



Review

## Basic principles of microvascular surgery applied in maxillofacial surgery. Bibliographic review

Principios básicos de la cirugía microvascular aplicados a la cirugía maxilofacial. Revisión bibliográfica

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### ABSTRACT

Treatment of head and neck defects after facial trauma, infection, or tumor resection is a major challenge for maxillofacial surgery; for this reason, it is essential that the correct way to perform this reconstruction is chosen, one of the options is microvascular flaps, so this article makes a bibliographic compilation in order to introduce the maxillofacial surgeon to the basic concepts of microvascular surgery being the cornerstone of microvascular flaps, and thus have one more tool to be able to apply it in cases that require it, as well as the advantages and disadvantages of the available magnification options, the instruments necessary for the correct practice of microvascular surgery, inanimate and living materials. Specimens where the necessary ability to perform microvascular surgery can be developed, the blood vessels most used in anastomosis of the maxillofacial area and finally the physical conditions and technical considerations to perform an anastomosis will be mentioned.

**Keywords:** Microsurgery, microvascular, anastomosis, microsurgical reconstruction, maxillofacial surgery.

### RESUMEN

*El tratamiento de los defectos de la cabeza y el cuello tras un traumatismo facial, una infección o la resección de un tumor es un reto importante para la cirugía maxilofacial; por este motivo, es fundamental elegir la forma correcta de realizar esta reconstrucción; una de las opciones son los colgajos microvasculares, por lo que este artículo hace una recopilación bibliográfica con el fin de introducir al cirujano maxilofacial en los conceptos básicos de dicho procedimiento, siendo la piedra angular de los colgajos microvasculares, y así tener una herramienta más para poder aplicarlo en los casos que lo requieran, así como las ventajas e inconvenientes de las opciones de aumento disponibles, los instrumentos necesarios para la correcta práctica de la cirugía microvascular y los materiales inanimados y vivos. Se mencionarán los especímenes en los que se puede desarrollar la capacidad necesaria para realizar la cirugía microvascular, los vasos sanguíneos más utilizados en las anastomosis del área maxilofacial y, finalmente, las condiciones físicas y las consideraciones técnicas para realizar una anastomosis.*

**Palabras clave:** Microcirugía, microvascular, anastomosis, reconstrucción microquirúrgica, cirugía maxilofacial.

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**How to cite:** Reyes CEG, Garduño MJE. Basic principles of microvascular surgery applied in maxillofacial surgery. Bibliographic review. Rev Mex Cir Bucal Maxilofac. 2021;17 (2): 62-83. <https://dx.doi.org/10.35366/102429>



## INTRODUCTION

During the last decade, oral and maxillofacial surgery has witnessed a significant trend in the inclusion of facial reconstruction from microvascular free tissue transfer. The inception dates back to the introduction of multiple surgical fellowship programs around the world that recruit oral and maxillofacial surgery graduates for training in head and neck surgery and microvascular reconstruction.

In Mexico, the Mexican Association of Oral and Maxillofacial Surgery (AMCBM) in conjunction with the International Association of Oral and Maxillofacial Surgery (IAOMS) as well as the teaching coordination of the Regional Hospital 1° de Octubre, ISSSTE and the postgraduate department of the Faculty of Medicine of the UNAM in 2018 created a training course in microvascular surgery and gave 12 scholarships to maxillofacial surgeons assigned to hospitals with maxillofacial surgery residencies in order to perform facial reconstruction treatments using microvascularized flaps and train new generations. This trend is likely to continue since head and neck defects caused by trauma, infections, osteoradionecrosis of the jaws, bone necrosis of the jaws due to drugs, tumor resections, or simply the physiological wear of the post-extraction maxillary processes represent a challenge. Unique for its reconstruction since the anatomical structures that make up the face and neck are closely related to the aesthetics and function of the patient. So also these patients have to struggle with an emotional and psychological aspect.

It is vitally important to properly choose the method by which the reconstruction is going to be done to return the basic development needs (feeding, breathing, talking) and raising the quality of life. The purpose of this article is to familiarize the maxillofacial surgeon on this subject, and it is very likely that in the following years there will be more publications similar to this one.

Microsurgery is not a specialty or subspecialty, it is any surgical technique designed to be performed with magnification through the use of a microscope or lenses to increase the size of anatomical structures. Microsurgical techniques are used by multiple medical and dental specialties, each of them will have specific procedures in their area, likewise in maxillofacial surgery microsurgical techniques can be used in different situations.

In this publication we will focus on microvascular surgery for microvascular grafts applied in facial

reconstruction. Microvascular surgery refers to microsurgery that includes the repair and anastomosis of small blood vessels generally less than 3 mm in diameter.<sup>1</sup>

70 years ago clinical microsurgery was not yet a reality. However, today, we can plan the surgical removal of a tumor with immediate microvascular reconstruction of hard and soft tissues, full dental implantation and prosthetic rehabilitation, in the same surgical time on the same day. Situation that returns self-esteem, and basic functions very quickly.<sup>2</sup>

It is important to mention that in 2020 the Maxillofacial Surgery service of the «Lic. Adolfo López Mateos» Medical Center of Toluca ISEM began to handle cases of microvascular surgery as a single service in the taking of microvascularized graft and its application for mandibular reconstruction, being those in charge are Dr. Erick G. Reyes Castañeda and Dr. Edgar Garduño Mejía, being the first maxillofacial surgery service in Mexico to take the complete case, in future publications a description of the cases as well as their planning will be made.

## HISTORY

Traditional microvascular surgery techniques have their beginnings in vascular surgery. In 1800, the only vascular operations performed were vessel ligation. In 1877, Eck (Leningrad) reported the first porto-cava anastomosis in dogs. The first successful end-to-end anastomosis of the carotid arteries was done in sheep and was reported in 1889 by Jassinowski, who used fine curved needles and silk sutures.<sup>1</sup> In 1896, Jaboulay and Briau reported the end-to-end anastomosis of a carotid artery injured on a donkey.<sup>2</sup>

In Chicago, Illinois, in 1896, John Benjamin Murphy performed the first successful human arterial repair after a femoral artery injury, also described the «intussusception technique», in which he used four double needle silk sutures to introduce the proximal artery into the distal artery at a distance of 8 mm, this technique led to narrowing of the anastomosis and thrombosis in animal experiments, but was successful in humans.<sup>1-3</sup>

This technique is still used today when the diameters of the blood vessels are not similar.

In 1899, Dorfler (Rostock, Germany), described his principles for successful vessel repair; and in 1900, Payr (Leipzig, Germany), described the use of extraluminal magnesium tubes to invaginate the cut proximal end of the blood vessel into the distal end. This was similar to the coupling devices used today.<sup>2,4</sup>

Carrel developed a triangulation technique that consisted of placing three simple triangular stitches distributed around the circumference of the vessel and then performing a continuous suture between the three stitches, performing the anastomosis with needles and fine sutures, thus developing the microvascular technique of Carrel, which led him to win the Nobel Prize in Medicine and Physiology in 1912.<sup>2,5</sup>

Before the standardization of vascular repair techniques, there was a controversy over whether to include the tunica intima in vascular sutures.<sup>1,2</sup> There were those such as Jaboulay and Briau, Dorfner, Tomaselli, Jensen and Hopfner who favored the inclusion of the intima, while Burci, Jassinowsky and Carrel and Morel were in favor of the exclusion of the intima.<sup>1,2</sup> Guthrie and Carrel examined various techniques for anastomoses and found that the inclusion of the intima promoted «uniformly successful results», laying the groundwork for standardization of anastomotic techniques.<sup>1</sup> Watts subsequently used the Carrel technique, and both advocated careful removal of the adventitia that led to long-term success in 13 of 13 carotid artery repairs.<sup>2,6</sup>

Despite advances in large vessel surgery from wartime experiences, there was no similar success rate for smaller vessel anastomosis. Schumacher and Lowenberg reported one of the first large animal studies for smaller vessels and found 12% thrombosis of 70 small arteries that were greater than 3.2 mm in diameter, compared to arteries less than 3.2 mm in diameter that had a rate 30% thrombosis of 26 arteries. Interestingly, it was a common belief in the 1950s that anastomosis of vessels smaller than 5 to 6 mm inevitably led to thrombosis.<sup>7</sup>

Advances in magnification technology paralleled those in surgical technique, being essential for the evolution of modern microsurgical techniques. The first compound microscope was invented by Zacharias and Hans Janseen in 1950.<sup>6</sup> Microsurgical techniques were used for the first time by the Swedish otolaryngologist Carl Olof Siggesson Nylen (1892-1978), who coined the term microvascular surgery and is considered the father of microsurgery, is credited with the design of the first surgical microscope, and demonstrated a 100% patency rate in vessels 1.6 to 3.2 mm in diameter.<sup>2,6</sup> On July 30, 1957, he performed an immediate reconstruction of the cervical esophagus using free jejunum in a man of 63 years, considered the first report of «free tissue transfer». In his report, they performed an end-to-end anastomosis of a branch of the superior mesenteric artery to the superior thyroid artery (2.3 to 3.0 mm in diameter).

The mesenteric vein was anastomosed to the anterior facial vein using a silicone titanium ring prosthesis; although the patient died of a stroke on postoperative day seven, the anastomosis was considered viable before the time of death. In 1960 Jacobson and Suárez (pioneers of microvascular surgery) observed that the problem was not in manual dexterity but in visualization, they designed a surgery with a microvascular free flap and are credited with being the first surgeons to use an operating microscope to small blood vessel anastomosis.<sup>2,7,8</sup> This was done in combination with Litmann from the Carl Zeiss Company. In 1961, Jacobson developed the first double binocular microscope, called a diploscope.<sup>7</sup> Vascular microsurgery had a before and after the introduction of the use of microscope, considering this tool an important piece for microvascular surgery. Shortly after reports of small vessel reanastomosis techniques, there were reports of upper extremity revascularization and subsequent finger reimplantation, leading to the increase in the field of clinical microvascular surgery. At Montefiore Hospital in New York, Seidenberg studied anastomosis of arteries varying between 1.5 and 4.0 mm in diameter in mongrel dogs and showed that successful anastomosis was actually the rule, rather than the exception.<sup>9</sup> Two years after the reports de Jacobson and Suarez, Chase and Schwartz reported 100% patency in 34 anastomoses performed in the brachial arteries of dogs (diameter range, 1.2 to 1.7 mm).<sup>9</sup> In this study, the authors used binocular loupes with 4x magnification. Contemporary reconstructive microsurgery was introduced by an American plastic surgeon, Dr. Harry J. Buncke, in 1964.<sup>10,11</sup>

They also reported implantation of a thumb, as well as an index finger in a rhesus monkey, and the first successful transfer from toe to thumb in rhesus monkey. Chen and colleagues reported the first successful reimplantation of the hand. The operating microscope was found to improve results, and this was demonstrated by Chen and his colleagues in Shanghai, China.<sup>2</sup> On July 27, 1965, Komatsu and Tamai report the first successful fully amputated single digit reimplantation performed in Nara, Japan, they reported the repair of two arteries and two veins performing end-to-end anastomosis using interrupted 7-0 and 8-0 sutures in a 28-year-old man whose thumb was amputated at the metacarpophalangeal joint on a steel cutting machine.<sup>12</sup> In 1966, Buncke reported reimplantation of rabbit ears with anastomosis of vessels approximately 1 mm in diameter. This microsurgical procedure was possible thanks to the

use of fine instruments adapted from those used by watchmakers and jewelers, as well as the development of fine sutures attached to fine needles.<sup>13,14</sup>

Between the years 1965 to 1980 in the medical literature there were many reports of tissue transplants from finger to hand, transplantation of feet to hand, also before an audience the reimplantation of an avulsed finger was performed. In the 1980s, microvascular surgery techniques made their way into the fields of hand surgery, plastic surgery, orthopedic surgery, ophthalmology, pediatric surgery, head and neck surgery, urology, and gynecology.

Facial reconstruction is an important part of oral and maxillofacial surgery, however in the United States the transfer of free tissue was integrated late in the procedures performed in this specialty, in contrast to European oral and maxillofacial surgery, where microvascularized free flaps they were practiced for many years earlier than in the United States. This was because free tissue transfer for facial reconstruction in the United States is closely related to the growth of head and neck cancer surgery.<sup>2</sup>

The Second World War was an important trigger for the development of facial reconstruction techniques, since during and after the war numerous traumatic injuries had to be treated, opening up many possibilities to treat defects and laying the foundations for facial reconstruction.

Currently the defects after surgery for resection of benign or malignant tumors of the face are one of the main reasons in the world that need reconstruction. However, there are other factors that can create facial defects and require reconstruction, for example, nowadays first-line or adjuvant radiation plays an important role in the interdisciplinary treatment of malignant neoplasms of the head and neck region, taking as complication osteoradionecrosis of the jaws, the treatment being resection which creates a defect that will need to be treated, likewise the osteonecrosis associated with drugs can create extensive defects or pathological fractures where reconstruction of the jaws is required, also rare forms of congenital hypoplasia of the jaw, as occurs in Goldenhar syndrome, may indicate reconstruction or patients who have suffered infections of dental origin affecting the supporting bone or sequelae of osteomyelitis, and finally the loss of bone in a physiological way when losing dental organs at an early age they are scenarios that require rebuilding. The common characteristic of the different etiological factors mentioned is the loss of mandibular and maxillary integrity, which leads to deficits with respect to aesthetics, lip competence, malocclusion,

phonetics, masticatory function and swallowing. Patients with untreated defects in this region generally suffer from loss of facial projection. This phenomenon causes psychosocial stress, among other situations.<sup>15</sup> Therefore, recovery of the continuity of the maxilla and mandible in three dimensions is essential. Further rehabilitation of the dental subunit is the key to achieving optimal long-term aesthetic and functional success. The complexity of the face with respect to form and function necessitates detailed diagnoses and a variety of reconstructive approaches to determine the ideal strategy, which is why different types of microvascular flaps were designed to be able to do head and neck reconstructions. The radial fasciocutaneous free flap was first reported in 1981 by Yang, the subfascial dissection technique became popular in the Western world for oral and mandibular reconstruction in the early 1980s by Muhlbauer, Song, and Soutar, and shortly thereafter in maxillofacial surgical practice by Vaughan.<sup>16-20</sup>

The vascularized fibula flap was first described in 1975 by Taylor.<sup>21</sup> In 1989, Hidalgo reported on its use for the reconstruction of mandibular defects.<sup>22,23</sup> It is currently the gold standard for maxillary and mandibular reconstruction. In 1977, Drever described the clinical application of an island of skin taken with the rectus abdominis muscle as a composite unit, and used it to repair a chest wall defect by rotating a pedunculated myocutaneous flap of superior base, said flap is nourished by the deep superior epigastric vessels, one of the most common uses of the rectus abdominis muscle flap in head and neck reconstruction is the reconstruction of the tongue and floor of the mouth after total or partial glossectomy.<sup>24-27</sup> The scapula flap was developed and popularized in the 1980s by Gilbert, Teot, dos Santos, Swartz, Cormack, and Lamberty. Since then it has been used for a wide range of reconstructive purposes in the head and neck area, the versatility of combining various amounts of skin, muscle and bone makes this flap a very attractive tool.<sup>28-31</sup> The latissimus dorsi flap was the first musculocutaneous flap reported in the medical literature. Tansini described this flap for chest wall reconstruction after radical mastectomy in 1896. In 1978, Quillen first reported the use of the pedunculated latissimus dorsi musculocutaneous flap for reconstruction of the head and neck area.<sup>32</sup>

Follow-up reports by Quillen and Barton confirmed this flap as a useful and versatile technique for repairing craniofacial defects.<sup>33,34</sup> The use of the latissimus dorsi musculocutaneous flap as a free microsurgical flap was reported by Maxwell and



colleagues in 1978.<sup>35</sup> The length and caliber of the neurovascular pedicle, the ease of dissection, the large surface area and the minimal morbidity of the donor site are the main factors that explain the popularity of this donor site for the transfer of tissue as a free flap to the region of the head and neck. Its role in the reconstruction of the head and neck lies in the coverage of extensive defects of the scalp and skull. It is particularly suitable for the reconstruction of defects in the orbit and cheek area, as well as a substitute for the tongue after total glossectomy.<sup>36,37</sup> In 1979 Taylor, Watson, Sanders, and Mayou independently described transfer of the iliac crest bone based on the vascular pedicle for bone reconstruction of the lower leg.<sup>38,39</sup> In 1982, Taylor was the first to report the use of the anterior iliac crest flap for mandibular reconstruction, and later this flap was used for functional reconstruction of the mandible and maxilla.<sup>40</sup> The vascularized iliac crest flap is one of the main flaps for bone reconstruction of head and neck defects after resection of benign or malignant conditions of the mandible and maxilla. Undoubtedly, this flap provides adequate bone stock for orofacial reconstruction and is ideal where prosthetic rehabilitation with dental implants is desired. The flap is based on the deep circumflex iliac artery, which originates from the external iliac artery and branches into muscle, bone, and skin.<sup>41</sup> The most recent development or refinement in facial flap reconstruction has been the advent of perforator vessel-based flaps. In 1988 Kroll and Rosenfield described the clinical application of «a new type of flap» based on unnamed perforator vessels located near the midline of the lumbar region to reconstruct lower posterior midline defects.<sup>42</sup> These perforator vessels are now known as lumbar perforators. Koshima and Soeda in 1989 reported the first true perforator vessel-free flap, in which an «inferior epigastric artery skin flap without rectus abdominis muscle» was used for the reconstruction of the floor of the mouth and groin.<sup>43-47</sup> With recent advances in reconstructive surgery, more emphasis is being placed on matching the quality and quantity of tissue with the necessary requirements at the defect site. To meet these requirements, new potential donor sites for free tissue transfer have been studied and introduced. More than 150 microvascular flaps with different variations and combinations have been described. At present, technology has made a great advance in microvascular and reconstructive surgery, since it reduces surgical time and reduces possible complications. During the growth of microvascular

surgery, microneurosurgery developed along with it; however, this topic will not be discussed in this article.

### HOW TO START TRAINING IN MICROVASCULAR SURGERY FOR APPLICATION IN ORAL AND MAXILLOFACIAL SURGERY?

Kleinert was known for his tireless practice efforts, he and Jacobson were told that the operating microscope was a «waste of time» and that it would «never be practical to bring a microscope to an operating room».<sup>2,47</sup> However the application of magnification in surgical procedures revolutionized surgery. For the implementation of microsurgery in a clinical way, microsurgical training in inanimate objects and in animal models is an essential stage, as well as knowledge of the instruments, the use of the microscope, knowledge of anatomy and specific techniques of anastomosis, taking grafts and application of the same. Acquiring the skills necessary to perform microsurgery can be beneficial to both the laboratory scientist and the clinical practice of the oral and maxillofacial surgeon. The learning curve of microsurgical techniques demands basic skills and continuous training, which is an important pillar for the success of microvascular surgery, however, resources for continuous training are scarce and patient safety limits teaching opportunities, the operating room has been recognized as a poor classroom for training novice surgeons as it is expensive, stress levels cannot be controlled, and cases may not be sufficient and adequate.<sup>48</sup> In recognition of this, institutions require students to attend a microsurgery course before entering the operating room, which is why laboratory training is basic.

At the Medical Center «Lic. Adolfo López Mateos» of the ISEM we developed a program for training in reconstruction of the face with microvascularized flaps, this program is divided into 3 training stages:

1. Laboratory training (development of the anastomosis).
2. Training in the classroom, amphitheater and computer center (virtual surgical planning and dental implant placement, development of taking microvascular grafts in cadaver and review of theoretical cases) (not reviewed in this article).
3. Application in patient (evaluation of head and neck defects, application of anastomosis and microvascular grafts for reconstruction of the maxillofacial area) (not reviewed in this article).

## INTRODUCTION TO THE MICROSURGICAL LABORATORY

### 1. Laboratory training (development of the anastomosis)

The purpose of a microsurgery course is to develop the ability to perform the anastomosis and make it functional with flow, the basic point of reconstructive surgery in maxillofacial surgery. There are different hospital institutions and universities in the Mexican Republic that offer these courses which vary in duration, levels, and training methods. This training course is taught at the Medical Center «Lic. Adolfo López Mateos» of the ISEM. In the initial microsurgical practice, having a place with the conditions and the necessary devices to learn these techniques is essential. The first steps in this field confront the microsurgeon with a series of elements that are alien to him, despite the fact that he has previous experience in conventional surgery.<sup>49</sup>

The appropriate material, the experimental animals, the means of magnification, the instruments and the microsurgical sutures are some of the elements that we must review (*Figure 1*).

#### Optical magnification

The vessels that are normally used in the anastomosis for mandible reconstruction are the facial artery, the facial vein and for maxillary reconstruction the superior labial artery and the angular vein are prepared, which have a variable caliber from 0.7 to 1.5 mm which makes it difficult to view directly.<sup>50</sup> Other blood vessels commonly used as receptors for the anastomosis are the superior thyroid artery and branches of the internal jugular vein whose diameters range from 1.5 to 5 mm.<sup>51</sup>

When the blood vessels to be reconstructed have a diameter of less than 5 mm, the use of optical magnification gives us certain advantages such as:

1. Increased illumination of the operative field.
2. Exact placement of the suture.
3. Allows the use of suture gauges 8-0, 9-0, 10-0.
4. Allows the use of microsurgical instruments.
5. In turn, the use of suture and proper instruments for microsurgery allows an atraumatic technique to be performed on the tissues of the blood vessel.

6. It allows the surgeon to critically evaluate the result of his work.
7. It allows correcting the deficiencies previously evaluated.

There are two types of optical magnification available to surgeons: surgical loupes (*Table 1*) and the surgical microscope (*Table 2*), each of which has advantages and disadvantages.

When we are about to choose a type of optical magnification we have to take into account the following characteristics:

**Magnification capacity:** the magnification of an optic is the relationship between the size of the image and the size of the object, it is given by two lenses, one that is the eyepiece (lens closest to the operator's eye and usually have between 5 or 20 magnification) and by the objective (lens closest to the object and usually have between 2 and 4 magnification), together the lenses can give between 10 and 80 increases and is expressed with an X, for example 10X indicates that the object is magnified 10 times its size real.

**Size of the operative or vision field:** the field of view is the area of operation that you see through the magnifying glasses. The field width is related to the diameter of the loupe, the optical design and the magnification power.

**Depth of focus:** depth of focus is the range of focus delivered by the magnifying glass. This determines how much the loupe can be tilted or moved while still keeping the entire field of view attentive. Depth of focus depends on lighting, optical design, magnification power, visual power, and the eye's ability to focus with less effort.

**Illumination:** the lighting is reflected, that is, a light source illuminates the surgical site and the light reflected from the surgical site is observed through the objectives and eyepieces, the light is provided by an external light that is usually LEDs.

However, we should not make the mistake of thinking that higher magnification is always better, since with higher magnification the size of the operative field and the depth of focus decrease, increasing the magnification also requires a gradual increase in illumination.<sup>52</sup>

#### Surgical loupes

Surgical loupes used in the medical or dental area have a variable magnification range (ranging from 1.5x to 10x). Loupes that have a magnification of

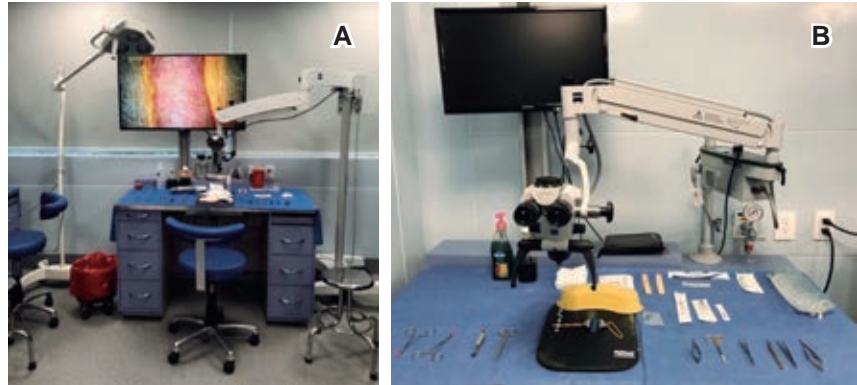


Figure 1:

- A) Microsurgery laboratory.
- B) Microsurgery surgical table.

Table 1: Advantages and disadvantages of surgical loupes.

Advantages of surgical loupes	Disadvantages of surgical loupes
It is cheap compared to the cost of a microscope Easy to use Less discomfort in the operative field Less possibility of contamination of the operative field	Lack of variable focus Requires independent light The focus is achieved or lost with the movements of the surgeon's head, which can become uncomfortable and make it difficult to adapt to work Loupes of higher magnification at 2.5x a greater size and weight, a limited field of view and a limited depth of field

Table 2: Advantages and disadvantages of the surgical microscope.

Advantages of the surgical microscope:	Disadvantages of the surgical microscope:
The magnification and lighting are modifiable manually or by means of a pedal The light is automatically directed to the workplace, it can be led or xenon The focus is independent and is not altered by the movements of the surgeon's head Binoculars with angle and tilt adjustment Possible camera adaptation for teaching other surgeons Some have two pairs of eyepieces, one for the surgeon and one for the assistant	Cost Initial handling



Figure 2: Surgical loupes.

less than 2x are unsuitable as well as those that are greater than 4.5x since they are difficult to use because they have a narrow operative field and a shallow depth of focus. Loupes between 2.5x to 3.5x provide an adequate combination of magnification, size of the operative field and depth of focus. Some surgical loupes are added with a lamp which also adds adequate lighting.<sup>52</sup>

In general, the working distance that magnifying glasses give us is 42 to 50 cm. We consider that the loupes are a good option for taking the flap, specifically during the dissection of the pedicle and in the preliminary preparation of the recipient blood vessels, the magnification with the loupes adequate for this stage of the procedure is 2.5x (Figure 2).

## Surgical microscope

The microscope used is called stereoscopic, this type of microscope is a type of optical microscope that allows observing the surgical site in three dimensions, therefore it does not have a condenser or diaphragm. Initially its use is more difficult unlike surgical loupes, as one adapts to it becomes flexible and comfortable.

Surgical microscopes have a higher magnification than loupes and their use is recommended in the final stage of dissection of the blood vessels or nerves of the pedicle and in the anastomosis. It is recommended that the microscope for use in the operating room or laboratory practice has at least the following characteristics:

Head: 360 degree rotatable trinocular with minimum 45 degree tilt, eyepiece: 30 mm-WF10X/20, Barlow lens: 2.0X, objective: 0.35-9.0X, zoom range: 1:6, diopter adjustment: +/- 5dp, working distance: 200-400 mm.

The eyepiece magnification and lens focal length are chosen based on the amount of magnification and the desired working distance.

## Instruments used in microsurgery

Properly designed, constructed, and well-maintained instruments are needed to be successful in microsurgery. Inappropriate instruments will not only frustrate the surgeon but will also indirectly affect the anastomosis by causing unnecessary trauma to the tissue. Usually in microsurgery the instruments used are: forceps, needle holders, scissors, vascular clamps, bipolar electrocoagulation unit.

### Forceps

The jeweler's forceps are an important and versatile instrument, as this can be used as needle holders, scissors, dissector and forceps as such, there are many commercial brands that design and manufacture these clamps, using forceps 3c which is a measure is recommended the active parts, their active parts must be sharp, without irregularities, they are used to hold tissue, manipulate and tie the suture, open the lumen of the vessel to give the suture point, proper maintenance must be carried out avoiding bending the tips or any distortion, only small needles and special suture material for microsurgery should be used (Figure 3).

## Microsurgical needle holder

A Schreiber TC Barraquero needle holder without clasp is recommended for easy handling when taking and leaving the needle, since those holders that have a lock can produce vibration when removed and cause damage to the structures of the blood vessel, its length must be 10-12 cm so that it does not weigh on the fingers, round and rough handle of 9 mm in diameter to facilitate the rotation of the needle and allow a completely digital handling, the bites must be small 7 mm in length to avoid that they can obstruct the visibility, flat, smooth and straight bits which allows a needle to be firmly held without bending it and prevents it from slipping, those bits that are toothed can unintentionally cut the suture, which is why smooth is recommended (Figure 4).

## Microsurgery scissors

The scissors used are the Schreiber Vannas type scissors of 12 cm in length, with a wide and flat handle, without clasp or zipper, the active part must be 10 mm straight and with an edge, the scissors not only help a sharp dissection of tissue also serves for suture cutting (Figure 5).

## Microvascular clamps

These small forceps are used to automatically and atraumatic occlude the blood flow in the arteries or veins to be treated during the anastomosis, it also helps to immobilize since the blood vessel is not retracted, there are single (Biemer-Muller) or double (Acland), the doubles are added with a bar which can help to face the blood vessels, however sometimes they make it difficult to rotate the blood vessel to be able to position the stitches in the posterior area of the diameter of the vessel, their bites must be smooth so as not to damage the endothelium and the pressure must be 40-30 g/mm<sup>2</sup>, the end of the blade must be round to avoid damaging the blood vessels, matt black is preferred to avoid light reflection, the measurements of the parts of a clamp are variable according to the diameter of the blood vessels in which it is going to work (Table 3 and Figure 6).

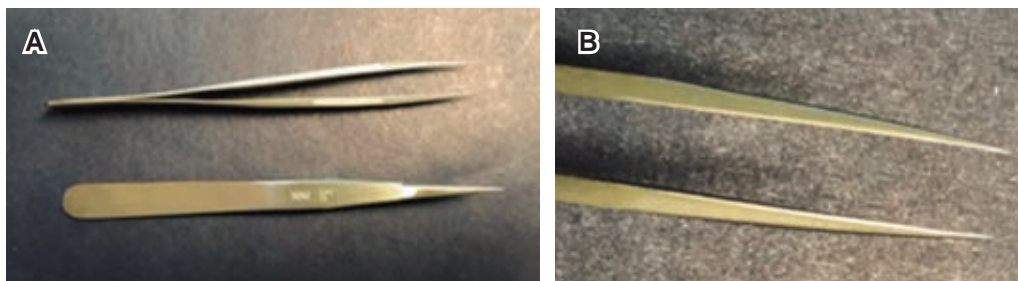
## Bipolar electrocoagulation

The electrocoagulation unit is important for haemostasis during dissection, there are two types of electrocoagulation: monopolar and bipolar, with



**Figure 3:**

A) Watchmaker's forceps 3c. B) Active part of the watchmaker's forceps.



**Figure 4:** Schreiber TC Barraquero needle holder.

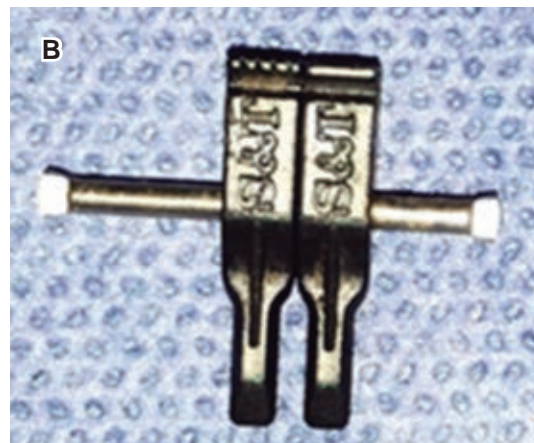
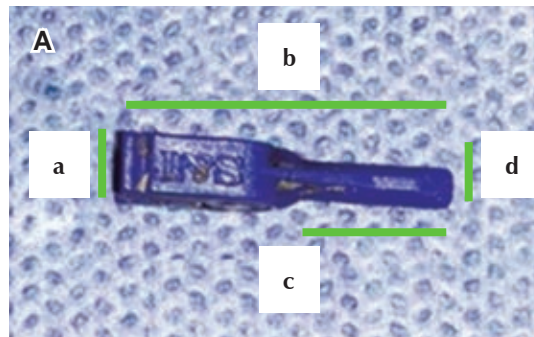


**Figure 5:** Schreiber Vannas 12 cm scissors.

**Table 3:** The different measurements that microvascular clamps can have, the pressure they can exert and their relationship with the diameter of the blood vessels are shown.

Clamp Serie	a (mm)	b (mm)	e (mm)	d (mm)	Pressure in grams	Pressure in grams	Blood vessel diameter (mm)
RD	6.0	36.0	16.0	3.0	120-140	-	2.0-5.0
HD	4.0	24.0	10.0	2.0	60-75	30-40	1.5-3.5
B-3	3.5	16.6	7.5	1.7	30-40	-	1.0-2.2
B-2	3.0	11.3	5.5	1.5	17-23	-	0.6-1.5
B-1	2.2	8.0	3.8	1.1	10-14	-	0.4-1.0

one important difference: with a monopolar unit, the current is distributed from the tips and coagulates a relatively large amount of tissue. The electrical current in a bipolar unit is restricted to the shortest distance between the two points and coagulates much less tissue. As current flows only between the tips, it is not necessary to isolate the handles, so it is recommended for dissection.



**Figure 6:** A) Biemer-Muller type simple clamp, the parts of the clam are shown, in relation to table one we can see the possible measurements and their relationship with the calibers of the blood vessels. B) Acland type double clamp.



**Figure 7:** 10-0 nylon suture.

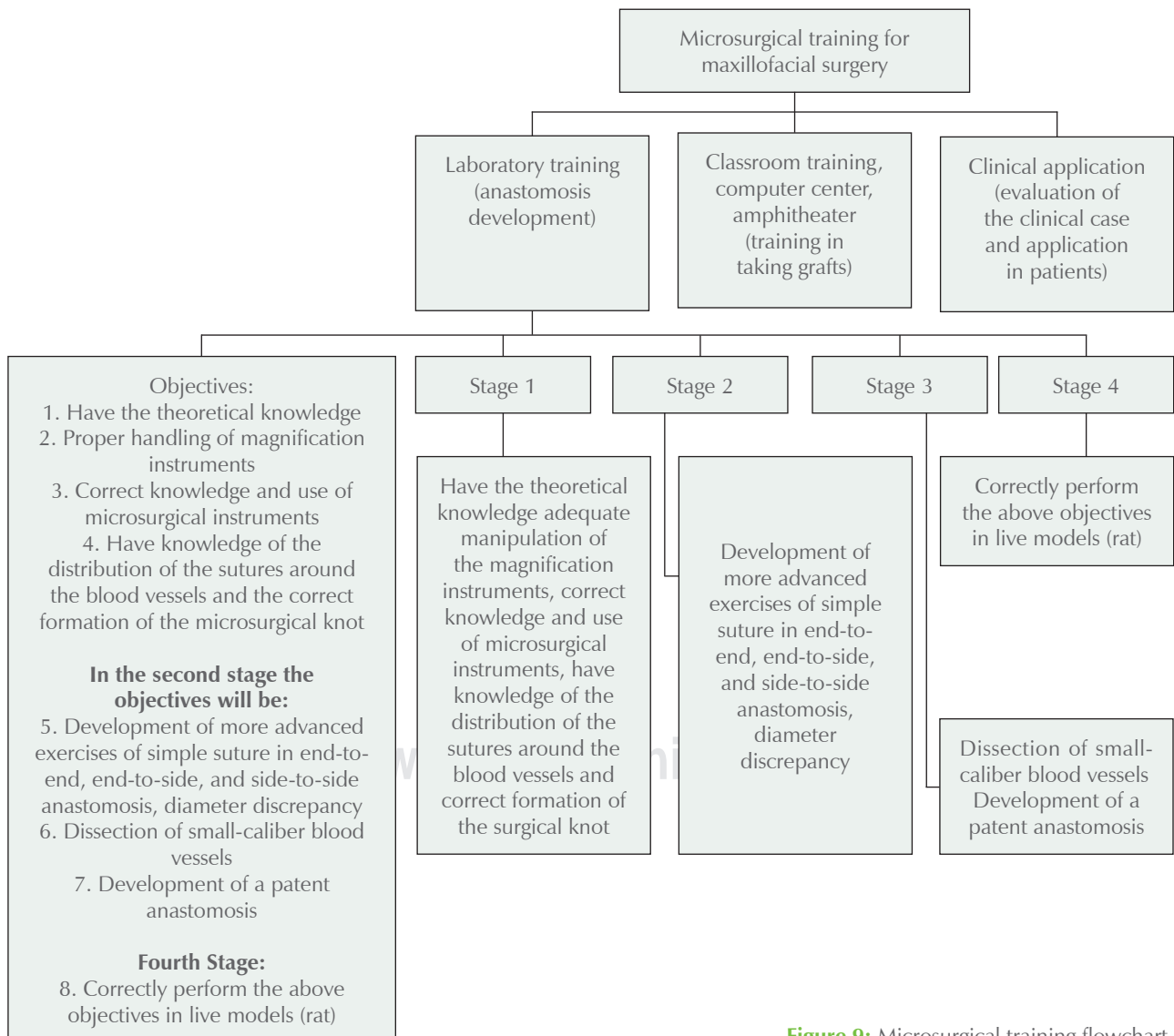


**Figure 8:** Gauze consumables, swabs, No. 15 scalpel blade, 3-0 silk, sol. Physiological, insulin syringe, 5 cc syringe, 22 G needle.

### Microvascular suture

Nylon is the most popular suture for microvascular surgery measuring 8-0 to 10-0. The size of the needle should be 75 to 100 microns in diameter, 1/2 to 3/8 of a circle, with a sharp, conical or combined tip. The needle with a cutting tip is used to penetrate rigid tissue or used in suturing of nerves, the needle with a conical tip is used to penetrate soft tissue and is mainly used in the microvascular anastomosis (Figure 7).

Other instruments used during macroscopic dissection are curved Halsted forceps, Adson forceps with and without teeth, Mayo scissors, and 15 cm



**Figure 9:** Microsurgical training flowchart.

**Table 4:** Evaluation of models for microsurgical practice.

Model	n	Availability	Ease of dissection	Dissection time (min)	Number of vessels	Vessel diameter (mm)	Vessel length (cm)	Number of anastomoses	Human similarity	Cost in Mexican pesos/USD
Latex	3	+++	-	-	-	-	-	0	0	10/2.5
Feeding probe	3	++	-	-	-	1.5	30	n	0	500/25
Chicken thigh	15	+++	+++	25	2	2.2	5	3	++	20/1
Chicken wing	3	++	++	25	3	1.1	8	5	++	10/0.5
Turkey wing	5	+++	+	40	2	3.0	6	5	+	30/1.5
Pork leg	3	+	+	60	3	1.8	4	3	+	20/1
Cow heart	2	+	+	60	5	1.7	2	10	+	40/2
Human placenta	1	+	0	120	n	n	15	n	+	0
Abdominoplasty piece	1	0	++	30	4	2.4	15	8	+++	0

**Figure 10:** Live model of the Wistar rat.

Mayo needle holders. These instruments will not be described in detail as they are instruments that we normally use.

### Consumables for practice in live animal model

0.9% physiological solution to irrigate, gauze, for the practice in live animal model separators made with clips and traction with garters, swabs or cottonoids, 10 mL syringe with needle, insulin syringe of 100 UI, scalpel blade No. 15 (Figure 8).

### Microsurgical training

Microsurgical training for vascular anastomosis requires acquiring and developing certain skills and abilities, which requires learning to operate with magnification, which requires a lot of practice and patience.

**Table 5:** Bioethical principles for practices in live animal models.

- Animal experiments should only be carried out when:
  - Are essential for the treatment, prevention, diagnosis or study of the etiology of any disease
  - The experimental results cannot be obtained by means of other procedures
  - The results are not known in advance, nor is it possible to predict them
- The animals selected for an investigation must be of the species, age and characteristics suitable for the type of study to be carried out, as well as the minimum number of animals necessary to obtain result
- All animals destined for research must be legally acquired and come from accredited animal facilities
- The animals must be housed in clean, dry facilities, adequately designed so that they are comfortable, with free access to water and food
- The conditions that are offered to the animals should promote their health
- Researchers must treat animals as beings that are capable of feeling pain and anguish
- Any procedure that causes pain or anguish must be performed under analgesia or anesthesia
- The administration of anesthetics and tranquilizers to the animals during the experiments must be supervised by a veterinarian
- No painful or invasive procedure should begin until it is certain that the animal is under anesthesia
- Researchers who work with animals must be aware that when they take the life of an animal into their hands, they also have the responsibility of ensuring a good death, providing euthanasia when necessary
- At the end of the experiment, the animal must receive a dignified death, fast and with a minimum of pain
- The corpses of animals should never be deposited in garbage containers or sent to the incinerator, until the animal presents cardiac and respiratory arrest and a doctor or the investigator has verified the death

Unfortunately, the skills developed in macrosurgery cannot be transpolated to microsurgery immediately, since hand-eye coordination is different, at the beginning the experience can be frustrating, due to the difficult digital manipulation of the instruments, for example, if pressing too hard on the instrument can cut the suture or the suture may fly off and be lost, causing the needle to break or bend. However, these frustrations or errors can be minimized through a structured and progressive learning system, which is why training should be started in the microsurgery laboratory and practicing from the simplest to the most complicated, taking into account It counts the size of the suture, the type of practice model used, the practices that will be performed on the models and finally the anastomosis on the patient. To be successful in microsurgery, you must have adequate training that allows you to develop dexterity and coordination, it has been shown in clinical and experimental studies that adequate and constant training improves skills and the final functional result of the anastomosis (patency).

As has been proposed in this article, we establish a progression for the development of skills and establish certain objectives that microsurgical training must meet; laboratory training (anastomosis development) will be divided into four stages (*Figure 9*) and in each of these, certain objectives must be met, in the first stage the following objectives must be met:

1. Have the theoretical knowledge.
2. Proper handling of magnification instruments.
3. Correct knowledge and use of microsurgical instruments.
4. Have knowledge of the distribution of the sutures around the blood vessels and correct formation of the microsurgical knot.

In the second stage the objectives will be:

5. Development of more advanced simple suture exercises (end to end (T-T), end to side (T-L), side to side (L-L) and handling of diameter discrepancies.

Third stage:

6. Dissection of small-caliber blood vessels.
7. Development of a patent anastomosis.

Fourth stage:

8. Correctly carry out the previous objectives in live models (rat).

### Practical models

Regarding the models in which practices can be done, they are divided into:

1. Inanimate which is subdivided: synthetic and biological.

- a. Synthetic models (latex, silicone, polyurethane) (used in the first and second stages of laboratory training). In the literature there is a wide range of models, many of which demonstrate the ingenuity of their creators, we will present later a synthetic model of practice, similar to a Japanese model.

- b. Biological models (thigh or wing of chicken, turkey, pork, placenta, split skin) (used in the second and third stages).

Dr. Patricio Andrades C and cols carried out a study in which they evaluate the different practice models, where it is mentioned that latex is ideal for the initial practice of knots despite not being biological tissue, the feeding tube (tube of silicone) is expensive, but it is a very useful model for practices, it is the most used and easily acquired, the chicken thigh is useful for dissecting blood vessels, the chicken wing has the same advantages as the chicken leg with the difference that the blood vessels are smaller, the turkey wing has large-caliber blood vessels which have fibrofatty adventitious tissue that makes dissection difficult, knotting and increases the degree of difficulty allowing the practice of dissection, the legs of pigs present difficult dissection and are not useful for practice, the cow heart is difficult to acquire but has special blood vessels and easy dissection, the human placenta had the di more difficult section but gives access to blood vessels of different lengths, diameters for which different sutures can be practiced, the abdominoplasty piece is of variable availability, but being human tissue certain precautions must be taken, it gives access to large epigastric vessels length and gauge suitable for initial practice (*Table 4*).<sup>49</sup> Based on this study, we designed a training program, since we consider that each model allows us to acquire different skills, therefore, we do not discard any material, rather we use them to develop specific skills.

2. Live models (most used Wistar rat) (*Figure 10*) (last stage). Biomedical experimentation in animals has allowed us to know in a more detailed and precise way, the physiology of the different devices and systems that make up humans and animals, as well as the pathogenesis of infectious and degenerative diseases, favoring



the advancement of knowledge about diseases, its treatment and prevention. The live animal model is a very good option for the practice of anastomosis, however, it is a resource of low availability, expensive, complicated maintenance, and at present the bioethical use of laboratory animals is under great debate. The use of animals in research has allowed great advances in the knowledge and development of biomedical sciences. However, the fact of carrying out experiments with beings capable of feeling pain implies a responsibility towards them on the part of the scientific community,<sup>53</sup> which is why we chose to carry out practices first in inanimate models before reaching the living model. Among the main vertebrate species that continue to be used as research subjects are mice, rats, guinea pigs, rabbits, hamsters, dogs, cats, pigs, goats, sheep, chickens and amphibians. Before thinking about going into the practice with live animals, we must take into account that they are living beings that feel, and thus put into practice the concept of the triple «R» (RRR) introduced in 1990 by Russell and Burch, which refers to a: reduce, refine, replace.<sup>49,53-55</sup> The reduction of animals used and the refinement of the methods and techniques in research will only be achieved if the work is planned in detail and with authentic responsibility, which implies having the minimum necessary number of animals to achieve statistical significance, the refinement of the techniques should reduce pain and discomfort in experimental subjects, and replacement or substitution of animals using alternative methods or other types of practice models. When planning to practice on animals, certain bioethical principles that are found in ethical codes or guides must be followed where the conditions in which live animal models must be treated are contemplated (Table 5).<sup>53-56</sup>

### General considerations of the anastomosis technique

Proper setup for anastomoses is one of the most critical steps in a microsurgical procedure as free tissue transfer must have a high blood flow rate to ensure survival. Therefore, the selection of recipient and donor vessels is a very important point to have an adequate evolution, however, in this publication we will not describe these characteristics as they will be addressed in subsequent publications.

### Preparation of the surgical environment to perform an anastomosis

When a surgery is properly prepared, whatever it may be, that preparation will be reflected in the anastomosis being easier to perform, a better surgical development, a reduction in surgical time, a reduction in errors and a decrease in stress on the surgeon.

A common mistake made by less experienced surgeons is not spending enough time on this step. We recommend following four preparation times that will serve us in practice in the microsurgery laboratory and in the operating room during the care of a patient:

**Position of the surgeon.** Surgeons must achieve an optimal position to achieve a comfortable position of the elbow and wrists to facilitate suturing, it is recommended to use a chair that has armrests and place a pad under the wrists, remember that the movements of microsurgical instruments They are digital, the more support the hand has, the shaking of these will decrease.

The surgeon's head and neck should be positioned comfortably when viewing the microscope eyepieces to minimize neck strain, this is accomplished with a chair that has lumbar support and is easy to raise and lower if necessary during surgery.

**Instrument area and instrument distribution.** The instrument area must be clean, free of unnecessary instruments or consumables. Everything essential during microvascular anastomoses, including a wet pad for cleaning instruments, heparinized irrigation solution, microsurgical instruments, and sutures must be installed before the anastomoses are performed, and they must be accommodated by the surgeon so that the surgeon remember where I put them and don't have to take your eyes off the eyepieces.

**Microscope adjustments.** Before starting the surgery, the pertinent adjustments must be made to the microscope, and they must be made by the surgeon who will perform the anastomosis, the distance of the eyepieces, the focus, the magnification and the light must be adjusted. At the beginning of the anastomosis the microscope should ideally be positioned so that the vessels are oriented horizontally in relation to the surgeon.

**Operative field.** Optimal vessel exposure should be achieved. Good lighting is critical, as it increases visual acuity and depth of field. If a vessel is deep within a gap, at an unfavorable inclination, or orientation, it is particularly important to dissect an additional length so that the vessel can be brought

into a position that will adequately expose it for anastomosis. The plane of each blood vessel must also be level. When the plane is uneven, this can cause focusing problems due to the limited depth of field that exists under high power magnification. It is helpful to place a moist sponge or cotton wool under the vessel to elevate the anastomosis site over the surrounding wound area.

This avoids problems of contamination from wound fluids seeping into the anastomosis site and helps to place the vessel on a level plane. A solid colored background can be placed under the vessels to visually simplify the surrounding area and provide a smooth surface against which to suture (green or blue rubber dam). Unfavorable vessel exposure is responsible for many of the technical errors made during surgery. Therefore, it is important to obtain adequate exposure and take the time to properly configure vessels prior to performing anastomoses.

### Steps for the construction of an adequate anastomosis

Final preparation of both the recipient and donor blood vessels must be done under the operating microscope. The operative field should be approximately level with the surgeon's elbows.<sup>10</sup>

1. Select in advance the blood vessels to be anastomosed by means of a previous evaluation with an angio-CT.
2. The receptor site must be positioned for optimal exposure.
3. Properly dissect the blood vessels in circumference and a minimum length of 4 cm so that they have an acceptable mobility to avoid tension at the site of the anastomosis.
4. The orientation of the flap pedicle is verified to ensure that the anastomosis is not under excessive tension.
5. The vessels to be anastomosed are positioned to allow adequate surface-to-surface adaptation without tension.
6. Place a contrast medium such as a blue or green rubber dam which will help us to clearly identify the blood vessels to be anastomosed.
7. Placement of microvascular clamps, in our experience it is recommended to use free clamps without a coping bar as it will allow better manipulation of the vessels (Figure 11).
8. Section of the vessel to be anastomosed.
9. Trim the excess adventitia from the end of each vessel so that it is not trapped in the lumen during the anastomosis, since poor removal of the adventitia may cause it to enter the lumen of the vessel and cause an obstruction or a turbulent flow, functioning as a catalyst for platelet aggregation predisposing to thrombus formation and anastomotic failure. Nor should the adventitia be dissected beyond the distance that ensures a clean anastomosis, since an excessive adventitial dissection can damage the vasorum and lead to the formation of pseudoaneurysms (Figure 12).
10. It is verified that the cut edges of the vessels have a clean and uniform edge and they are trimmed again if necessary to avoid that the loose tissue ends invade the lumen because these can be sources for the formation of thrombosis.
11. Inspect the lumen of each vessel by turning the end and looking directly under the microscope to see that there is no obstruction (Figure 13).
12. Gentle irrigation with warm physiological solution to eliminate any loose clot in the light, also the warm water will slightly dilate the walls of the blood vessel.
13. The end of the vessel can also be gently dilated with vessel dilation forceps. However, the excessive stretching of a vessel can cause intimate damage, for which we recommend using the watchmaker's forceps, they are introduced open in physiological solution and closed inside the solution, which will make the forceps retain a little solution, When they are brought into the light of the vessel, they open and this will release a drop, this effect of the drop inside the light of the vessel will allow the walls not to collapse and the light can be seen properly (Figure 14).
14. Level the vessels to be anastomosed, if the surgical field does not allow a similar level to be maintained between the recipient vessel and the donor vessel, a sponge or cottonoid can be used that provides adequate leveling and has the lumen edges parallel. of the vessels (Figure 15).
15. Start suturing with 10-0 nylon, most anastomoses are performed by hand with a simple or continuous suture technique. The selection of a simple or continuous suture technique is determined by the size of the vessel, by the experience and preference of the surgeon, as well as by the suitability of one technique or another in a particular situation. For small vessels, the single dot technique is more accurate. The continuous

stitch technique is faster, but requires careful attention to the spacing and amount of tension on the sutures. Excessive tension tends to have a bag effect in an anastomosis, while insufficient tension tends to produce leaks between the sutures, the following suture technique is suggested for its simplicity and good results, this includes simple stitches, these sutures must be placed at the same distance to distribute the stress evenly around the circumference of the vessels to be anastomosed. During the manipulation of the blood vessel it is suggested to take them from the adventitia or the points previously placed. Many times inserting and withdrawing the needle causes trauma and can rupture the vessel causing bleeding at the suture site, this can be avoided by minimizing hand shaking, keeping the needle perpendicular to the vessel wall and having a mental image of as the anastomosis is going to be completed, the intima of the vessel should not be clamped, and all sutures should be in direct vision since most of the problems or errors occur when it is done blind (Figure 16).

16. Eight stitches must be positioned (Figure 17) on the circumference of the blood vessels, starting with the upper one or at 12 o'clock.
17. The second stitch must be made at six o'clock or in the lower part of the circumference of the blood vessels.
18. The third stitch is placed at three o'clock or at the back of the circumference of the blood vessels.
19. A 1 mm diameter medical grade silicone tube can be placed which will function as a guide inside the blood vessels, and which will be removed before placing stitch number 8.
20. The fourth stitch is placed at nine o'clock or in the anterior part of the blood vessels, these four stitches must be left with a long and a short end, a long one is left to be able to manipulate the blood vessel without the need to pull it directly.
21. The fifth stitch is placed between stitch two and three, in a position at approximately 4:30 o'clock.
22. The sixth stitch is placed between points two and four, in a position at approximately 7:30 o'clock.
23. The seventh stitch is placed between point 1 and 3 at 1:30 o'clock.
24. The silicone tube previously placed in the lumen of the vessel is removed.
25. The eighth stitch is placed between stitches 1 and 4, at 10:30 o'clock.
26. The anastomosis is covered with the contrast plastic (rubber dam) and a wet gauze is placed

over it, the vascular clamps are removed and we wait a minute (Figure 18).

27. The functionality of the anastomosis is verified, with a «milking» test by clamping the blood vessel with two watchmaker's forceps, occluding the flow beyond the anastomosis, the vessel is squeezed to where the blood flow runs through a clamp to create a vacuum in the vessel, without releasing the upper end of the vessel, the proximal clamp is released, which cuts off the flow and a rapid flow of blood should be observed running through the anastomosis and filling the empty segment, if it does not flow or there is a leak the anastomosis should be rechecked verifying each stitch. Slow flow with little vessel distention suggests a problem with the anastomosis (Figure 19).

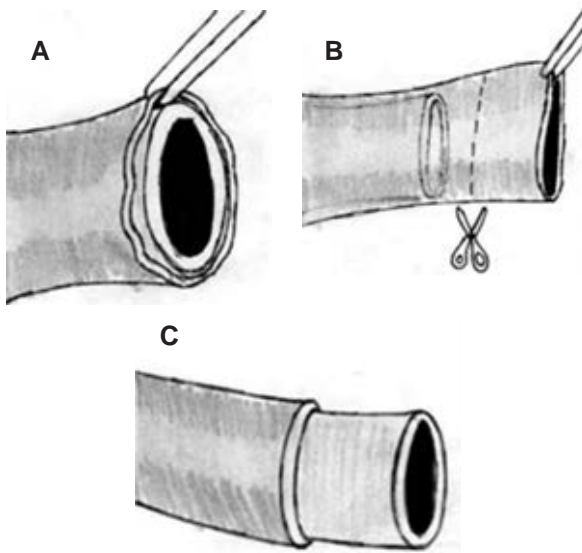
After restoring flow, the anastomoses are inspected for leaks. Large leaks need additional suture, but small leaks will stop spontaneously. After completing the anastomoses, the distal artery should be filled and pulsatile; and the venous anastomosis should be smooth pink or light blue. Arteries that lack turgor and pulse, as well as veins that are firm, distended, and black are likely to be thrombosed. The patency of the anastomosis can also be assessed indirectly by observing the color and amount of bleeding from the flap dermis or its muscle tissue. The blood from the dermal edges of the flap should be bright red when the dermis is rubbed with gauze.

Slow blood flow to the flap suggests an arterial problem. Rapid and abundant flow of dark blood in the flap indicates venous obstruction. Muscle flaps without islands of skin should remain moist and reddish-pink during insertion. When there is any doubt about the patency of an anastomosis, we generally check blood pressure to make sure the patient is normotensive. Sometimes the artery can go into spasm, and we recommend the use of papaverine (antispasmodic) or lidocaine. If there is still concern, the anastomosis should be partially or completely removed and the lumen inspected.<sup>10,57-59</sup>

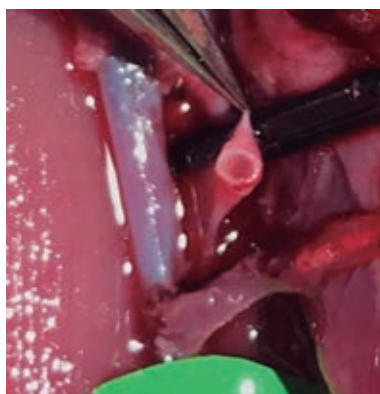
To prevent thrombus in the suture line, an anastomosis must be constructed which is both anatomically and hemodynamically solid. The flow through a cylinder is mediated by four factors and was expressed mathematically by Poiseuille ( $Q = PR^4$ ) in the formula: Q is the flow, P is the pressure per quadrant, R is the radius of



**Figure 11:** Placement of clamps in the carotid artery of a live animal model.



**Figure 12:** The sequence of removal of excess adventitia is shown to allow a clean anastomosis. **A)** The adventitia is taken from the blood vessel. **B)** The adventitia is tractioned and the excess is cut. **C)** Clean blood vessel from adventitia in the light of it.

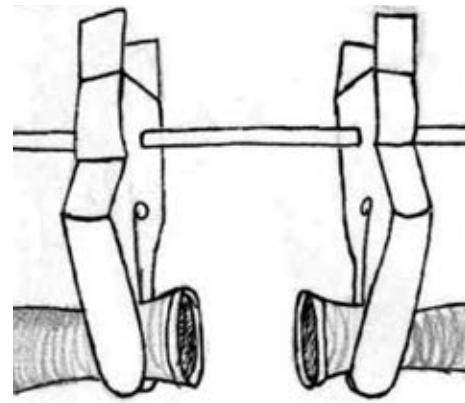
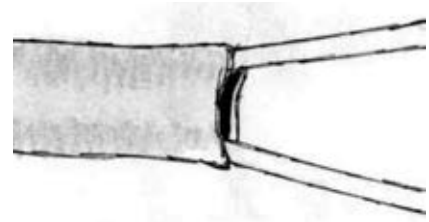


**Figure 13:**

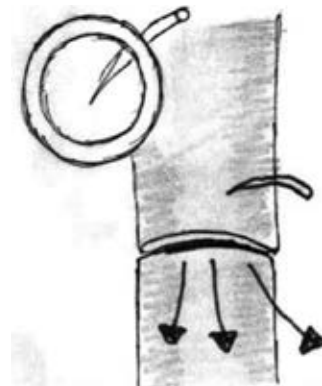
Check the lumen of the vessel that does not have thrombi or obstructing tissues, always taking it from the adventitia to avoid damaging it.

**Figure 14:**

Opening of the vessel lumen with a drop of physiological solution applied with the watchmaker's forceps.



**Figure 15:** Blood vessel alignment.



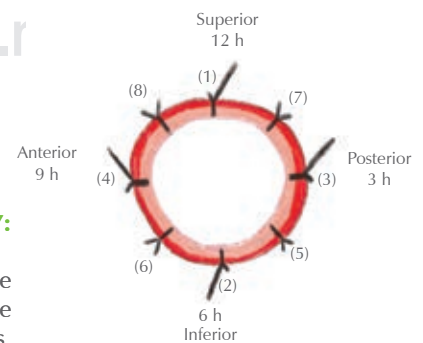
**Figure 16:**

Placement of the needle perpendicular to the vessel wall.

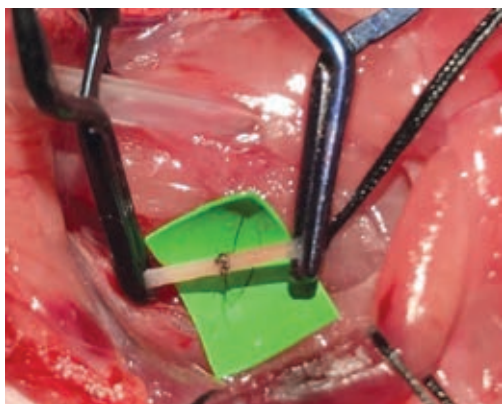
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**Figure 17:**

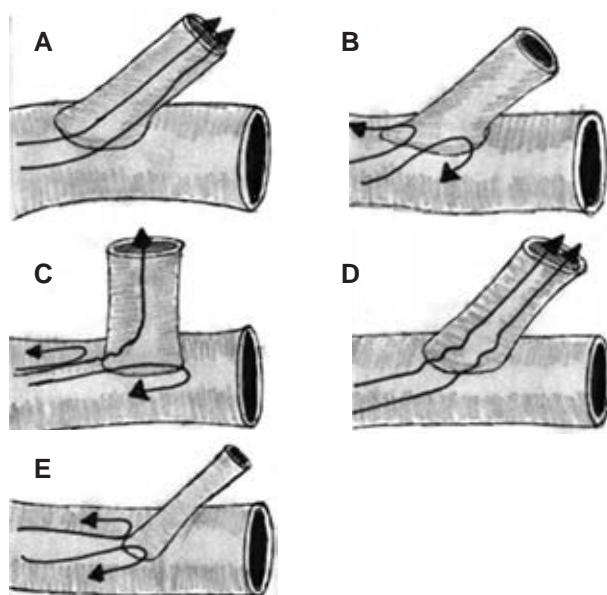
Suggested sequence of suturing in the anastomosis.



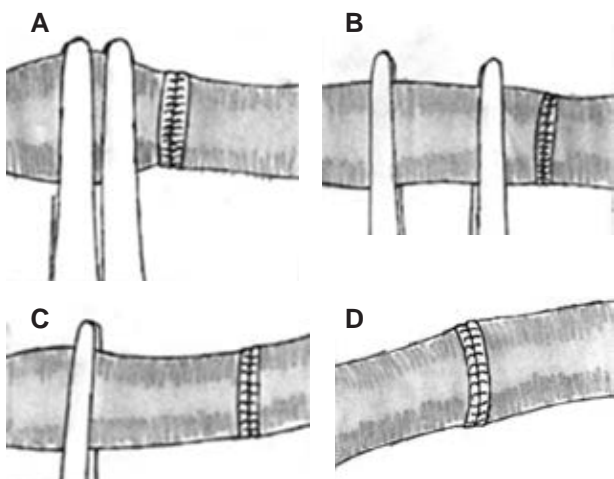




**Figure 18:** Finished suture sequence.



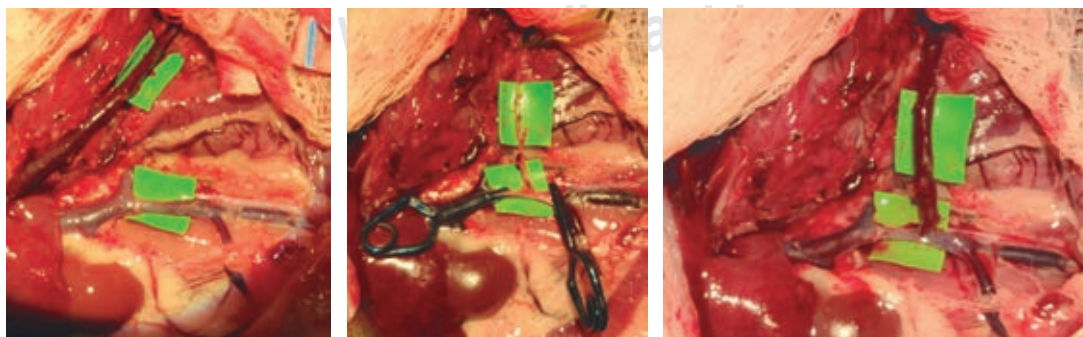
**Figure 20:** Laminar and turbulent flow due to the difference in vascular diameters. **A)** The angle between two vessels should be as acute as possible for adequate flow. **B)** If the cut in the vessel is linear and not elliptical, a flow is created turbulent. **C)** Right angles between the vessels creates turbulent flow. **D)** If an elliptical cut is created in the vessel wall, a laminar flow is created. **E)** Drastic changes in the diameter of the vessel cause turbulent flows.



**Figure 19:** Anastomosis «milking» test sequence. **A)** The blood vessel is clamped with two clamps at the end distal to the flow. **B)** The vessel is squeezed by mobilizing one clamp against the blood flow and the other Leave it at the distal end. **C)** The clamp that obstructs the flow is removed and the blood must flow through the anastomosis. **D)** The filling of the blood vessel should be observed.



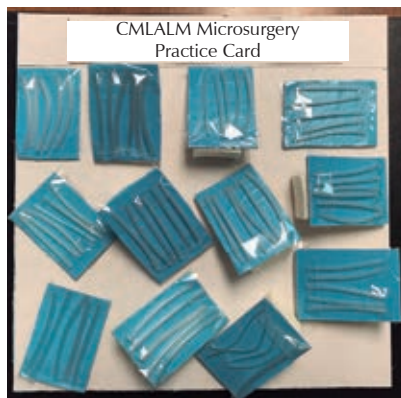
**Figure 21:** End to end anastomosis.



**Figure 22:** End to side porto-cava artery anastomosis.

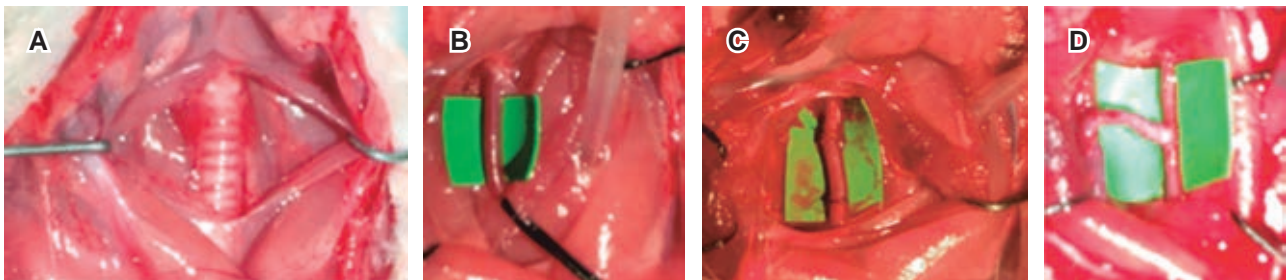


**Figure 23:** Medical grade feeding tube in diameters of 2.0, 1.0, 0.5 and 0.3 mm.

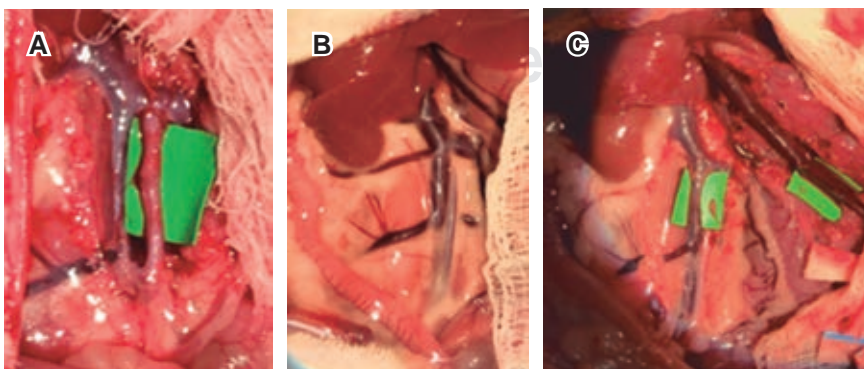


**Figure 24:** CMLALM practice card.

the cylinder, L is the length of the cylinder, N the viscosity of the fluid, this formula is not entirely applicable to the biological system, however, the general aspects can be transferred. The most important determinant of blood flow is the diameter of the blood vessel, as it is determined by the pressure of the blood and the radius of the vessel to the fourth power. This function is exponential and minute changes in gauge can cause a dramatic increase or decrease in flow. This hemodynamic principle is important in all vascular anastomoses, but its importance is exaggerated as the size of the vessel decreases. For example, a 20 percent reduction in the diameter of the aorta might not produce any clinically significant effect on flow through that vessel, but a similar reduction in a 1 mm diameter vessel would result in thrombosis. Flow is also influenced by changes in direction and size of the vessels. This is especially important since changes in direction and size are common in the vascular field of both man and animal. Flow is reduced under the above-mentioned conditions due to loss of input and output energy and because normal laminar flow of blood becomes turbulent flow which is less efficient.



**Figure 25:** A) Tracheostomy, B) carotid dissection, C) taking a vascular graft with bilateral end to end anastomosis and D) end to side anastomosis.



**Figure 26:**

A) Vein cava dissection, aorta. B) Aorta and vena cava. C) Portal vein dissection.

Whenever possible, a vascular anastomosis should be created that maximizes laminar flow and minimizes turbulent flow. Laminar flow is the normal type of blood movement within the vascular field. This type of flow is characterized by fluid moving in multiple individual layers that intersect or slide over others. The velocity of the fluid is greater in the center and less in the periphery. A velocity blood gradient in a large glass would be in the shape of a parabola. In a small container, the flow is somewhat fuzzy and the velocity gradient is paraboloid. Turbulent flow is not only less efficient than laminar flow, but it also improves platelet aggregation and thrombus formation. Turbulent flow is created by sharp edges in the blood vessel, changes in direction, sudden changes in vessel size, and uneven endothelial surfaces (*Figure 20*).

### Types of anastomosis

There are three types: end to end, end to side and side to side, which will be explained below:

**End-to-end anastomosis:** it is the simplest anastomosis concept and consists of the union of two blood vessels in the circumference of their lumen, the cut end of the donor vessel is sutured to the cut end of the recipient vessel. always an anastomosis end to end due to its flow characteristics and technical facility is preferred.<sup>10</sup>

However, an end-to-end anastomosis should not be performed if there is a greater than 50 percent discrepancy in diameter between the two vessels to be joined. In this context, end-to-side anastomosis is preferable. Alexis Carrel, originally described the end-to-end anastomosis for the microvascular anastomosis (*Figure 21*).

**End-to-side anastomosis:** an end-to-side anastomosis has many features that could potentially significantly reduce the flow frequently between vessels of unequal size (less energy in and out and creating turbulent flow) however if performed properly this will not it will happen and it will be successful.

A change in flow direction also causes turbulent flow and energy loss. If the lumen of the anastomosis has sharp edges, turbulent flow is also created. These limitations can be minimized by constructing the anastomosis in such a way that an acute angle is formed between two vessels, the smaller vessel dilating to produce a gradual change in size. End-to-side anastomosis is applied in situations where the

appropriate size receptor vessels are not available, or the flow pattern of the selected receptor vessel must be maintained rather than sacrificed for the sole purpose of supplying flow to the remaining tissue at the site. of taking the graft. The end-to-side anastomosis is more commonly performed clinically in head and neck reconstruction so that the venous flow from a donor vein goes to the internal jugular vein. To create an end-to-side anastomosis, a venotomy appropriate to the size of the recipient vessel lumen is created slightly larger than the cut end of the donor vessel in an elliptical shape (*Figure 22*).

End-to-end and end-to-side anastomoses have similar patency rates when performed correctly.<sup>10,58</sup>

### The choice of the type of anastomosis is determined by

1. The discrepancy of the size of the vessel.
2. The relative expansion capacity of the receiving vessel.
3. The particular anatomical relationships in the region of the anastomosis.

End-to-end anastomosis can be performed in any recipient vessel that does not have a critical distal vascular distribution and as long as the size discrepancy between the vessels is not greater than 2:1. End-to-side anastomosis is indicated when these conditions are not met.

### Postoperative monitoring of the anastomosis

Scheduled observation of the flap by trained personnel during the first days is still considered the best means of postoperative monitoring. A pale flap with poor capillary filling usually indicates an arterial problem, and a blue flap with rapid filling indicates venous obstruction. Muscle flaps with an arterial problem appear dry and flabby, while muscle flaps with venous obstruction appear dark and swollen. In addition, the flap can be punctured with a 20 gauge needle away from the pedicle and the quality of bleeding can be observed. Bright red blood that appears immediately and continues to form after being cleaned is a sign that all is well. No blood flow or serum exudation indicates arterial obstruction, and dark, rapid bleeding indicates venous obstruction. If there is any doubt, it is best to return to the operating room and explore the anastomosis. In addition to monitoring flap color, capillary filling, and temperature, the flap can also be monitored with a portable Doppler.



### Microsurgery training protocol that is performed in the CMLALM

Regarding our experience, below, we present a training protocol for the handling of the microscope, instruments, suture and developing the ability to perform the anastomosis, starting from the most basic to the most complex, this being the anastomosis in live animal models.

The first practice is carried out in latex (balloon, rubber dam, gloves) mounted on a square wooden skeleton (tongue depressor), a linear incision is made in the latex and it is used to practice simple stitch, the practices must begin with the handling suture 7-0 and change little by little until reaching a 10-0 suture, in our program 50 simple stitches are performed with 7-0 nylon suture, 50 simple stitches with 8-0 nylon, 50 simple stitches with 10- nylon 0, you can find nylon sutures for practice on the internet, its cost ranges from 87 MXN (4.5 USD) to 100 MXN (5 USD) each, since the 10-0 suture for patients is usually very expensive between 1,200 MXN (60 USD) to 1,500 MXN (75 USD) each.

The second practice is proposed with medical grade silicone tubes, the tubes are available in diameters of 2.0, 1.0, 0.5 and 0.3 mm and the tube walls can have a thickness of 0.05 to 0.1 mm. It should start with diameters of 2.0 and progress to a diameter of 1.0 to refine the skills of the anastomosis, the diameters of 0.5 and 0.1 help the surgeon to adapt to the magnification (*Figure 23*).

The neurosurgery service of the Tomaya University School of Medicine, Japan,<sup>60</sup> proposes a microsurgical training card, which consists of placing 4 groups of silicone tubes, each group with six tubes of different calibers, each group will be in different position (vertical, horizontal, left oblique and right oblique) which simulates the different positions that a blood vessel could have in a real patient, thus developing the ability to perform anastomosis in different positions and not only in a comfortable position As it is the horizontal, many times in the operating room we cannot move the patient to obtain that horizontal position, we retake that card for microsurgical training and redesign it adding new features, our card has the following characteristics:

A rigid card measuring 21 × 21 cm, each card has 12 sets (each set has six silicone tubes), each set represents a position (*Figure 24*):

1. Longitudinal without inclination.

2. Longitudinal with posterior inclination.
3. Longitudinal with anterior inclination.
4. Transversal without inclination.
5. Transversal with right inclination.
6. Transverse with left inclination.
7. Diagonal with right drop without inclination.
8. Diagonal with right drop with inclination to the right.
9. Diagonal with drop right with inclination to the left.
10. Diagonal with left drop without inclination.
11. Diagonal with drop left with inclination to the right.
12. Diagonal with drop left with inclination to the left.

The tilt represents an angulation of 15 degrees. There are lines on the back of the card to allow the surgeon to make some annotations.

The practices that must be done in each set are:

**1st tube:** make a straight line on the tube and make single stitches with 10-0 nylon suture.

**2nd tube:** end to end anastomosis.

**3rd and 4th tube:** end to side.

**5th and 6th tube:** side to side.

The student must finish all the practices on his card to be able to go on to the next practice. Continuous training to perform the anastomosis will allow skills to be improved.

There are other practices with synthetic materials and without the use of a microscope reported in the literature that can help improve suturing skills, and they propose the use of tubes manufactured by the same surgeon with liquid latex giving different calibers to the tube, as well as a magnifying glass with 2.5× magnification and a led desk light lamp, all purchased on internet sales pages, being very easy to access and cheap, giving an option to practice at home.<sup>61</sup> Another option to continue practicing at home is to use of the camera and lamp of an iPad, placing this tool on a support, and developing the sutures in latex materials.<sup>62-65</sup>

With these two practices, the training in synthetic materials is completed and the practices in non-living animal models such as the wing and chicken thigh are completed, in which the blood vessels are dissected and end to end and end to side anastomosis can be done, it is recommended to do a minimum of five of each one to pass to the practice with live animals.

At the end of the practices with a non-living animal model, the practices with live animal models are carried out, taking into account the bioethical



points described above. The procedures that can be performed in live animal models are divided into three modules according to the degree of difficulty, each module lasts one week with a minimum of five practices, below are the procedures performed in each module:

**First module:** tracheostomy, dissection of the carotid artery, internal jugular vein in which end to end, end to side anastomosis is performed, taking a vascular graft and applying it (*Figure 25*).

**Second module:** dissection of the major vein, aorta artery, femoral vein and femoral artery, and in them end to end, end to side anastomosis and porto-major vein shunts are performed (*Figure 26*).

**Third module:** kidney transplant, heart transplant and liver transplant.

The diameters of the vessels of living animals models are 1 to 2 mm which helps refine the technique for the anastomosis.<sup>56</sup>

At the end of this anastomosis development training program, you should continue practicing in the microsurgery laboratory at least once a week to continue developing the skills or at home with the proposed methods, then you can move on to the second stage of learning to take microvascular grafts.

## CONCLUSIONS

Facial reconstruction has represented a challenge for maxillofacial surgery, therefore all available techniques should be explored to be able to do so, microsurgical techniques coupled with graft taking is an excellent option to solve problems when there are losses of hard tissues and soft, the result of facial trauma, cervicofacial infections, benign and malignant head and neck pathologies among other conditions, however the way to apply these techniques requires special training, remembering that training is not only taking the aforementioned practices. Microsurgical training should be practiced as much as possible and constantly, practicing at least once a week at home or in a microsurgical laboratory. We suggest that microvascular techniques be incorporated into the Academic Programs of the Residencies of the Maxillofacial Surgery Specialty so that the maxillofacial surgeon in training has contact with this type of procedure. At the Medical Center «Lic. Adolfo López Mateos» of the *Instituto de Salud del Estado de México*, Toluca, we have a microsurgery laboratory and it is planned to offer a course on

microsurgical techniques, taking and application of microvascular grafts for facial reconstruction for residents and specialists in maxillofacial surgery.

In the Academic Program of the Maxillofacial Surgery Specialty of this Medical Center, three modules of microsurgical techniques were incorporated as of 2019, aimed at residents of the 3rd and 4th year of the specialty. We firmly believe that the Specialty of Maxillofacial Surgery in Mexico should evolve and grow, therefore it is important that trained and training maxillofacial surgeons become familiar with microsurgical reconstruction techniques to offer the best in treatment to our patients.

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