. The gracilis flap can be lifted as a muscle flap or as a musculocutaneous flap with the skin perforator. It has been also used in total tongue resection when the aim is to reconstruct a functioning tongue (Yoleri and Mavioğlu 2000).
5.4.1.5 Scapular and Parascapular Flap

Scapular and parascapular musculocutaneous flaps comprise of different combinations of skin and muscle flaps based on the subscapular artery and its branches. The scapular fasciocutaneous flap anatomy was first described by Saijo in 1978 (Saijo 1978). Initially, scapular and parascapular flaps were successfully used in the head and neck region to reconstruct congenital and acquired cheek defects like hemifacial atrophy (Upton et al. 1992). The scapular flap is harvested in a horizontal direction and the parascapular flap in a vertical direction, the main axis along the lateral border of the scapular bone. The scapular flap can also be elevated as a bony flap; and this is discussed separately.

5.4.1.6 Jejunal Flap

The jejunal flap is a traditional microvascular workhorse in treatment of pharyngeal and esophageal defects (Coleman et al. 1989). It was first described by Seidenberg in 1957 for the reconstruction of defects after cervical esophagectomy and was the first first free flaps introduced in head and neck reconstructions (Seidenberg et al. 1959). For a long time, it remained as the chief method for tube-like reconstructions after, for example, pharyngolaryngectomy, but during recent decades it has been abandoned because of the favourable outcome and donor-site morbidity of tubed fasciocutaneous flaps (Wong and Wei 2010). The jejunal flap gets its vascular supply from superior mesenteric vessels. Several segmental branches each communicates with an arcade that in turn communicates with vasa recta. Vasa recta supplies segments of the jejunum, allowing the surgeon to pick a segment, usually 10 to 20 cm of length. Although it has a safe and reliable recipient-site outcome, for example low percentage of fistulas, the raising of the flap adds comorbidity as it is done by separate laparotomy (Reece et al. 1995). Moreover, the voice quality after an esophageal reconstructions is wet (Welkoborsky et al. 2013). Due to these reasons, nowadays other free flaps, such as ALT and RFA are generally preferred over the jejunal free flap (Sabri 2003, Yu et al. 2006a).
5.4.1.7 Gastro-omental Free Flap

In reconstruction of pharyngolaryngeal defects, an alternative choice is the gastro-omental flap (Mixter et al. 1990). The gastro-omental flap is a richly vascularized flap consisting of the greater curvature of the stomach and great omentum, with arterial supply from right gastroepiploic artery. It is lifted by midline laparotomy similarly to the jejunal free flap. The rich vasculature of the included omentum provides good healing capacity even in the post-radiation neck. Additionally, the gastric mucosa lining allows speech- and swallowing rehabilitation (Patel et al. 2009). An additional special advantage of the gastro-omental flap is the possibility of laparoscopic harvesting. (Craig et al. 2017)

5.4.1.8 Rectus Abdominis Flap

The rectus abdominis muscle free flap is based on the deep inferior epigastric vessels and has been used widely in reconstruction of the breast and extremities. Urken et al were the first to report its use in head and neck reconstructions (Urken et al. 1991). Rectus abdominis flaps can be lifted as muscle flaps or musculocutaneous flaps. Different alternatives are known as TRAM, DIEP and VRAM flaps. Rectus abdominis based flaps form a group of versatile soft-tissue flaps with a pedicle and vessels usually of a large diameter. In musculocutaneous flaps, the area of skin transferred with the flap can be extensive. The muscle flap can be elevated with varying thicknesses and varying amounts of underlying muscle.

TRAM Flap

The transverse rectus abdominis muscle flap was first experimented upon in 1979 by Holmström and colleagues (Holmström 1979). The TRAM flap is a musculocutaneous flap which includes a small area of anterior rectus fascia, rectus abdominis muscle, and a large skin-subcutis flap. The pedicle consists of inferior epigastric vessels. The amount of subcutaneous tissue can make the flap a bit bulky. Compared to many other free flaps, the vessels of the pedicle are of a decent diameter, and flap tissue is highly vascularized, which makes TRAM also a good option for a second-line reconstructive procedure. In salvage and
secondary reconstructive surgery of the head and neck, the long pedicle can also be anastomosed to internal mammary vessels (Roche et al. 2012).

**DIEP Flap**

The deep inferior epigastric perforator flap is formed of the same skin-subcutis island as the TRAM. It is based on the perforators originating from the deep epigastric vessels, but only a small amount of the anterior rectus fascia and muscle are included (Koshima and Soeda 1989, Allen and Treece 1994).

**VRAM Flap**

The vertical rectus abdominis muscle flap is elevated with the same pedicle as the abovementioned flaps, but in a vertical fashion sacrificing more muscle than DIEP or TRAM flaps. Traditionally, it is used in perineal and groin reconstruction and for example when previous abdominal procedures interfere with elevating a transverse flap (Russo et al. 1994). In hypopharyngeal reconstruction, use of this flap was reported by Ninkovic in the 1990's (Ninković et al. 1999).

**5.4.1.9 Other Soft-Tissue Free Flaps**

In addition to these free flaps, a wide variety of microvascular tissue flaps has been described and utilized during the evolution of head and neck reconstructions. At our center, we have used, to date, over 40 different free flap types for head and neck microvascular reconstructions.

**5.4.2 Composite Flaps**

In complex head and neck defects, replacing like with like and restoring functionality can be challenging. Vascularized bone grafts offer a tool in reconstructing maxillomandibular defects without sacrificing the special functional features of the anatomical area, as speech and dental rehabilitation.
5.4.2.1 Osteocutaneous Radial Forearm Flap

The osteocutaneous radial forearm flap was described by Matthews and Soutar in 1984 and 1986 (Matthews et al. 1984, Soutar and Widdowson 1986). At the time of its introduction, it was thought to be a promising tool in head and neck reconstruction because of the relatively easy harvesting and a thin pliable soft-tissue part, especially suitable for mandibular reconstruction. The bone stock provided is rather thin and best applicable in non-tooth-bearing areas. The OC-RFA flap is harvested in a similar fashion to that of RFA flap, including a 5 to 12 cm piece of radial bone. In the first published patient series, there was a significant incidence of donor-site fractures, which, prophylactic plate fixation has served to avoid (Timmone et al. 1986, Werle et al. 2000). Although the OC-RFA is one of the oldest composite free flaps in use, the clinical use of the flap has been precluded by potential complications related to donor site bone refixation and need for skin grafting (Villaret and Futran 2003).

5.4.2.2 Fibular Flap

The fibular free flap is probably the most popular flap used in composite maxilla-mandibular reconstructions because of its many advantages. Germain et al first introduced the fibular flap for jaw reconstruction 1991 (Germain et al. 1991). Since then, it has been the main workhorse in head and neck reconstruction. Many advantages of the fibular flap include its easy tailoring and low donor-site morbidity. The flap provides a good length of vascularized bone which allows osteotomies and is easily contoured to fit orofacial bone defects (López-Arcas et al. 2010). In addition, the elevation of the flap can be done simultaneously with reconstruction-site preparation. In contrast, the soft-tissue stock might be insufficient in extensive reconstructions and the pedicle might be short. Use of the fibular flap may be compromised because of peripheral artery atherosclerotic disease, especially in the elderly, so the vascular anatomy is generally preoperatively screened with angiography (Blackwell 1998, Ling and Peng 2012).
5.4.2.3 Scapular Flap

The scapular bone flap provides a reconstructive option with several alternative soft tissue components and versatile bone stock. The pedicle can be harvested as a circumflex scapular pedicle or a thoracodorsal pedicle. Moreover, the scapular bone flap provides many alternatives for soft tissue reconstruction, in comparison to fibular and DCIA flaps (Brown, Bekiroglu and Shaw 2010). Scapular vasculature is also seldom affected by atherosclerotic disease. The one disadvantage of the scapula has been thought to be its location, as there would be a need for repositioning of the patient after harvesting the flap. At our institution we nowadays perform the procedure positioning the patients in a tilted decubital position, also described by other institutes (Clark, Vesely and Gilbert 2008). Concerns arise regarding the relatively thin bone material, especially when planning dental implant therapy (Moscoso et al. 1994, Urken et al. 2001).

5.4.2.4 Iliac Crest Flap

The idea of the iliac crest (deep circumflex iliaca artery flap) flap was already presented by Tamai in 1979 (Tamai 1979). The DCIA provides a sufficient reconstructive stock of bone and soft tissue, but the skin island of the flap is of limited size and can be bulky, which is a limitation in maxilla-mandibular reconstructions. Elevation of the flap is slightly more challenging, and the pedicle can be short. The donor-site complications are known to include chronic pain, hernias, gait problems, and fractures of the anterior superior iliac spine (Brown 1996, Kim et al. 2016).

5.4.2.5 Helix Flap

Structural similarities between the nasal alar and auricular helices have allowed the use of free helical composite grafts to repair small nasal defects. The helix flap was described first by Parkhouse in the 1980’s, utilizing antegrade perfusion, and later in the 1990’s by Tanaka and Pribaz with the retrograde pedicle to provide a sufficient pedicle (Parkhouse and Evans 1985, Tanaka et al. 1993, Pribaz and Falco 1993). The pedicle is based on superficial temporal vessels. The helix flap provides excellent tissue and texture match in nasal
reconstructions, but the disadvantage is the limitations in size of the cartilage, which can be transferred without mutilating the donor-site. The major advantage of a helix flap is that it can serve to reconstruct full-thickness nasal deformities with a single flap containing cartilage and skin. The donor-site carries acceptable mortality and can be closed primarily or with assistance of skin grafting.

5.5 Recent Improvements in and Future Prospects for Head and Neck Reconstructions

5.5.1 Suprvmicrosurgery

In 1997 pioneering microsurgeon Isao Koshima reported at the First International Course on Perforator Flaps and Artelialized Skin Flaps, that it is possible to raise flaps based on perforator vessels of caliber less than 0.8 mm. Since then, the concept of microsurgery including microcaliber vessels ranging from 0.3 to 0.8 mm has been called supermicrosurgery (Koshima et al. 2010). The introduction of this practice and its technical advancements apply to transfer of flaps like auricular to eye lid and finger- and toe-tip transplantations. In addition, the applications of supermicrosurgery include lymphedema treatment, vascularized nerve grafts, microsurgical flap salvage and aesthetic supermicrosurgery in the form of adiposal and dermal fat flaps (Masia et al. 2014).

5.5.2 New Concepts of Local and Pedicled Flaps

5.5.2.1 Internal Mammary Artery Perforator Flap

The IMAP flap is a pedicled fasciocutaneous flap developed as a modification of the deltopectoral flap and described first by Yu et al in 2006 (Yu, Robin and Chevray 2006b). It is based on single or multiple internal mammary artery perforators. Unlike traditional deltopectoral flap, it receives its blood supply medially and because of that, the flap provides thin pliable tissue with a wide arc of rotation. This reliable and well-vascularized flap is we— suited to cutaneous and pharyngeal reconstructions and is also applicable in post-sternotomy wound infections; and donor site can be closed primarily (Vesely et al. 2007, Kannan 2016).
5.5.2.2 Supraclavicular Artery Flap

The supraclavicular artery flap is a fasciocutaneous pedicled flap based on the supraclavicular artery. This flap can be used as a fasciocutaneous flap or as a tunneled flap, so the pedicle becomes longer (Pallua and Magnus Noah 2000). The shoulder region provides optimal skin color and texture match for the head and neck region and donor-site morbidity is low. This flap has been reported with a successful outcome in various reconstructions for limited-to-extensive pharyngeal defects, and for cutaneous reconstructions (Emerick et al. 2014). It can be designed as extended with prefabrication, to allow a larger flap area and prevent flap-tip necrosis (Pallua and Kim 2017).

5.5.2.3 Submental Artery Flap

Martin et al. described the submental artery flap in 1990 (Martin et al. 1994). This is an alternative flap especially for intraoral reconstruction, based on the submental branch of the facial artery. It is a pliable and thin flap, which makes it ideal for reconstructing defects in the oral cavity. It also provides an excellent texture and color match in facial reconstructions. This flap has traditionally been used in intraoral, lip, and pharyngeal defects. In oncological surgery, meticulous consideration must be given to level I nodes, to prevent the transfer of tumor cells along with the flap (Chow et al. 2007). To reconstruct nasal, forehead glabellar, preauricular, periorbital, and socket defects, the flap can be used as a reverse-flow flap (Karaçal et al. 2006).

5.5.2.4 Propeller Flaps

In 1991, Hyakusoku et al. introduced a propeller shaped flap based on a central subcutaneous pedicle, which could be rotated from 90 degrees (Hyakusoku, Yamamoto and Fumiiri 1991). This concept was further developed into a perforator propeller formed flap based on a skeletonized perforating vessel and which could be rotated 180 degrees on an eccentric pivot point, as described by Hallock in 2006 and later modified by Teo (Hallock
2006, Teo 2010). The main advantage of perforator propeller flaps is the possibility of free-style reconstruction which benefits local anatomical features. In addition, the harvesting of propeller flaps is simpler and does not necessary require advanced microsurgical skills. The disadvantage is risk for vascular compromise due to torsion of the pedicle. In the head and neck area, facial vessel-based propeller flaps have been used for reconstructing limited-size lip and nose defects (Brunetti et al. 2017).

5.5.3 New Concepts of Free Flaps

5.5.3.1 Chimeric Flaps

Chimeric flaps are widely used in oral and facial reconstruction because of their versatility in treating composite tissue defects. Generally, this is a flap consisting of at least two different tissue types, which receive their blood supply from separate perforators arising from the same main vessel. The main advantage of this flap is its three-dimensional structure (Huang et al. 2003). The requirement for this kind of flap is sufficient length of the perforators reaching different tissue layers. The vascular systems which can supply chimeric flaps are the deep circumflex iliac, lateral femoral circumflex, thoracodorsal, peroneal, subscapular, radial, and inferior gluteal arterial systems. It is generally advised to fill the dead spaces in an open fracture, for example with musculocutaneous free flap, to reduce the risk for complications. Similarly, in head and neck reconstruction indications are that filling the dead spaces in composite reconstructions reduces the risk for intraoral fistulas (Wilkman et al. 2016). In head and neck reconstructions, especially scapular bone-latissimus dorsi, and DCIA-antjerolateral thigh chimeric flaps are regularly utilized for this purpose (Lee, Wiraatmadja and Mun 2015, Chao et al. 2016)

5.5.3.2 Ultrathin Fascial Flaps

Vascularized fascial flaps provide an excellent ultrathin reconstructive alternative for head and neck defects when traditional flaps are too bulky (Rose and Norris 1990). The advantages especially in orofacial reconstruction include excellent contour and pliability, but the disadvantage of this flap type, the need for separate skin grafting, is common for all of their types. The numerous possible donor-sites include anterolateral thigh, temporoparietal,

5.5.3.4 TAPAS Flap

The free temporal artery posterior auricular skin flap (TAPAS) is a small fasciocutaneous flap suitable for small-to medium-sized facial defects, especially when the need is for a pliable flap with excellent color and texture match with minimal donor-site morbidity. A pedicled retroauricular flap had been already described in 1969 and has been used in numerous variations (Washio 1969). In 2016 Lassus and colleagues presented the free flap variant of this flap which utilized retroauricular skin flap (Lassus and Lindford 2017). The vasculature of this skin flap consists of an anastomosis between superior temporal vessels and posterior auricular vessels.

5.5.3.5 Paraumbilical Perforator Flap

The use of the paraumbilical tissue flap in total reconstruction of the external auditory meatus was described in 2015 (Lassus et al. 2015). This flap was used to reconstruct an exceptional defect after total ear amputation in case of invasive melanoma. The pedicle consisted of a paraumbilical perforator raising from the deep inferior epigastric artery. This flap includes skin, umbilical stalk, and an additional fat pad.

5.5.4 Facial Transplantation

Facial transplantation is a composite tissue transplantation from deceased donor to recipient. In terms of facial reconstructions, facial transplantation is an ultimate alternative in the reconstructive armamentarium, being an extremely complex and invasive procedure. In cases of complex facial deformities when the conventional reconstructive methods fall short, the face transplant may offer the ultimate method of “like with like” reconstruction and the possibility to restore multiple functions of this special anatomic area. Facial transplantation is thought to be ethically similar to and subject to similar concerns and laws as other organ transplantations. Unlike most other organ transplantations, like heart or liver, the face transplantation is not performed for a vital indication and this raises another kind of ethical
question. The first facial transplantation was performed in France in 2005 by Devauchelle and Dubernard, in 2014 there were in total 29 reported cases worldwide, and the number keeps rising (Devauchelle et al. 2006, Dubernard and Devauchelle 2008, Smeets et al. 2014). The first facial transplantation in Finland was performed in Helsinki University Hospital in 2016 (Lassus et al, in press) on a patient who had undergone multiple local and free flap face reconstructions with failures and suffered a severe functional and esthetical disability. Up to date, two facial transplantations have been performed and the recovery and restoration of the patients’ functionality and aesthetics of have fulfilled expectations.

5.5.5 The Future of Reconstructive Head and Neck Surgery

Definitive surgical repair aiming for functional and anatomical reconstruction is the gold standard for all the patients, and advances in microsurgical techniques and in knowledge of special anatomical features of free flaps aid this goal. The development of supermicrosurgical techniques during the recent decades has added new flaps to the reconstructive selection. Minimally invasive approaches are arising in all surgical fields. The basic philosophy is to avoid the extensive morbidity of “maxi-invasive” surgical approaches and in that way achieve shorter hospitalization and superior aesthetic and functional recovery (Goh, Ng and Teo 2010). In head and neck microsurgery, the mini-invasive approaches include utilizing the natural orifices, small incisions and possible endoscopic ports, and robotic assistance.

In addition, stem cells and tissue engineering in reconstructive applications has been under active investigation during recent years. In the head and neck area, maxilla-mandibular bone defects present a challenge, and the interest has been high in developing tools to aid de novo bone formation and tissue regeneration. The methods under research include bioactive factors, scaffold materials, gene delivery, and mesenchymal and adipose stem cells (Smith et al. 2015). In benign maxilla-mandibular lesions, some promising results have been achieved by growing neomaxilla originating from adipose stem cells in combination with tricalcium phosphate granules (Mesimäki et al. 2009, Sándor et al. 2013). In tissue engineering, one of the most-studied bioactive adjuncts is human bone morphogenetic protein-2 (BMP-2), which has been used along with collagen carrier and allogeneic bone to reconstruct benign
mandibular defects (Herford and Boyne 2008). However, its safe use for malignant lesions remains controversial (Woo 2013). Calcium phosphate is the most widely used bone substitute shown to be osteoconductive and regenerative. Calcium phosphate based scaffolds are promising tools combined with 3D technology in reconstructing maxilla-mandibular defects (Bose and Tarafder 2012).

The nature of the three-dimensional functional anatomy of the head and neck area aroused the interest for utilizing 3D technologies and developing 3-D-planning and computer-aided design and manufacturing (CAD/CAM). Such 3-D imaging and planning in medicine was first described by Mankovich in the 1990’s, and since then it has slowly gained success in certain fields of medicine, for example in planning orthognatic therapies (Mankovich et al. 1994). In head and neck surgery, these technologies are mainly used in manufacturing tools for resection and shaping bone flaps in mandibular reconstructions. The 3D technique is utilized in patient specific saw guides and reconstruction plates and eventually it serves as aid in pre- and intraoperative planning (Wilde and Schramm 2014). Still, 3D technologies remain time consuming and offer a chance for error (Choi and Kim 2015). In our institute, 3D technology is nowadays regularly used in preoperative planning and implant design.

**5.5.6 Ethical Aspects**

Innovation and development of modern technologies unavoidably raise policy and ethical concerns. As in any surgical specialty, reconstructive surgery and development of new methods should be subjected to meticulous research and protocols before applications to patients. The fundamental ethical aspects which should be taken to consideration are patient’s autonomy, informed consent, benefits and non-malfeasance. In developing new reconstructive methods, often no extensive research or even experience exists for that particular method, and the nature of reconstructive surgery is extremely heterogenic. In this delicate situation, it is highly important to practice total transparency towards patients and towards the reconstructive community. The introductions of totally new methods are, by good scientific and ethical manners, managed by introducing a research protocol. In Finland, local ethical committees require authorizations. In addition, the law of patient autonomy and
6. Aims of the Present Study

The overall aim of this study was to evaluate the practice, and different methods in head and neck reconstructive surgery

Specifically the aims were as follows.

**Study I**

To evaluate the changing trends in and characteristics of head and neck microvascular reconstructive surgical practice at our institution between 1995 to 2012.

**Study II**

To compare the advantages and disadvantages of the three most used composite free flaps in head and neck surgery; DCIA, scapular and fibular flap.

**Study III**

To evaluate a single institution experience of using the submental artery flap as a reconstructive method in patients who are not candidates for a microvascular free flap reconstruction.

**Study IV**

To present and evaluate novel methods of facial and head and neck reconstruction by using three different microvascular free tissue transfers raised from the external ear; TAPAS, helix and hemiauricular flap.
7. Patients and Methods

At Helsinki University Hospital plastic surgeons and maxillofacial surgeons, in collaboration with otorhinolaryngologist – head and neck surgeons, manage the reconstructions of head and neck patients. The multidisciplinary head and neck tumor board was established in the 1970’s, and in addition to these specialists, it consists of pathologists and radiologists. All the patients with head and neck malignancy are referred to the meeting prior to treatment. In addition, plastic surgeons are involved in the reconstruction of traumatic facial lesions as well as in skull base defects with neurosurgeons. Patients with congenital head and neck defects are referred to pediatric craniofacial unit in the Department of Plastic Surgery, and head and neck plastic surgeons and plastic surgeons with pediatric congenital subspecialty manage their treatment. The follow-up data of the patients was collected retrospectively from the hospital charts during 2012 and 2013.

The Research Board at the Helsinki University Hospital approved all the study protocols and granted an institutional research permission.
7.1 Patients

Study I

During the study period between 1995 to 2012 all consecutive patients receiving a free flap for oral, oropharyngeal, laryngeal, facial, or skull base defects in the Department of Plastic Surgery at the Helsinki University Hospital were included. The 541 patients were receiving 594 single- or double-flap reconstructions. Most of the patients were treated for malignancy, n=497, in addition the indications for reconstruction included traumas, benign tumours, congenital defects, burn injuries, postoperative defects, infections, and complications of radiotherapy. To analyze the trends, the data was divided into three equal time periods, from 1995 to 2000, from 2001 to 2006, and from 2007 to 2012. From the first study semester the data were collected regarding patients age, gender, disease location, diagnosis, and type of reconstruction. Additional data regarding complications, oncological classification and perioperative parameters came from the last two study trimesters.

Table 1. Indications for reconstructions.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>%</td>
<td></td>
<td>%</td>
<td></td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Number of free flaps</td>
<td>205</td>
<td></td>
<td>152</td>
<td></td>
<td>237</td>
<td></td>
</tr>
<tr>
<td>Oncological</td>
<td>168 81.9</td>
<td></td>
<td>116 76.3</td>
<td></td>
<td>213 89.9</td>
<td></td>
</tr>
<tr>
<td>Trauma</td>
<td>8 3.9</td>
<td></td>
<td>7 4.6</td>
<td></td>
<td>6 2.5</td>
<td></td>
</tr>
<tr>
<td>Congenital</td>
<td>8 3.9</td>
<td></td>
<td>1 0.7</td>
<td></td>
<td>1 0.4</td>
<td></td>
</tr>
<tr>
<td>Burn injuries</td>
<td>4 2.0</td>
<td></td>
<td>1 0.7</td>
<td></td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td>Benign tumors</td>
<td>3 1.5</td>
<td></td>
<td>3 2</td>
<td></td>
<td>2 0.8</td>
<td></td>
</tr>
<tr>
<td>Infections</td>
<td>1 0.5</td>
<td></td>
<td>0 0</td>
<td></td>
<td>3 1.3</td>
<td></td>
</tr>
</tbody>
</table>
Study II

Between 2000 and 2012 a total of 163 patients received maxillo-mandibular microvascular reconstruction with an iliac crest, scapular or fibular composite flap at Helsinki University Hospital. The patients of this study included patients from Study I with iliac crest (DCIA), scapular or fibular composite reconstructions and patients receiving the abovementioned reconstructions at the Department of Maxillofacial Surgery. Patients’ average age was 58 years (range, 17 to 89).

Table 2. Patient demographics.

<table>
<thead>
<tr>
<th></th>
<th>All n</th>
<th>%</th>
<th>DCIA n</th>
<th>%</th>
<th>Scapula n</th>
<th>%</th>
<th>Fibula n</th>
<th>%</th>
</tr>
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<tr>
<td>Number</td>
<td>163</td>
<td></td>
<td>92</td>
<td>56.4</td>
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<td>17.8</td>
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<tr>
<td>Male</td>
<td>105</td>
<td>64.4</td>
<td>62</td>
<td>67.4</td>
<td>26</td>
<td>61.9</td>
<td>17</td>
<td>58.6</td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>35.6</td>
<td>30</td>
<td>32.6</td>
<td>16</td>
<td>38.1</td>
<td>12</td>
<td>41.4</td>
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<tr>
<td>Age (range) median</td>
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<td>(17-89)</td>
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<td>(17-89)</td>
<td>60</td>
<td>(33-78)</td>
<td>55</td>
<td>(20-87)</td>
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<td>Oncological surgery</td>
<td>149</td>
<td>91.4</td>
<td>87</td>
<td>94.6</td>
<td>41</td>
<td>97.6</td>
<td>21</td>
<td>72.4</td>
</tr>
</tbody>
</table>


**Study III**

Between 2004 and 2007, a total of 10 patients (5 male, 5 female) with oral squamous cell cancer unsuitable for traditional microvascular repair of the surgical defect after primary resection received submental artery flap reconstruction. In selective cases, a sentinel lymph node biopsy was performed to secure oncological safety. Patient records were reviewed retrospectively. The average follow-up time was 100 months (range, 72-109). The average age of the patients was 61 years (range, 33-82). Two of them had early stage disease (T1-2 N0) and the rest had locally advanced disease (T3-4 N0).

Table 3. Patient and tumor demographics.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Male/Female</th>
<th>Location</th>
<th>Clinical Stage</th>
<th>Pathological Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83</td>
<td>F</td>
<td>Nose + Maxilla</td>
<td>T4N0M0</td>
<td>T4N0M0</td>
</tr>
<tr>
<td>2</td>
<td>53</td>
<td>M</td>
<td>Soft palate</td>
<td>T2N0M0</td>
<td>T2N0M0</td>
</tr>
<tr>
<td>3</td>
<td>63</td>
<td>M</td>
<td>Soft palate</td>
<td>T1N0M0</td>
<td>T3N0M0</td>
</tr>
<tr>
<td>4</td>
<td>53</td>
<td>M</td>
<td>Tongue</td>
<td>T2N2cM0</td>
<td>T2N1M0</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>M</td>
<td>Tongue</td>
<td>T3N0M0</td>
<td>T3N1M0</td>
</tr>
<tr>
<td>6</td>
<td>67</td>
<td>F</td>
<td>Tongue</td>
<td>T3N0M0</td>
<td>T3N0M0</td>
</tr>
<tr>
<td>7</td>
<td>82</td>
<td>F</td>
<td>Tongue</td>
<td>T3N0M0</td>
<td>T3N0M0</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>M</td>
<td>Tonsil</td>
<td>T3N2bM0</td>
<td>T3N2bM0</td>
</tr>
<tr>
<td>9</td>
<td>77</td>
<td>F</td>
<td>Tonsil</td>
<td>T3N2M0</td>
<td>T3N2M0</td>
</tr>
<tr>
<td>10</td>
<td>51</td>
<td>F</td>
<td>Floor of mouth</td>
<td>T2N0M0</td>
<td>T2N0M0</td>
</tr>
</tbody>
</table>
Study IV

Between 2011 and 2016 20 free flaps comprising three different flap types of ear origin were performed to reconstruct maxillofacial defects. The flap types were the helix, the TAPAS, and the hemiauricular, all of them based on branches of the superficial temporal vasculature. A total of 19 patients received reconstruction, one of them with two separate flaps, because of a failure. Patients’ mean age was 57 years (range, 21 to 81).
Table 4. Patient demographics.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Male/Female</th>
<th>Flap</th>
<th>Diagnosis</th>
<th>Reconstruction area</th>
<th>Primary/Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53</td>
<td>F</td>
<td>HELIX</td>
<td>BCC</td>
<td>Nasal-alar</td>
<td>Secondary</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>F</td>
<td>HELIX</td>
<td>BCC</td>
<td>Nasal-alar, nasolabial</td>
<td>Primary</td>
</tr>
<tr>
<td>3</td>
<td>55</td>
<td>M</td>
<td>HELIX</td>
<td>TRAUMA</td>
<td>Nasal-alar</td>
<td>Primary</td>
</tr>
<tr>
<td>4</td>
<td>62</td>
<td>M</td>
<td>HELIX</td>
<td>TRAUMA</td>
<td>Nasal-alar</td>
<td>Primary</td>
</tr>
<tr>
<td>5</td>
<td>62</td>
<td>M</td>
<td>HELIX</td>
<td>Post-RXT</td>
<td>Nasal-alar</td>
<td>Primary</td>
</tr>
<tr>
<td>6</td>
<td>40</td>
<td>F</td>
<td>HELIX + hair bearing scalp</td>
<td>BURN</td>
<td>Nasal-alar, dorsum brow</td>
<td>Primary</td>
</tr>
<tr>
<td>7</td>
<td>62</td>
<td>F</td>
<td>HELIX</td>
<td>BCC</td>
<td>Nasal-alar</td>
<td>Primary</td>
</tr>
<tr>
<td>8</td>
<td>58</td>
<td>F</td>
<td>HELIX</td>
<td>SCC</td>
<td>Nasal columnella</td>
<td>Secondary</td>
</tr>
<tr>
<td>8b</td>
<td>58</td>
<td>F</td>
<td>HELIX</td>
<td>SCC</td>
<td>Nasal columnella</td>
<td>Salvage</td>
</tr>
<tr>
<td>9</td>
<td>46</td>
<td>F</td>
<td>HELIX</td>
<td>BURN</td>
<td>Nasal-alar</td>
<td>Primary</td>
</tr>
<tr>
<td>10</td>
<td>71</td>
<td>M</td>
<td>HELIX</td>
<td>BCC</td>
<td>Nasal-alar</td>
<td>Primary</td>
</tr>
<tr>
<td>11</td>
<td>22</td>
<td>F</td>
<td>TAPAS</td>
<td>TRAUMA</td>
<td>Lower eyelid</td>
<td>Secondary</td>
</tr>
<tr>
<td>12</td>
<td>42</td>
<td>M</td>
<td>TAPAS</td>
<td>SCC</td>
<td>FOM</td>
<td>Primary</td>
</tr>
<tr>
<td>13</td>
<td>69</td>
<td>F</td>
<td>TAPAS</td>
<td>SCC of MANDIBLE</td>
<td>Lower lip</td>
<td>Secondary</td>
</tr>
<tr>
<td>14</td>
<td>64</td>
<td>M</td>
<td>TAPAS</td>
<td>SCC</td>
<td>Tongue</td>
<td>Primary</td>
</tr>
<tr>
<td>15</td>
<td>55</td>
<td>M</td>
<td>TAPAS + CONCHA</td>
<td>BCC</td>
<td>Lateral nose</td>
<td>Primary</td>
</tr>
<tr>
<td>16</td>
<td>70</td>
<td>M</td>
<td>TAPAS</td>
<td>SCC</td>
<td>FOM</td>
<td>Primary</td>
</tr>
<tr>
<td>17</td>
<td>81</td>
<td>M</td>
<td>TAPAS</td>
<td>SCC</td>
<td>FOM</td>
<td>Primary</td>
</tr>
<tr>
<td>18</td>
<td>79</td>
<td>M</td>
<td>AURICULAR</td>
<td>SCC</td>
<td>Subtotal nose</td>
<td>Secondary</td>
</tr>
<tr>
<td>19</td>
<td>69</td>
<td>F</td>
<td>AURICULAR + RFA</td>
<td>BCC</td>
<td>Subtotal nose</td>
<td>Secondary</td>
</tr>
</tbody>
</table>

BCC = Basal cell carcinoma, SCC = Squamous cell carcinoma, RFA = Radial forearm flap, FOM = Floor of mouth, RXT = Radiation therapy, AURICULAR = Hemiauricular
7.2 Data Collection

Study I & Study II

The retrospective data in these studies came from hospital charts regarding reconstructive method, patient characteristics, and reconstruction results for all the head and neck reconstruction patients treated at our institution during the study period. Regarding the Study II, all the patients registered with the operation code for composite reconstruction were reviewed, and all patients with an iliac crest, fibular or scapular composite reconstruction were. Data came from individual patient charts in electronic and paper form with these characteristics recorded. Regarding the older files, the hospital archive was searched. In addition, in selective cases, dental x-rays were collected and reviewed, and the data then analyzed.

Study III and Study IV

Patient data and follow-up details were recorded from patient charts. Intraoperative details regarding surgical operative techniques came from each operating surgeon. Patients were included in the study at the time of surgery, and the data regarding preoperative, intraoperative, and postoperative measurements came from patient charts.

7.3 Statistical Analyzes

Statistical analyse took place in Study II. The data were analyzed with SPSS 21 (IBM, Armonk, NY, USA). The Kruskall-Wallis and Chi² served for the categorical data and Mann-Whitney U-test for comparison of the groups of continuous data.
7.4 Surgical Methods

Study III

7.4.1 Submental Artery Flap

The elliptical flap below the mandibular arch and above the hyoid bone was designed to match the resection size and flap size measured by pinch test, to secure the primary closure. Identification of the pedicle was begun from the base of the designed flap. Additionally, level 1 nodes at the border of the submandibular gland were identified at this stage in five cases of a clinically staged N0 neck either SLNB or nodal sampling for frozen sections was performed. In case of SLNB the static lymphoscintigraphy was performed with radiocolloid (Nanocoll, Sorin Biomedical, Sorin, Italy), one day preoperatively. The level 1 nodes were carefully dissected to avoid a possible transfer of cancer cells with the flap. In one case of a positive SLNB, an extra attention was paid to dissection of the pedicle. In three patients, who did not undergo SLNB or nodal sampling because of the palliative intentions, the nodes were still carefully separated from the pedicle. After identification and securing of the submental artery, the flap was raised under the subplatysmal layer, approaching from distal to proximal and inferior to superior direction. Additional pedicle length could be gained by dividing the facial vessels distal to the origin of the submental artery, but in our experience, this was unnecessary. After intraoral tumor resection, the flap was de-epithelized and tailored to fit the acquired defect. Transposition of the flap under the mandible and fixation intraorally took place. In cases with cancer of the floor of mouth, the flap donor area exposition was used for intraoral tumor resection. This gave an adequate exposure without splitting the mandible. In one case with a palatal defect the skin was placed at the oral site, and the platysmal muscle layer at the nasal site of the defect, to allow mucosalization of the mucosal defect area. The donor area was closed primary.
Figure 3. Lifting of the submental artery flap.

Figure 4. Submental flap sutured in place of tongue defect.
Study IV

7.4.2 Helix Flap

The ascending helix of the contralateral ear serve in reconstruction of nasal alar defects. A preauricular incision was made down to the lobule, and the ST vessels were identified. The pedicle consisted of the proximal end of the ST vessels. The proximal dissection was carried out close to the maxillary branches, and if the need arose for a better exposure, an additional extension of the incision towards temporal hairline was performed. Distally the dissection of the pedicle included ligation of the small branches supplying the tragus. All subcutaneous tissue between the ST vessels and the helix flap was preserved to protect the small branches of vasculature supplying the flap itself. The distal ends of ST vessels were ligated cranially in cases with an antegrade pedicle. A longer retrograde pedicle could also serve. The flap was designed to include the root of the helix and adjacent preauricular skin. Furthermore, the dissection was continued along the avascular plane superficially to the deep temporal fascia and the flaps were released from the remainder of the helical rim and root. The pedicle was divided once the recipient vessels were available. The donor-site was reconstructed with an Antia-Buch chondrocutaneous advancement flap and the preauricular incision was primary closed.
Figures 5 and 6. Planning the helix flap.
7.4.3 TAPAS Flap

This flap was designed over the retroauricular sulcus to include the non-hairbearing skin behind the ear and mastoid region. The anterior border was parallel to the auricular rim approximately 5 mm behind it, the cranial border was the helical attachment to the temporal skin, the caudal limit was where the concha ends, and the posterior border was a mirror image of the anterior line overlying the posterior auricular skin. Dissection of the superficial temporal artery and vein was performed extending the incision preauricularly. If extra exposure was needed a short temporal hairline incision was performed. The dissection was performed proximally to the maxillary branches and then continued in a cranial direction where temporal vessels were ligated distally. Small branches of the tragus area were ligated. Above the helical root the small branches supplying the flap were preserved. The suprathelical fat and the pedicle were dissected superficial to the deep temporal fascia along the avascular plane. At the distal end of the flap the posterior auricular artery was ligated, and the small perforators to the cartilage coagulated. The dissection near the helical root was maintained tightly on the cartilage to avoid damage to the vascular branches. The pedicle was ligated at the desired level, proximal to the maxillary branches of temporal vessels, and care was taken
not to damage the branches of the facial nerve at this level. The defect was closed directly, or if the anterior skin line extended close to the helical rim, with a skin graft. The preauricular incision was directly closed.

Figure 8. Preoperative planning of the TAPAS flap

Figure 9. TAPAS flap before implantation.
7.4.4 Hemiauricular Flap

For a subtotal nose reconstruction, the extended helix flap, the hemiauricular flap, is an option. The flap designed included preauricular skin, 3 cm of the superior helix, the helical root, and part of the concha, the tragus, and part of the lobulus. Raising of the flap was performed in a similar fashion to the helix flap but with additional preservation of the soft tissue near the ST pedicle and the ear. In addition, tragal and lobular vascular branches were preserved. The remains of the ear were reconstructed by advancement of the lateral part of the ear.

Figure 10. Preoperative planning of the hemiauricular flap.
Figure 11. Hemiauricular flap before implantation.

Figure 12. Hemiauricular, TAPAS and helix flaps.
8. Results

8.1 Study I – Evolution and characteristics of head and neck microvascular reconstructions at our institute between 1995 and 2012

Demographic Results

Median patient age was 56 years, and average age 54 (range, 2 to 88). The majority of the patients were male (325, 60.1%), and the minority were female (216, 39.9%). Most of the patients were treated for oncological indications (497, 83.7%). During the study period an increasing trend emerged in both primary oncological surgery (85% to 89.9%) and secondary salvage surgery (17.2% to 26.7%).

Table 5. Patient characteristics.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Number of free flaps</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>205</td>
<td></td>
<td>152</td>
<td></td>
<td>237</td>
<td></td>
<td>594</td>
<td></td>
</tr>
<tr>
<td>Age, years (range)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>median</td>
<td>53</td>
<td>(6-85)</td>
<td>55</td>
<td>(2-82)</td>
<td>59</td>
<td>(5-88)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>132</td>
<td>63.9</td>
<td>79</td>
<td>52.0</td>
<td>146</td>
<td>61.6</td>
<td>357</td>
<td>60.1</td>
</tr>
<tr>
<td>Female</td>
<td>73</td>
<td>36.1</td>
<td>73</td>
<td>48.0</td>
<td>91</td>
<td>38.4</td>
<td>237</td>
<td>39.9</td>
</tr>
<tr>
<td>Oncological indication</td>
<td>168</td>
<td>81.9</td>
<td>116</td>
<td>76.3</td>
<td>213</td>
<td>89.9</td>
<td>497</td>
<td>83.7</td>
</tr>
</tbody>
</table>
The most common location for an oncological defect was the oral cavity, followed by the oropharynx and laryngopharynx (tonsils, base of tongue and larynx/pharynx), sinonasal and skull base areas and facial soft tissue. No significant variation existed in defect sites during the study period. Most of the malignancies were squamous cell carcinomas (249, 75.7%). There were in addition no significant changes in tumor staging, T1-T2 disease comprised approximately 49.6% of the cases and T3-T4 disease 50.4% during the study period. Neoadjuvant chemoradiation was given to one patient between 2001 and 2006, and to 20 patients between 2007 and 2012.

Table 6. Distribution of the defect location after oncological surgery.

<table>
<thead>
<tr>
<th>Location</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral cavity</td>
<td>237</td>
<td>47.7</td>
</tr>
<tr>
<td>Oropharynx</td>
<td>165</td>
<td>33.2</td>
</tr>
<tr>
<td>Sinonasal &amp; skullbase</td>
<td>46</td>
<td>9.3</td>
</tr>
<tr>
<td>Soft tissue</td>
<td>37</td>
<td>7.4</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Reconstructions

During the study period, the total number used was 25 different flaps and 8 different flap combinations. Most of the reconstructions were performed with soft tissue flaps (506, 82.9%). The number of different flap types increased during the three study periods from 14 to 17 to 24. In addition, similar expansion in versatility was seen in chimeric and double flaps, which were used as a reconstructive method in 4.9% of operations during the first study trimester, 2.6% during the second, and 12.2% during the last.

The main workhorses in head and neck free flap reconstruction were the ALT, the RFA, the LD, the gracilis flap, the chimeric scapular bone-LD flap and the fibular flap. The ALT was first introduced in our center in 2001 and soon after it replaced the RFA as the most commonly performed flap type.
Table 7. Changing trends in flap reconstruction.

<table>
<thead>
<tr>
<th>Year</th>
<th>ALT</th>
<th>RFA</th>
<th>LD</th>
<th>Gracilis</th>
<th>LD-Scapular bone</th>
<th>Scapula</th>
<th>Fibula</th>
<th>Jejunum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995-2000</td>
<td>0</td>
<td>103</td>
<td>41</td>
<td>11</td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>2001-2006</td>
<td>64</td>
<td>37</td>
<td>5</td>
<td>17</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>2007-2012</td>
<td>86</td>
<td>53</td>
<td>24</td>
<td>10</td>
<td>18</td>
<td>2</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

ALT = Anterolateral thigh flap, RFA = Radial forearm flap, LD = Latissimus dorsi flap

The average operation length was 8 hours 31 minutes (range, 3 h 30 min to 14 h 24 min). Non-oncological reconstructions had in general the shortest operative times, averaging 6 hours 42 minutes (range, 3 h 48 min to 11 h 54 min) and bone flaps the longest, on average 10 hours 14 minutes (range, 4 h 48 min to 14 h 24 min). The workhorses, ALT and RFA, required similar operative times: 8.8 hours and 8.7 hours for ALT versus 8.1 and 8.5 for RFA. The shortest operative time for a single flap was for reconstructions of facial paralysis with the gracilis flap.
Table 8. Operation duration.

<table>
<thead>
<tr>
<th></th>
<th>2001-2006</th>
<th></th>
<th>2007-2012</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>h</td>
<td>min - max</td>
<td>h</td>
<td>min-max</td>
</tr>
<tr>
<td>All</td>
<td>8.1</td>
<td>(3.8-12.3)</td>
<td>8.8</td>
<td>(3.4-14.4)</td>
</tr>
<tr>
<td>Oncological</td>
<td>8.6</td>
<td>(5.3-12.3)</td>
<td>9.1</td>
<td>(3.5-14.4)</td>
</tr>
<tr>
<td>Non-oncological</td>
<td>6.5</td>
<td>(3.8-11.5)</td>
<td>7</td>
<td>(4.6-11.9)</td>
</tr>
<tr>
<td>ALT flap</td>
<td>8.8</td>
<td>(5.7-10.8)</td>
<td>8.7</td>
<td>(4.6-12.6)</td>
</tr>
<tr>
<td>RFA flap</td>
<td>8.1</td>
<td>(5.3-11.6)</td>
<td>8.5</td>
<td>(3.5-12.4)</td>
</tr>
<tr>
<td>Muscle flap</td>
<td>8.1</td>
<td>(3.8-11.6)</td>
<td>8.5</td>
<td>(3-5-13.6)</td>
</tr>
<tr>
<td>Bone flap</td>
<td>8.7</td>
<td>(6.8-12.3)</td>
<td>10.9</td>
<td>(4.8-14.4)</td>
</tr>
<tr>
<td>Double and chimeric flaps</td>
<td>7.1</td>
<td>(6.5-8.5)</td>
<td>10.9</td>
<td>(5.8-14.4)</td>
</tr>
</tbody>
</table>

**Outcome**

Surgical failures and surgery-related complications from 2001 to 2012 were analyzed. Data regarding the first study trimester and neck dissection-related complications were excluded due to a lack of reliable data. Complications were listed by site: donor site versus recipient site, and upon timing: early if occurring during the first month post-operatively versus late stage.

Overall flap survival rate for all flap types during the follow-up was 96.9%. There were four failures (2.6%) between 2001 and 2006, and eight failures (3.4%) between 2007 and 2012. Partial flap failure was reported in seven cases (2.0%). Failures occurred in the following flap types: 100% failure rate for the genicular artery flap (n=1), 50.0% rate for DIEP (n=1), 6.7% for fibula (n = 1), 3.4% for RFA (n = 3), 3.3% for ALT (n = 5), and 1.9% for LD (n = 1). Secondary flap reconstruction, performed due to prior partial or total failure, had a survival rate of 93.7%.
Most common complications were early recipient-site complications, including total failures. These complications occurred in 15.8% (2001 - 2006) and 10.1% (2007 - 2012) of cases. The other causes, excluding failures, are presented in the Table 9. Major early recipient site complications, requiring a return to the operating room, occurred in 12.5% versus 7.6% of cases. Minor recipient-site complications, including infections and wound dehiscence, occurred in 3.3% versus 2.5% of cases. The incidence of re-anastomosis remained the same during these study periods at 6.6% and 6.5%. Late recipient-site complications were rare, occurring in 5.9% versus 6.3% of the cases. Late recipient-site complications are in Table 10. Donor-site morbidity remained low during the whole study period. The overall complication rate, including both major and minor complications, was 22.4% and it decreased from 26.3% to 20.7% during the study period. The overall complication rate for secondary reconstructions was 37.5%, including one venous thrombosis solved with re-anastomosis and four fistulas.

Table 9. Early recipient-site complications.

<table>
<thead>
<tr>
<th></th>
<th>2001-2006</th>
<th></th>
<th>2007-2012</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Venous thrombosis</td>
<td>5</td>
<td>3.3</td>
<td>6</td>
<td>2.5</td>
</tr>
<tr>
<td>Partial failure</td>
<td>4</td>
<td>2.6</td>
<td>3</td>
<td>1.3</td>
</tr>
<tr>
<td>Haematoma</td>
<td>4</td>
<td>2.6</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Wound problem</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>1.7</td>
</tr>
<tr>
<td>Arterial thrombosis</td>
<td>2</td>
<td>1.3</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Bleeding</td>
<td>1</td>
<td>0.7</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Infection</td>
<td>1</td>
<td>0.7</td>
<td>3</td>
<td>1.3</td>
</tr>
<tr>
<td>Perfusion problem</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>Skin necrosis</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Table 10. Late recipient-site complications.

<table>
<thead>
<tr>
<th></th>
<th>2001-2006</th>
<th></th>
<th>2007-2012</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Fistula</td>
<td>9</td>
<td>5.9</td>
<td>15</td>
<td>6.3</td>
</tr>
<tr>
<td>Partial failure</td>
<td>1</td>
<td>0.7</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Skin necrosis</td>
<td>2</td>
<td>1.3</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Osteoradionecrosis</td>
<td>1</td>
<td>0.7</td>
<td>5</td>
<td>2.1</td>
</tr>
<tr>
<td>Infection</td>
<td>0</td>
<td>0.0</td>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>Pseudoarthrosis</td>
<td>2</td>
<td>1.3</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Failure of osteosynthesis</td>
<td>1</td>
<td>0.7</td>
<td>1</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 11. Early and late donor-site complications.

<table>
<thead>
<tr>
<th></th>
<th>2001-2006</th>
<th></th>
<th>2007-2012</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Hematoma</td>
<td>1</td>
<td>0.7</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Skin necrosis</td>
<td>1</td>
<td>0.7</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Critical Ischemia</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Late: Infection</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>0.4</td>
</tr>
</tbody>
</table>
8.2 Study II

Comparison of the iliac crest, the scapular and the fibular free flaps in maxillo-mandibular reconstructions

Demographic results

The iliac crest flap was the flap most regularly used, performed in 92 cases, followed by the scapular flap in 42 cases and fibular flap in 29. In four cases there were a musculocutaneous flap combined to reconstruction, two iliac crest – ALT chimeric flaps, one fibula-ALT combination and one fibula radial forearm combination. Reconstructions with iliac crest and scapula were most often performed for oncological purposes, in over 90% of patients. In fibular reconstructions, over 70% of patients had a malignancy. In addition, patients who had extensive benign tumors and traumatic defects were treated.

The gender’ and age distributions showed minor variation between groups. Patients in the iliac crest’ and scapular groups had a slightly higher average age (60 versus 62 years) compared to the fibular group (59 years) and a corresponding higher Charlson Comorbidity Index (CCI) (1.1 versus 1.8 and 0.6). Male patients were the majority in all groups, involved in approximately 65% of reconstructions.

There were 122 mandibular reconstructions, and they included nearly 80% of the iliac crest and the scapular flap reconstructions and over 50% of the fibular flap reconstructions. In addition, there were 37 maxillary and 4 orbital defects reconstructed. Approximately one in five was re-microvascular reconstruction. Indications for re-reconstructions were recurrent malignancy and failed or insufficient primary reconstruction.
Table 12. Demographic data.

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th></th>
<th>DCIA</th>
<th></th>
<th>Scapula</th>
<th></th>
<th>Fibula</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Patients</td>
<td>163</td>
<td></td>
<td>92</td>
<td>56.4</td>
<td>42</td>
<td>25.8</td>
<td>29</td>
<td>17.8</td>
</tr>
<tr>
<td>Male/Female</td>
<td>105/58</td>
<td>64.4/35.6</td>
<td>62/30</td>
<td>67.4/32.6</td>
<td>26/16</td>
<td>61.9/38.1</td>
<td>17/12</td>
<td>58.6/41.4</td>
</tr>
<tr>
<td>Median age (range)</td>
<td>60 (17-89)</td>
<td></td>
<td>60 (17-89)</td>
<td></td>
<td>62 (33-78)</td>
<td></td>
<td>59 (20-87)</td>
<td></td>
</tr>
<tr>
<td>Median CCI (age adjusted)</td>
<td>1,2 (2.0)</td>
<td></td>
<td>1,1 (1.9)</td>
<td></td>
<td>1,8 (2.8)</td>
<td></td>
<td>0,6 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Malignancy</td>
<td>149</td>
<td>91.4</td>
<td>87</td>
<td>94.6</td>
<td>41</td>
<td>97.6</td>
<td>21</td>
<td>72.4</td>
</tr>
<tr>
<td>Mandible</td>
<td>119</td>
<td>73.0</td>
<td>70</td>
<td>76.1</td>
<td>32</td>
<td>76.2</td>
<td>17</td>
<td>58.6</td>
</tr>
<tr>
<td>Maxilla</td>
<td>39</td>
<td>23.9</td>
<td>20</td>
<td>21.7</td>
<td>8</td>
<td>19.0</td>
<td>12</td>
<td>41.4</td>
</tr>
<tr>
<td>Orbita</td>
<td>4</td>
<td>2.5</td>
<td>2</td>
<td>2.2</td>
<td>2</td>
<td>4.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Secondary reconstruction*</td>
<td>38</td>
<td>23.3</td>
<td>19</td>
<td>20.7</td>
<td>12</td>
<td>28.6</td>
<td>7</td>
<td>24.1</td>
</tr>
<tr>
<td>Previous radiotherapy</td>
<td>51</td>
<td>31.3</td>
<td>27</td>
<td>29.3</td>
<td>19</td>
<td>44.2</td>
<td>5</td>
<td>17.2</td>
</tr>
</tbody>
</table>

*Reconstruction after previous microsurgical reconstruction of the same site

Perioperative details

Of all flaps 72 (44%) required at least one osteotomy and in 15 (9%) there were several osteotomies. The fibula was the most common flap to be tailored with osteotomy, in 23 cases (79%) in comparison with scapula (20, 48%) and iliac crest (29, 32%). Dental implants were implanted in 45 of reconstructions during the postoperative period (28%) and there were at least a single implant failure in 25 cases (40%). No significant difference emerged between the flap types regarding implantation.

57
Table 13. Perioperative results.

<table>
<thead>
<tr>
<th></th>
<th>All (9.4 (range, 4.6-15.6))</th>
<th>DCIA (8.6)</th>
<th>Scapula (10.7)</th>
<th>Fibula (8.8)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average duration of surgery hour</td>
<td>2180 (range, 300-10000)</td>
<td>2358</td>
<td>2197</td>
<td>1589</td>
<td>0.013</td>
</tr>
<tr>
<td>Blood loss ml</td>
<td>5 (range, 2-8)</td>
<td>4.7</td>
<td>5.4</td>
<td>4.6</td>
<td>NS</td>
</tr>
<tr>
<td>ICU stay days</td>
<td>20 (range, 13-25)</td>
<td>20</td>
<td>19</td>
<td>20</td>
<td>NS</td>
</tr>
<tr>
<td>Hospital stay days</td>
<td>9 (range, 0.5-12.5)</td>
<td>10.1</td>
<td>8.6</td>
<td>5.0</td>
<td>0.001</td>
</tr>
</tbody>
</table>

**Mandibular resection**

The modified Jewer classification described the mandibular resection width. Most of the reconstructions were extended in the iliac crest and scapular groups, and were lateral in the fibular group.

Table 14. Modified Jewer Classification

<table>
<thead>
<tr>
<th>Anterior resection</th>
<th>Symphysis, anterior to canine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral resection</td>
<td>Body of mandible, with or without condyle</td>
</tr>
<tr>
<td>Extended resection</td>
<td>Combined anterior and lateral, or extended soft tissue resection</td>
</tr>
</tbody>
</table>
Complications

Overall flap survival rate was 91.4% with 14 failures. Of these, 6 failures occurred in 2004, which resulted in abandoning the use of COX-2 analgesics during postoperative care (see Discussion). Excluding 2004 the survival rate rises to 94.6%. The most failed flap type was iliac crest with survival rate of 85.9% (13 failures) during the whole study period, nevertheless five of these failures occurred in 2004. One fibular flap failed in 2004, and none of the scapular flaps failed during the study period. There was no statistical difference in the presentation of complications comparing the three flap types.

The early reconstruction-site complications in iliac crest group included 13 flap failures, 7 partial flap necrosis, 2 bleeding complications, 2 salvaged anastomotic thromboses, and one early infection. In the scapular flap group there were 2 minor flap edge necrosis, 6 fistulas, 3 salvaged anastomotic thromboses and 2 bleeding complications. In the fibular flap group there were one total flap loss, 3 minor flap edge necrosis, and one salvaged arterial thrombosis.

Early donor-site complications were present in approximately 10% of the cases. In the iliac crest group there were 3 bleedings, 3 hernias, 2 anterior superior iliac spine fractures and one partial paraesthesia of femoral nerve. In the group with the scapular flaps there were
one seroma and one severe pain syndrome. In the fibular flap reconstructions there were 2 critical ischemia's of the donor site and 2 infections.

Late reconstruction-site complications consisted, in all groups, of fistulas, non-unions and osteonecrosis. Late donor-site complications included hernias and iliac spine fractures, in the iliac crest group, impaired motion range in the scapular group and chronic pain and chronic tissue defect exposing the peroneal tendons in fibular group.

Preoperative risk factors, including age, CCI score, radiation therapy, previous reconstruction, and smoking were analyzed in regard to prevalence of complications. A significant correlation was appeared with prior radiation therapy (p=0.009). Also, perioperative factors, including duration of surgery, bleeding, and osteotomy were also analysed, showing no significant correlation.
Table 16. Complications.

<table>
<thead>
<tr>
<th></th>
<th>All n</th>
<th>%</th>
<th>DCIA n</th>
<th>%</th>
<th>Scapula n</th>
<th>%</th>
<th>Fibula n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re-anastomosis</td>
<td>20</td>
<td>12.3</td>
<td>14</td>
<td>15.2</td>
<td>1</td>
<td>2.4</td>
<td>1</td>
<td>3.4</td>
</tr>
<tr>
<td>Early reconstruction -site complications*</td>
<td>43</td>
<td>26.4</td>
<td>25</td>
<td>27.2</td>
<td>13</td>
<td>31.0</td>
<td>5</td>
<td>17.3</td>
</tr>
<tr>
<td>Early donor-site complications</td>
<td>15</td>
<td>9.2</td>
<td>9</td>
<td>9.8</td>
<td>2</td>
<td>4.8</td>
<td>4</td>
<td>13.8</td>
</tr>
<tr>
<td>Late reconstruction -site complications</td>
<td>49</td>
<td>30.1</td>
<td>27</td>
<td>29.3</td>
<td>11</td>
<td>26.2</td>
<td>11</td>
<td>37.9</td>
</tr>
<tr>
<td>Late donor-site complications</td>
<td>17</td>
<td>10.4</td>
<td>10</td>
<td>10.9</td>
<td>4</td>
<td>9.5</td>
<td>3</td>
<td>10.3</td>
</tr>
<tr>
<td>Implant complications (all implants)</td>
<td>9 (45)</td>
<td>20.0</td>
<td>5 (25)</td>
<td>20.0</td>
<td>1 (9)</td>
<td>11.1</td>
<td>3 (11)</td>
<td>27.3</td>
</tr>
</tbody>
</table>

* Including flap losses

**Functional outcome**

Most of the patients with permanent PEG alimentation were reconstructed with fibular flaps (12%) and the least with DCIA (7%). Regarding speech, the patients reconstructed with the scapula performed best, with over 90% of them restored to normal or near-normal speech ability according to speech therapists’ evaluation.
Table 17. Oral function.

Full oral = No supplementary alimentation needed.
Partial = Limited oral intake, supplementation needed.
Total PEG = No oral intake.

Table 18. Speech outcome.

1 = No, 2 = Understandable, 3 = Good (Near normal)
8.3 Study III

The Submental artery flap in reconstructing oncological orofacial defects.

Patient data

Ten patients with a mean defect size of 5 x 9 cm (range, 2.5 x 3 to 6.0 x 12) were treated for squamous cell carcinoma of the oral cavity and oropharynx. The submental artery flap was preferred over free microvascular flap because of major comorbidities (for example alcohol abuse and several obesity) or palliative intent of treatment. The most common tumor location was the tongue in four cases, followed by tonsils in two cases, the soft palate in two cases, the floor of the mouth in one case, and maxilla with nasal lining in one. All the flaps had anterograde blood flow. Three patients were treated with palliative intent. Postoperatively, six of the patients received radiotherapy alone (60 Gy), two patients received chemo radiotherapy, and two patients had no adjuvant therapy.

The average operating time was, including tracheostomy, preparation of the flap, tumour resection, neck dissection, and reconstruction, was 5 hours 50 minutes (range, 3.5 to 11 hours).

Oncological outcome

Of the 10 patients, 6 patients developed a local recurrence, 3 of them treated with palliative intent. These patients had had pT2-pT4 tumors. The average time from surgery to recurrence was 18 months (range, 6 to 41). In one case recurrence was curatively treated with radiation therapy. There were no manifestations of neck or distal metastasis. Three of the cases with local recurrences had perioperative sentinel lymph node biopsy, and in one case it revealed positive nodes. In one case, an additional nodal sampling was carried out with no signs of nodal disease.

There were four deaths of cancer (average 34 months; range, 8 to 46 months) and two of these patients were operated on palliatively. In total 7 out of the 10 patients died during
follow-up. One patient with a diagnose of recurrence died of cardiopulmonary collapse provoked by alcohol cardiomyopathy, one patient died of another malignancy without any recurrence of the head and neck cancer, and one patient, who had received palliative surgery because of advanced age and poor general condition, died one month postoperatively due to respiratory failure.
<table>
<thead>
<tr>
<th>Patient / Sex / Age</th>
<th>Location</th>
<th>Pathological Stage</th>
<th>SLNB / ND</th>
<th>Flap Complication</th>
<th>Postop Adjuvant Therapy</th>
<th>Reason for SAF</th>
<th>Time of Recurrence (months)</th>
<th>Follow Up (months) / Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/F/83</td>
<td>Nose + Maxilla</td>
<td>T4aN0M0</td>
<td>No SLNB / No ND</td>
<td>No</td>
<td>RXT</td>
<td>Advanced age, general condition</td>
<td>21</td>
<td>45 / DOD</td>
</tr>
<tr>
<td>2/M53</td>
<td>Soft Palate</td>
<td>T2N0M0</td>
<td>SLNB (-/-)/ Bilateral ND</td>
<td>No</td>
<td>RXT</td>
<td>General condition</td>
<td>41</td>
<td>46 / DOD</td>
</tr>
<tr>
<td>3/M/63</td>
<td>Soft Palate</td>
<td>T3N0M0</td>
<td>NS (-) / no ND</td>
<td>Partial necrosis of the flap, Debridement / Revision</td>
<td>RXT, Chemo</td>
<td>Second primary, general condition</td>
<td>No</td>
<td>39 / NED</td>
</tr>
<tr>
<td>4/M/53</td>
<td>Tongue</td>
<td>T2N1M0</td>
<td>No SLNB / Bilateral ND</td>
<td>Minor edge necrosis</td>
<td>None</td>
<td>Major comorbidities</td>
<td>9</td>
<td>10 / DOC</td>
</tr>
<tr>
<td>5/M/33</td>
<td>Tongue</td>
<td>T2N1M0</td>
<td>SLNB (+2/3)</td>
<td>No</td>
<td>RXT, Chemo</td>
<td>General condition, comorbidities</td>
<td>No</td>
<td>21 / NED</td>
</tr>
<tr>
<td>6/F/67</td>
<td>Tongue</td>
<td>T3N0M0</td>
<td>SLNB (-/-) / Bilateral ND</td>
<td>No</td>
<td>RXT</td>
<td>General condition, comorbidities</td>
<td>24</td>
<td>35 / DOD</td>
</tr>
<tr>
<td>7/F/82</td>
<td>Tongue</td>
<td>T3N0M0</td>
<td>No SLNB / Unilateral ND</td>
<td>No</td>
<td>RXT</td>
<td>Advanced age, general condition</td>
<td>7</td>
<td>8 / DOD</td>
</tr>
<tr>
<td>8/M/50</td>
<td>Tonsil</td>
<td>T3N2bM0</td>
<td>No SLNB / Unilateral ND</td>
<td>No</td>
<td>RXT</td>
<td>General condition, comorbidities</td>
<td>No</td>
<td>54 / DOC</td>
</tr>
<tr>
<td>9/F/77</td>
<td>Tonsil</td>
<td>T3N2M0</td>
<td>No SLNB / Unilateral ND</td>
<td>Minor edge necrosis</td>
<td>None</td>
<td>Advanced age, general condition</td>
<td>No</td>
<td>1 / DOC</td>
</tr>
<tr>
<td>10/F/51</td>
<td>Floor of mouth</td>
<td>T2N0M0</td>
<td>NS (-) / Unilateral ND</td>
<td>Minor edge necrosis</td>
<td>RXT</td>
<td>General condition, comorbidities</td>
<td>6 (cured with RXT)</td>
<td>44 / NED</td>
</tr>
</tbody>
</table>
Abbreviations: SLNB; sentinel lymph node biopsy, NS; nodal sampling, ND; neck dissection, RXT; radiation therapy, DOC; dead due to other cause, DOD; dead due to disease, NED; no evidence of disease

Complications

Out of 10 patients, 4 developed complications. There was one partial flap loss, which occurred after a delay. The patient had severe alcohol abuse and incompliance, and the partial flap loss was first diagnosed one month postoperatively; the exact timing and mechanism of the complication remained unknown. One patient was re-operated because of profuse bleeding from the recipient site on postoperative day one and later developed a partial necrosis of the flap. Necrotic tissue was debrided and closed primarily with good outcome. Two of the patients had minor flap-edge necrosis of size less than one centimeter. Both were debrided and closed primarily with good results. No infections, wound dehiscence, hematomas or seromas of donor- or recipient-site were present. One patient presented with relative mandibular nerve dysfunction of unknown etiology, at the three-year follow-up visit.
8.4 Study IV

Microvascular flaps arising from the ear; Evaluating methods and outcomes of the TAPAS, helix and hemiauricular flap.

Reconstruction data

Average defect size was 36 x 44 mm (range, 25 x 40 to 40 x 100). The flaps used were 12 helix flaps including one combined helix + hair-bearing scalp flap, seven TAPAS flaps including one TAPAS + conchal, flap and one hemiauricular flap. The helix and hemiauricular flaps had a mean pedicle length of 56 mm (range, 40 to 80) and the TAPAS flaps of 59 mm (range, 55 to 60).

In nasal reconstructions the recipient vessels consisted of nasolabial vessels in 13 of 14 cases and in one case a vein graft from the facial artery in the neck was used. In TAPAS reconstructions, the facial vessels from the neck and superior thyroid vessels were utilized as well as the nasolabial fold vessels in one case. In addition, in one case of lower eyelid reconstruction with TAPAS flap, the superficial temporal vessels were used.

The average operation time was 7 h 54 min (range, 5 h 45 min to 10 h 16 min).

Outcome

Despite good primary outcome, minor contouring and scar corrections were performed in most of the cases (13/19) because of the important esthetic role of the facial area. These procedures included fat grafting, scar shaping and cartilage grafting to alar area. Moderate to excellent esthetic and functional outcome was achieved in all cases. The retroauricular donor site required primary skin grafting in three TAPAS cases, and in one helix flap case. In one case with a combined TAPAS + conchal flap the donor-site was closed with preauricular skin flap. For helix flap donor-sites, rim advancement (Antia-Buch advancement flap) was used to achieve a tension-free closure and to preserve the helical root sulcus.
Complications

Three of the patients developed severe venous congestions, which in two cases resolved without intervention but resulted in minor edge necrosis corrected with debridement and re-suturing. In one case venous re-anastomosis was performed, but the helix flap was nonetheless lost. Later, this patient received a successful reconstruction with helix flap from the contralateral side. In this case the superficial temporal pedicle was abnormally small on both sides. In addition, there were two more cases of edge necrosis and wound dehiscence, of which one required local glabellar flap closure.
9. Discussion

Evolution of and current practice of head and neck microsurgery

Microvascular surgery has already played an essential role in reconstructing oncological and non-oncological head and neck defects for a few decades. At our institute, microvascular head and neck surgery was introduced in the 1970’s and since then it has been established as standard practice. Mäkitie et al. published in 1997 the first Finnish study of head and neck free flaps in oncological surgery, presenting results from between years 1986 and 1995 (Mäkitie et al. 1997). The nationwide 10-year series consisted of 313 consecutive cases reconstructed with 317 free flaps. The flap types most used were RFA (47%), latissimus dorsi (19%), free jejunum, or colon transfers (15%) and DCIA (8%). The series reported a total flap survival rate of 91.5%, with thrombosis being the most common reason of failure. In present study (Study I) we analyzed all 594 head and neck microvascular reconstructions performed in our unit during a 18-year follow-up. In the present study the overall survival rate reached 96.9% with only a slight annual variation. Compared to this earlier nationwide series, the number of microsurgical head and neck reconstructions has increased, as there were 205 reconstructions during the six-year period from 1995 to 2000 at our institute, 152 from 2001 to 2006 and rising to 237 during 2007 to 2012.

In 2014 Kansy et al. published a report of current oral and maxillofacial microsurgical practices in 137 European centers, excluding the Nordic countries, based on a survey performed by the European Association for Cranio-Maxillo-Facial Surgery (Kansy et al. 2014). According to this study, the workhorse for the free tissue reconstruction was the RFA, followed by the fibula. Overall flap survival rates were around 95%, which confirms the reliability and established status of the practice all over Europe. Flap survival rate of 97% in our study stands in line with this finding. In 2015, Kansy et al. presented current oral and maxillofacial surgical practice from 226 centers worldwide (Kansy et al. 2015). It was a remarkable finding that 91% of European centers and 100% of centers in German-speaking countries performed head and neck microsurgery, whereas the world-wide percentage is only 59%; and this is most obviously due to lack of training, poor financing, or inadequate equipment.
The findings of the present series (Study I) are comparable to those of other similar reports from European departments of oral and maxillofacial surgery both regarding flap selection and survival rates (Brown et al. 2006, Pohlenz et al. 2012, Geressen et al. 2013). Pohlenz et al. published their experience with 1000 free flaps during a 24-year period in Germany with an overall survival rate of 94.1%. The flap types were LD, RFA, and fibula, followed by DCIA, jejunal flap, and ALT. Due to their large patient-referral areas, some extensive reviews have been published by Asian centers (Wu et al. 2014, Zhang et al. 2015a). Zhang et al. presented the Shanghai experience of 34 years and 4481 flaps, with a survival rate of 97.5%. The free flap of choice was most often the RFA, followed by the DCIA, the fibula, and the ALT. Generally, the modern-days head and neck free flap survival rates reportedly range from 92 to 99% (Brown et al. 2006, Pohlenz et al. 2012, Lindau, Detwiller and Wax 2013).

In addition to the highly reliable fasciocutaneous flaps ALT and RFA, at present, the survival rates of composite flaps were in general excellent. It has previously been postulated that composite flaps could carry higher complication rates (Wolff et al. 2008, Mücke et al. 2013). Nevertheless, in the patients of Study I, the only failed composite flap type was the fibular free flap resulting in its survival rate of 93.3%, and the overall composite flap survival was non-inferior to that of other flaps.

During recent years the advantages of chimeric flap reconstructions in head and neck reconstructions have been noted in several studies (George and Krishnamurthy 2013, Roan et al. 2013Steel and Cope 2015). At our institute, during the study period, the chimeric flaps, especially from the subscapular region, gained popularity. In addition, a remarkable increase occurred in the variation of reconstruction alternatives. Between the first and the last study trimester, the number of used flap types and their combinations increased from 15 to 24.

Most of the patients receiving microvascular head and neck flaps are elderly, and are treated for oncological purposes (Beausang et al. 2003, Nakatsuka et al. 2003). The shift towards older patients with more comorbidities was also evident in the present study. Spyropoulou et al. studied patients over 70 years old and Bhama et al. presented a group of patients over 80 years old receiving head and neck reconstructions (Spyropoulou et al. 2014, Bhama et al. 2014). They concluded that at experienced centers and under meticulous
selection there were no elevated flap failure rates in the elderly population. Moreover, several other studies have reported similar conclusions, stating that advanced age is no longer an independent contraindication to extensive surgical reconstructions (Coskunfirat et al. 2005, Ferrari et al. 2013, Peters et al. 2015). In addition, the percentage of oncological reconstructions increased during our study from approximately 80% of reconstructions in the beginning of the study period, to nearly 90% at the end. Despite the aging patient population and increasing number of oncological reconstructions, the overall survival rate remained similar.

Approximately one fifth of patients receiving head and neck free flap reconstruction suffer early or late surgical complications (Bianchi et al. 2009, Pohlenz et al. 2012). The most devastating complications in the present study (Study I) were the early recipient-site complications; bleeding and vessel thrombosis, which can lead to partial or total flap failure. The rate of re-anastomosis in the present study was 6 to 7%, comparable to the rate presented in other studies (Bianchi et al. 2009, Pohlenz et al. 2012). The rate of early recipient-site complications and salvaged flaps decreased during the follow-up, thus the overall complication rate remained the same. The operation length of microvascular procedures including other combined procedures, can be extensive, and in studies have shown the negative impact of operation length to occurrence of complications (Farwell et al. 2002, Rosenberg et al. 2009). In present study the average operation length was 8.5 to 9 hours, which is similar to reported operative times from other centers (Jones et al. 2007, Wolff et al. 2008). Our material also showed a slightly increasing trend, with more extensive operation lengths reported in oncological reconstructions, and in composite, chimeric and double flap reconstructions. The increase in operative lengths supports the trend towards more complex and anatomically demanding at our institute and it also reflects the general shift in the ideology of microvascular reconstructions towards more customized approaches (Kanazawa et al. 2011, Hayden and Nagel 2013). Nevertheless, no decrease in flap survival rates occured during the shift towards more complex reconstructions.

As mentioned, still in many centers in the world microsurgical reconstructions are not an established practice. In our opinion, the present excellent survival rates are due to our well-established program during three decades, our experienced microsurgical teams and constant analysis of the structure and outcome of this practice area. The many advantages of
free flap reconstructions in restoring functional and anatomical integrity of the head and neck patient outweigh the possible advantages of local reconstructive alternatives. The findings of our study support the hypothesis that we can manage complex head and neck defects with individualized microvascular reconstructions aiming for functional and anatomical restoration with a successful outcome. Moreover, although the flap survival rate did not increase, major complications decreased, despite the aging patient population and expanding reconstruction armamentarium.

**Advantages, disadvantages, and outcomes of maxilla-mandibular composite flap reconstructions**

Composite flaps generally available for head and neck reconstructions are the scapula, the fibula, the DCIA, and historically the radial forearm with bone (Takashima et al. 2005). There is a great variation in practice of preference for the composite flap between institutes, also based on surgeons’ personal preferences (Urken 1991, Hanasono, Matros and Disa 2014). In most studies, the comparison of flap alternatives has been limited to two different flap types, commonly comparing the fibula to the scapula or the DCIA (Disa and Cordeiro 2000, Winters and van Loenen 2007, Fujiki et al. 2013). In Study II we compared the three most-used composite flap alternatives in maxillofacial reconstructions of our institute to analyze the difference and characteristics influencing their clinical use.

The biggest group in our comparative retrospective study was the DCIA, comprising 92 (56%) flaps. The DCIA is known to offer good bone width and height and reliability for placement of dental implants and is therefore preferred in extensive resections (Brown et al. 2002). It is also thought to offer a better contour match in mandibular body and angle resections. In contrast, the relatively short pedicle may require the use of a vein graft, and that, in itself, is a risk factor for thrombosis (He et al. 2016). In our institute the vein graft in this indication is rarely used. In our study, the DCIA was the most-often-used flap in lateral resections (Jewer classification), although the popularity of the DCIA in general decreased during the study period. In comparison, the scapular flap, used in 26% of cases, was preferred for extensive resections. Compared to the DCIA and the fibula, the scapular flap considered a superior alternative to patients with osteoporosis or peripheral vascular disease, excluding
the use of the DCIA and the fibula. The pedicle of the scapula is long, and reliable and also in our study there were no scapular flap losses (Brown et al. 2010). If the pedicle for the scapular tip is included in the harvesting, its length will be sufficient for the anastomosis with neck vessels. The fibula in maxilla-mandibular reconstructions is a generally established method and the length of the fibula is advantageous in reconstructing subtotal and total mandibulectomies (Shpitzer et al. 1999, Fujiki et al. 2013). In addition, the fibula has less flap volume, when less bulkiness is preferred. The fibular flap was used in 18% of reconstructions in the present study, and most of the reconstructions with this flap were for long mandibular defects.

The survival rates of composite free flaps are known to be challenged by the rates of non-composite flaps (Wolff et al. 2008). Study II there had in total 14 failures (survival rate 91%), but 6 of these occurred during 2004. The elevated incidence in flap failures during the postoperative course were thought to be associated to new COX-2 selective anti-inflammatory drugs, which were excluded from postoperative protocol in the end of the year 2004. After exclusion, the abnormal failure rates normalized. Excluding the year 2004, there were 7 DCIA losses. The only fibular flap failure occurred in 2004 and in the scapular group there were no failures. Therefore, the overall survival rate excluding 2004 is 95%, and the fibula and the scapula each had an individual survival rates of 100% and 100%.

The meta-analysis of Markiewicz et al. reviewed the survival of composite free flaps in mandibular reconstruction in a total of 1262 free flaps (Markiewicz et al. 2015). The overall survival rate was 95%, in line with our findings. They found no significant difference in survival rates between the DCIA, the fibula and the scapula but the DCIA showed a significantly decreased survival compared to the radial forearm flap. In recent meta-analysis of 24 studies conducted by Lonie et al there was no significant difference in flap loss between the DCIA and fibula (Lonie et al. 2016). DCIA showed to have a higher risk of recipient-site complications, for example delayed healing. Conversely, the donor-site morbidity seemed to be higher in the group with fibular flaps and in addition, the loss of dental implants was higher in the fibula group (5.3% vs. 1.7%). Our study population showed no significant difference in complications following the dental implants among the three flaps.
Here, comparison of overall complication rates showed no significant differences among the three flap types, but results were slightly more unfavourable for the DCIA. When Fujiki et al. compared the complications of scapular and fibular flaps, they found no difference in recipient-site complications, but the fibular group presented slightly more donor-site complications, mostly wound problems (Fujiki et al. 2013). In our study the DCIA group required the most early re-anastomoses, which is also explained by the elevated thrombosis rate in 2004, and the fibula required the fewest re-anastomosis. Rogers and al compared the health-related quality of life in patients with DCIA and fibula free flaps (Rogers et al. 2003). No major differences appeared, but the negative effect of appearance on donor-site morbidities was noticed in general. In addition, Schardt et al. showed no significant differences in donor-site morbidity and quality of life between fibula and DCIA flaps in a small group of 46 patients (Schardt et al. 2017). According to the literature the most disabling complications are those affecting mobility and causing pain. Our DCIA group experienced donor-site hernias and pain syndrome, whilst in the fibular group there were one case of critical ischemia and one case of compartment syndrome due to too tight closure. The scapular group appeared superior in terms of disabling, late donor-site complications, showing only a few impaired motion ranges.

In our study, only preoperative factor having significant effect on complications was previous radiotherapy, and a similar trend has also been shown by others (Al Deek and Lalonde 2016). Patients’ age seemed to be a significant factor, but median age was actually lower in the group with complications. This might reflect either the severity of the disorders treated in the younger group or meticulous preoperative screening of the older population. Other pre- and perioperative factors had no significant influence on occurrence of complications, but the small sample size and heterogenic patient groups warrant cautious interpretation of the results.

At most institutes, the scapular flap is not raised simultaneously with head and neck tumor resection resulting in 1,5 to 2 hours elevation of operating times (Takushima et al. 2001, Urken et al. 2001). This is a relevant factor because the longer operative length is known to cause increased risk for postoperative complications in microvascular reconstructions (Cordeiro et al. 1999). Furthermore, in the present study, the scapular flap requires an approximately 1,5 hours longer operation. At our institute, positioning of the patient allows the two-team approach, but the proximity of the reconstruction area results in
challenges, making the operative setting in the room more crowded. Nevertheless, the scapular flap group was not inferior to other groups, regarding to complications.

Variation between groups in the present study, regarding postoperative speech ability and oral function was minor. The majority of patients were restored to near-normal status in both parameters, but the fibula group had slightly more permanent PEG alimentation and slightly less normal speech than other groups did. However, because of patient heterogeneity in investigated groups and their reconstructive indications, it is clear, that the volume of the resection and other resection-related factors affect these results as much, or even more than the does reconstructive method.

Although the DCIA, the scapula and the fibula can serve successfully in maxillofacial reconstructions, the three flap types have individual advantages and disadvantages which must be considered in individual patient selection. In our experience, the DCIA is less reliable and carries higher donor-site morbidity than do two other flap types, which favors the fibular flap and the scapular flap as primary reconstructive options. We could show no difference between the flap types regarding their suitability for osteotomies or dental implants. It remains obvious that the familiarity with all three flap alternatives will ensure that surgeon select the most suitable flap type for each individual patient.

**Local submental artery flap as an alternative tool in orofacial reconstructive surgery**

Free tissue transfer is the standard treatment in oncological head and neck reconstructions, but there exists patient-related situations in which other alternatives need considerations. The submental artery flap is a seldom-used local alternative in orofacial reconstruction, which could be compared to other similar local flaps; pectoralis major, latissimus dorsi and trapezius flaps. Advantages of the submental artery flap in comparison to other pedicled alternatives are its close proximity to the resection site in intraoral reconstructions. Moreover, the submental artery pedicle has a reasonable length, is reliable, and has a wide arc of rotation. In addition, it provides a great color and texture match, and

In the present study (Study III) the patients were selected to treatment according to several factors: advanced age in combination with other major comorbidities such as heart failure, severe alcoholism, liver disease, general frailty, morbid obesity, or palliative intent of treatment. Age is generally known not a contraindication to extensive microvascular surgery, because successful microvascular surgery with reasonable morbidity and mortality can be performed even in the elderly (Coskunfirat et al. 2005, Ferrari et al. 2013, Peters et al. 2015). It has actually been postulated that incidence of complications is rather related to preoperative medical condition rather than age only (Hwang et al. 2016). Hwang et al. demonstrated in their meta-analysis that the older population receiving microvascular reconstructions also had higher CCI and ASA comorbidity scores, which correlated with outcome. In the present study the multidisciplinary team evaluated the comorbidity, but with no scoring systems utilized. In addition, as discussed earlier, long operative time is known to raise the incidence of medical and surgical complications, which favors local flap alternatives in high-risk patients (Farwell et al. 2002, Rosenberg et al. 2009). Our average operation time was 5 hours 50 minutes, which is significantly shorter than average operation times for similar reconstructions with microvascular flaps at our institute reported in Study I.

The SAF has shown its reliability in several earlier studies (Pistre et al. 2001, Multinu et al. 2007). In the present retrospective study, 10 high-risk patients received reconstruction with SAF, and all flaps excluding one survived. The only flap loss was diagnosed in a delayed manner and was due to a compromised patient compliance. Other major complications were related to bleeding and did not affect long-term flap survival. Temporal and mandibular nerve palsies have been suggested as potential flap-related complication, and in the present study one patient developed persistent temporal nerve marginal-branch palsy (Karaçal et al. 2006). All of our donor-sites healed uneventfully, and that is also presented as a major advantage of this flap by other authors (Pistre et al. 2001, Lee et al. 2013).

A question has been raised as to whether the lifting of the SAF compromises the oncological safety and treatment of the potential nodal disease in the neck, and will cause spreading of the tumor (Martin et al. 1994, Pistre et al. 2001). However, with meticulous
anatomical dissection, the plane of flap dissection follows the plane of the oncological dissection and chances of tumor spread can be minimized (Chow et al. 2007). In report of Chow et al, ten patients with aggressive oral cancer were treated with SAF, and there were three recurrences, of which all were thought to be intead related to the aggressive nature of the disease. In 2011, Amin et al. published their experience of 21 patients which included local recurrences in follow up time of 3 to 44 months, but not after they started completing the neck dissection before harvesting the flap (Amin et al. 2011). In present study six out of ten patients, of whom three had been treated for palliative purposes, developed local recurrence in a lengthy follow-up time of at least 72 months. Three of the cases had SLNB, and in one case this showed positive nodes. The dissection of the nodes was conducted first and the raising of the flap began after the report from regarding the frozen sample was available. In cases of nodal disease, extra attention focused on lymph-node-free preparation of the pedicle. Multinu et al. presented a series of 12 patients with local oral cancer, of which one developed a neck recurrence (Multinu et al. 2007). The present study showed no signs of neck recurrence or distal metastatic disease.

Applications of microvascular ear based free flaps in facial reconstructions

In reconstructing small facial structures such as the tip and alar of the nose or eyelids, a demand exists for thin and pliable flap alternatives with minimal texture and color discrepancy. Park et al. described the anatomical basis for external ear flaps based on vessels of superior temporal origin in 1992 (Park et al. 1992). The rich vasculature of the ST axis and its special tissue properties, including thin cartilage, provide unique alternatives for facial reconstruction.

Many different local and free flaps have been described for nasal reconstruction such as local nasolabial and forehead flaps and free radial forearm and helix flaps (Menick 1999, Guo, Pribaz and Pribaz 2008, Menick and Salibian 2011, Son et al. 2012). The main concern in the reconstruction of this area is flap-related inability to reproduce the exact anatomical features of the recipient-site. Instead, certain segments of the ear contain topographical features very similar to those of the nostril margin or nasal columella. The flaps originating from this area also offer a great contour and color match, and further, they are thin flaps with.
all three anatomical layers. The first chondrocutaneous composite flaps of the ear region were already described in 1914, but it was postulated that the flap surveillance is challenged when the size of the graft reaches 1 centimeter (Lehman, Garrett and Musgrave 1971). Pribaz and Falco reconstructed alar defects with free chondrocutaneous flaps in 1993, and Bakhach described nasal reconstruction with a reverse auricular flow flap in 1999 (Pribaz and Falco 1993, Bakhach et al. 1999). Zhang et al. reported vascularized preauricular and helical rim flaps based on ST vessels in nose reconstruction in 63 patients with good functional and esthetic outcome (Zhang et al. 2008). In their study, the recipient site anastomosis was facilitated with interposition vein grafts. In the present study, 13 nasal defects were reconstructed with helix flaps based on the superior auricular branch of ST pedicle and anastomosed directly to the vessels in the nasolabial fold. In one case, there was an additional tunnelled vein graft used. The versatility of this flap was proven in one case where additional hair bearing scalp was included into the flap for partial brow reconstruction.

The idea of the TAPAS flap was born when a branch of the ST artery, rising more cranially anterior to helix was noticed. This branch was originally described and named to the superior auricular artery by Song in 1996 (Song et al. 1996). A TAPAS flap consisting of a skin island behind the ear and the retroauricular sulcus, was described by Lassus et al. in 2016 (Lassus and Lindford 2017). Its first clinical applications were in eyelid and lower lip reconstructions, but in the present study it was used in an additional three cases of floor of mouth defects and one tongue defect. The major advantage of the flap is its pliability and contour, which form an excellent advantage for small-to-medium facial and intraoral defects.

Several arterial branches vascularize different parts of the ear. In studies of Park et al. 1992, the collaterals were reported to originate from the superior auricular branch from both anterior and posterior auricular surfaces and there are numerous collaterals from both arterial systems perforating the conchal floor (Park et al. 1992). Therefore, the ear lobe remains vascularized despite the sacrifice of its arterial systems. This feature of the vasculature enables performance of a hemiauricular flap, which is the most extensive alternative among ear-based flaps. However, in contrast to other ear based flaps, donor-site morbidity is worth consideration in the hemiauricular flap, as the remaining ear becomes significantly smaller.
In the present series, one flap loss occurred in a patient receiving a helix flap reconstruction. This patient presented with abnormally small nasolabial vessels and eventually a flap loss due to thrombosis. Secondary reconstruction was conducted successfully with the contralateral helix. Nevertheless, in most of the cases nasolabial vessels appeared suitable recipient vessels, as has also been stated in other studies (Oh, Jeon and Koh 2011, Haffey, McBride and Fritz 2014). Otherwise, there were no major recipient-site complications. In addition, most auricular donor-sites in our study healed uneventfully.

In our study the external ear region proved to be a safe and versatile donor site for reconstructions of nose, eyelids, and lips. In addition, the pedicle offers a sufficient length for intraoral reconstructions. The flaps of this area exhibit unique qualities absent in many other free flaps. The helix and hemiauricular flaps feature skin-cartilage-skin as a thin unit, and the TAPAS flap raised from behind the ear lobe is extremely pliable and esthetic flap for facial reconstructions.
10. Conclusions

Study I

In conclusion, this study demonstrates the well-established practice of microvascular management of head and neck defects at our institute. The proportion of the aging patient population, increasing variation in reconstructive methods, and the flap survival rate were found to be at the same level as in reported from other centers. In addition, the trend forward an expanding flap variety seen in this study supports our hypothesis of providing individualized and reliable reconstructive treatment to each patient.

Study II

Of the three most commonly used composite flaps in head and neck reconstructions, the findings of this study advocate preference for the fibular and the scapular flap types at the expense of the DCIA, which seems not to be as reliable as the other two alternatives. Nevertheless, we conclude that composite reconstructions of head and neck defects can be performed with excellent outcomes and it is justified to include all the three alternatives in the reconstructive armamentarium to enable a customized approach for every patient.

Study III

The submental artery flap is a feasible and well-tolerated option with low donor-site morbidity for microvascular reconstruction in patients who are not candidates for extensive surgical interventions. In the treatment of malignant disease, use of the submental flap as the reconstructive modality requires caution, due to the proximity of its pedicle to lymph nodes in the neck.

Study IV
Tissues of the external ear provide at least three unique, versatile, and reliable flap alternatives to fill many anatomical and esthetic demands present in facial reconstructive surgery. The helix, hemiauricular, and TAPAS flaps are surgically reliable, and their donor-site morbidity is acceptable. In conclusion, the external-ear-based free flaps offer excellent alternatives in reconstruction of fine facial structures.
11. Future Prospects

The approach to develop an even more patient-oriented, individualized, and customized reconstructive surgical strategy for various head and neck defects will continue at the Head and Neck Center, Helsinki University Hospital. Future goals are to develop more accurate ways to choose the right flap for specific indications, considering donor-site morbidity and the defect requirements to achieve the best possible outcome. In addition, we also plan to proceed in development of new flap types and to refine the indications and the use of established reconstructive methods. In the future, modern technology with virtual planning and the aid of additive manufacturing (3-D production) will incorporate useful technologies into the reconstructive process, and this will open new areas of research. The face transplant program is active also, and new patients are continuously recruited into the program.
12. Acknowledgements

This study was carried out at the Department of Plastic Surgery, Department of Otorhinolaryngology and Department of Maxillofacial Surgery during 2012-2018. The financial support from Finska Läkaresällskapet and HUS-EVO are gratefully acknowledged.

First and foremost, I want to thank my two supervisors, Docent Patrik Lassus from Department of the Plastic Surgery and Professor Antti Mäkitie from the Department of Otorhinolaryngology for your guidance and support during these years. You two provided me with endless sources of enthusiasm and extraordinary professionalism, and working with you has been a great privilege. Your positive feedback and attitude kept me going through struggles and made this journey possible.

I am deeply thankful to my co-authors; Docent Sinikka Suominen for supervising my first manuscript, Docent Jyrki Vuola for sharing his expertise in head and neck surgery and Docent Leif Bäck for his assistance and feedback. In addition, I want to express my gratitude to Tommy Wilkman MD, PhD, for the productive and fulfilling co-operation when working with our shared manuscript and to Andrew Lindford MD, PhD, for the valuable support. Thank you docent Erika Wilkman for statistical help.

I want to humble thank Docent Paula Mustonen and Docent Minna Kääriäinen for their commitment in revising and reviewing this thesis.

I am grateful to Jaana Jäppinen for excellent secretarial assistance, and originally introducing me to Dr. Lassus.

I want to thank all my colleagues and friends from Jorvi Hospital, Vaasa Central Hospital, Turku University Hospital, Meilahti Hospital and Kuopio University Hospital. Thank you Café Procto for providing 24/7 peer support about just everything. Especially I want to thank my fellow cardiothoracic surgeons and mentors; you know who you are.
My amazing grandparents, Annikki and Voitto Korpilinne and Liisa and Lauri Husso, thank you for providing me with your unconditional love and support. You have made it possible for me to reach for my dreams.

My brilliant and extraordinary parents, you have had the patience and faith, at least almost always, to support me in my choices as well as providing me with more love, more support and safer harbor than I could ever ask for. Thank you Josefina, my beloved little sister, if more people were like you, the world would most certainly be a better place.

And finally. I want to thank Jukka, for keeping my feet on the ground if I reached too high and lifting me up when I fell. You heard the questions I didn’t ask and had the right answers. As with this thesis, this is not the end – this is a beginning.

May 2018, Helsinki

Annastiina Husso
13. References


Carrel, A. (1902) La technique opérateure des anastomoses vasculares et la transplanter des viscères


Supplemental material

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14. Original Publications