Available online at www.sciencedirect.com

ScienceDirect

British Journal of Oral and Maxillofacial Surgery 59 (2021) 16–20

BRITISH Journal of Oral and Maxillofacial Surgery

www.bjoms.com

Review

Review and update on the use of the microanastomotic coupler device for arterial anastomosis in free tissue transfer

B. El Baba [a], W. Watfa [b,c,*], L. Youssef [d], P.G. Di Summa [c], P. Bou Khalil [e], A.R. Jurjus [e], D.B. Loyens [f], S. Sertel [g], R.A. Jurjus [h]

[a] *Division of Otolaryngology, Head and Neck Surgery, Faculty of Medicine, Beirut Arab University, Beirut, Lebanon*
[b] *Plastic Surgery Division, St George Hospital University Medical Center, Beirut, Lebanon*
[c] *Plastic Surgery Department, Centre Hospitalier Universitaire Vaudois, Lausanne, University of Lausanne, Switzerland*
[d] *Faculty of Nursing and Health Sciences, Notre Dame University, Zouk Mosbeh, Lebanon*
[e] *Faculty of Medicine, American University of Beirut, Beirut, Lebanon*
[f] *Instituto de Ciencias Biomedicas Abel Salazar da Universidade do Porto, Porto, Portugal*
[g] *Faculty of Medicine, University of Heidelberg, Heidelberg, Germany*
[h] *Faculty of Medicine, George Washington University, Washington D.C., USA*

Available online 1 July 2020

Abstract

While a simple interrupted sutured anastomosis remains the gold standard in microsurgery, the introduction of the microanastomotic coupler device (MACD) has decreased procedure time and thrombosis risk, and improved the patency of venous anastomoses. The aim of this review is to update the evidence-based advantages of the MACD on arteries, based on clinical and experimental data, and to compare them to the hand-sewn approach in free flap transfer. All relevant articles that appeared in the PubMed and Medline/Ovid databases during the past three decades were reviewed. After exclusions, 11 studies were retained and discussed. The MACD had a generally shorter arterial anastomosis time, with improved flap survival and reduced ischaemia compared with the hand-sewn approach. The use of the MACD in arterial anastomosis is an efficient and less time-consuming alternative to the hand-sewn technique, provided that the selection of vessels is appropriate and the vessel diameter is large enough to do the anastomosis.

Keywords: Anastomosis; coupler; arterial; synovis; unilink; free tissue transfer

Introduction

Since the introduction of microsurgery in 1961 by Suarez and Jacobson, the need for improving vascular anastomoses, especially in small vessel surgery, remains a priority.[1,2] Microvascular anastomosis is considered to be the most critical determinant of successful free-tissue transfer. While the gold standard for anastomosis has always been simple interrupted sutures,[2] the need for decreasing operative time, and increasing patency, have urged researchers to develop the microvascular anastomotic coupler system (MACD),[3–8] which became commercially available in 1990. Among the different types of MACD, the Synovis (Synovis Life Technologies) and Unilink/3M have been assessed in numerous studies. The MACD consists of two high-density polyethylene rings with six pins that interlock, and an internal diameter ranging from 1-4 mm.[9–12] The importance of this device relies on its capability to achieve intima-to-intima contact without the presence of intraluminal foreign material such as sutures, which reduces thrombosis risk and increases the patency rate.[9–13] The MACD also reduces the operating time,

* Corresponding author at: Plastic, Reconstructive and Aesthetic Surgery Department, Saint George Hospital University Medical Center, Beirut, Lebanon. Tel: +961 01441899, Fax: +961 1582560.
E-mail address: williamwatfa@gmail.com (W. Watfa).

https://doi.org/10.1016/j.bjoms.2020.06.019

which minimises the period of ischaemia, and increases the flap survival rate.[2,8,11–14]

Safe MACD is mostly used during venous anastomoses, both end-to-end and end-to-side, as the wall structure of the veins presents less of a technical challenge for anastomosis.[13] Despite the controversy surrounding the use of a coupler in arterial anastomoses (because the thickness and structural nature of the arterial wall make it more difficult to evert edges on to the pins), several recent studies have supported this option.[12,14,15] Facing this important dilemma, our review will describe and analyse the experience with MACD in arterial anastomosis over the past 30 years. It will also evaluate the success and efficiency of this technique in arterial coupling as an option to replace the conventional hand-sewn approach.

Material and methods

Our search of published papers covered the PubMed and Ovid databases for the period between 1990 and July 2018. The MeSHes used included: microsurgery, surgical anastomosis, coupler, arterial coupling, synovis, reconstructive surgery, surgical flaps, and vascular surgical procedures. In addition we looked at mode coupler devices, and MACD coupling. The search screened the abstracts of 113 papers on microvascular anastomoses, of which only 11 (9.7%) were reviewed because the rest (90.3%) either described venous anastomoses, or were not written in English. For the purpose of discussion, nine of the 11 papers were retained.

Results

Unilink coupler

In 1996, Shindo et al reported 79 free flap transfers (FFT), with a total of 105 anastomoses (17 arterial and 88 venous), using MACD ring diameters ranging from 1.0 to 2.5 mm.[12] The follow-up time ranged from six months to 2.5 years with no thrombosis in the venous anastomoses. Of the 17 arterial anastomoses only two thrombosed, one of which was the result of the difficulty in eversion of the vessel wall intraoperatively, causing a microtear in the intima. The mean anastomosis time was 8 -18 min in arteries, and 4 - 16 min in veins. This study reported no significant advantages from using MACD for arterial anastomoses of greater calibre, although it could be beneficial in smaller arteries where the walls are softer, as in the superior thyroid artery. This study also concluded that MACD should not be used if the difference in calibre between the recipient and the donor arteries was greater than 1-1.5 mm, in oversized arteries, or in atherosclerotic or previously irradiated arteries.

In 2005, Ross et al reported the use of a Unilink coupling device in assessing flap survival and thrombosis of the arterial anastomosis.[13] The study covered 49 patients in a total of 50 FFT - 50 arterial and 100 venous anastomotic procedures. The recipient vessels were the superior thyroid and facial arteries, which showed resistance to the penetrating pin of the MACD. Postoperatively, the patients were given only aspirin without heparin. As a result, only one intraoperative thrombosis occurred in a 2.0 mm calibre MACD, which required repeated coupling with a 2.5 mm device.

The other complication was a ruptured anastomosis of the radial artery on an immunosuppressed renal transplant patient on postoperative day 12, but the flap survived because of adequate neovascularisation. The arterial anastomosis was made in 6-7 minutes. Based on their success (49 of 50) in head and neck free tissue transfers, and recognising that the patients were young and healthy (which improved the vessel wall quality) no particular technical difficulties were noted in this study. Based on these findings, the authors suggested that the mechanical coupling technique is reliable and safe with a low complication rate. They concluded that MACD, being reliable and safe, is a better alternative to the hand-sewn technique in arterial anastomoses.

The largest series of arterial anastomoses to our knowledge was reported in 2008 by Chernichenko et al who demonstrated the efficacy of MACD in arterial anastomoses.[16] A retrospective review of all FFT done at the Yale-New Haven Hospital from November 2001 to December 2006 reported 127 microvascular FFT (124 MACD and three hand-sewn). The flaps were harvested from the radial forearm, the fibula, the rectus abdominis, and the iliac crest. The predominant coupler size was 2.5 mm. During anastomosis, the arteries were adequately dilated while the thicker ones were resistant to the coupler pins, which caused intimal tears during eversion in some arteries. There were three flap failures (2.4%) in this series, with an overall survival rate of 97.6%; and four complications (3.1%) resulting from arterial insufficiency of which three were salvageable. The authors concluded that MACD anastomosis was cost-effective, decreased the operative time considerably, and allowed for vessels of different diameters to be accommodated, provided that these diameters did not exceed a ratio of 1.5:1 for the difference in donor:recipient arterial luminal diameter.

Synovis coupler

Another retrospective review in 2006 by Spector et al covered 60 patients who had microsurgical breast reconstruction (both delayed and immediate) between 1998 and 2004 using arterial MACD.[15] The flap success rate was 100%. However, one anastomosis had to be reviewed surgically, and partial necrosis of another flap required only minor revision. The slight difference between the luminal diameters of the flap recipient arteries (thoracodorsal and internal mammary arteries) and the donor vessels, and their optimal wall diameter and pliability, rendered these arteries ideal for coupled anastomosis. In addition, the authors recommended that the hand-sewn technique be mandatory in thick-walled recipient arteries. They also suggested that while the coupling device is extremely useful in microvascular free flap reconstruction

of the breast, intraluminal diameter discrepancies of 1.5:1 or more make arterial coupling unfavourable. Consequently, with adequate vessel selection, arterial coupling with MACD becomes a safe and reliable method with minimal morbidities and complications.

In 2008, Rad et al did autologous breast reconstructions on nine patients with FFT using deep inferior epigastric artery perforator (DIEAP) flaps and superficial inferior epigastric artery (SIEA) flaps, anastomosed to the internal mammary artery.[17] These included seven DIEAP anastomoses using a 1.5 mm coupler, one DIEAP anastomosis using a 2.0 mm coupler, and one SIEA anastomosis using a 2.0 mm coupler. In bilateral reconstructions, one side was hand-sewn while the other was coupled. All the arterial anastomoses were successful and healed uneventfully. The mean ischaemic time for flaps with arterial coupled anastomosis was 40.8 min, whereas that of the flaps of the hand-sewn arterial anastomosis was 56 min, resulting in a mean difference of 15.2 min. Based on the cost of an operating room of US$ 15/min and a coupler price of about US$180, the device becomes cost-effective as long as it can cut 12 minutes from the anastomotic operating time. The authors noted that coupling the DIEAP and the SIEAP flap arteries was technically feasible and shortened the total flap ischaemic time. They also added that the internal mammary artery can be anastomosed using the coupling device in immediate or staged reconstruction, as well as in the setting of radiation, which makes the coupling technique in safe, effective, and efficient in free flap breast reconstruction.

In addition to the above, a cohort study by Rozen et al in 2010 covered 1000 patients who underwent a variety of reconstructions (600 breast, 150 extremities, and 250 head and neck) with three different types of vascular anastomosis: standard sutures, microstaple clips (Anastoclip Vessel Closure system, Le Maitre Vascular Inc), and a Synovis Microvascular Anastomotic Coupling System.[18] With regard to the ring coupler, the device itself everted the vessel wall whereas, in the case of the microstaples, a combination of stay sutures and everting forceps were required. In the 1000 reconstructive cases, 2500 vascular anastomoses were made, of which 1400 required the use of an anastomotic device (80% of all venous anastomoses, and 10% of all arterial anastomoses). The anastomotic time for the hand-sewn sutured anastomosis was 22 min, for the microstaples 15 min, and for the MACD 4 min. Statistically, the durations referred to above showed a significant reduction ($p<0.01$) in anastomotic times related to the use of these devices. Overall, there were 90 failures, of which 12 were arterial (all hand-sewn anastomosis), and 78 were venous (29 hand-sewn, 20 stapled, and 29 coupled). The authors concluded that the use of anastomotic couplers would decrease operative times without jeopardising the free-flap outcomes. Indeed, in the 1000 free flaps which were anastomosed, the mean reduction in operative time was 15 min when using a ring-coupler device, which is significantly less ($p<0.001$) than the duration taken by the hand-sewn technique. They also found that the micro-clip (VCS clip-applier) is particularly useful in vessels with thicker walls.

In a systematic review by Grewal et al in 2012, 25 studies were included for analysis covering a total of 3576 FFT, of which 1103 were in the head and neck region, 2094 were in breast, 300 in limbs, and 79 were not specified.[11] There were only 26 reported flap failures out of a total of 3497 venous and 342 arterial anastomoses done with the MACD. The thrombosis rate was 1.7% for the venous anastomoses and 3.6% for the arterial anastomoses. The duration of the anastomosis procedure was approximately 5 min if the veins were coupled using the 3 and 2.5 mm rings, while the arteries were coupled using the 1.5 mm, 2.5 mm, and 3 mm pins or rings. The success rate was about 99%. Moreover, the rate of venous thrombosis fell from 2.8% to 0.6% when a MACD was used in place of hand sutures. In 2017, Genther et al underlined the role of MACD in salvaging hand-sewn arterial anastomosis[14] by the elimination of intraluminal foreign material and improved flow from the MACD.

On the other hand, in an animal experiment, Sando et al in 2018 used a Synovis coupler with the help of an everter device on five pigs,[19] using the external femoral artery. Five anastomoses were made using the MACD and the everter, and five using the hand-sewn technique. Because of the high elastic recoil of the pig arteries, Satinsky clamps were used in the anastomoses. The mean coupling time was 6.35 min. At one week postoperatively, 80% (four out of five) of the anastomoses using a MACD were still patent, and all five of the hand-sewn anastomoses were also patent. The increased tension on the arterial wall caused by the use of Satinsky clamps may have contributed to the intimal tearing and the appearance of only one thrombus in the coupled anastomosis. However, based on the shorter duration of anastomosis (6 min compared with 25 min) and similar histological analysis (new intima formation, elastin degeneration, and necrosis), the use of a MACD with an everter proved safe. The authors acknowledged that the small number of animals and the big calibre of pig arteries compared with humans were considered limiting factors. They also added that more studies on the use of the Synovis, the everter and the cost-effectiveness of arterial anastomosis using a coupler, were needed.

Table 1 summarises the outcome of the different studies.

Discussion

In free flap transfer, microvascular anastomosis remains a key critical step. Its success relies not only on the competence of the surgeon but also on the quality of the anastomosis, which requires high surgical skills in using the appropriate material resources that are required to avoid flap failure. The patency of the anastomosis is the key to a successful reconstruction, and any failure in this procedure may lead to flap necrosis, wound breakdown, and fistula formation.[6]

To improve the anastomotic outcomes, the MACD has been developed to focus on decreasing anastomotic operating

Table 1
Summary of studies using arterial coupler anastomosis*.

First author, year, and reference	No. of arterial anastomoses	Arterial anastomosis		Arterial thrombosis		Type of MACD
		MACD	Hand sewn	MACD	Hand sewn	
Shindo 1996[12]	79	17	62	2 (11.76%)	0	Unilink
Ross 2005[13]	50	50	0	1 (2%)	0	Unilink
Spector 2006[15]	80	62	18	1 (16.13%)	0	Synovis
Chernichenko 2008[16]	127	124	3	4 (3.23%)	0	Unilink
Rad 2008[17]	12	9	3	0	0	Synovis
Rozen 2010[18]	1000	100	900	0	12 (1.33%)	Anastoclip/ Synovis

MACD=microanastomotic coupler device.
* Studies older than 1996, reviews, case reports and animal studies were excluded from the table.

time and optimise vessel patency. However, arterial coupling remains the main challenge because the thick arterial wall renders eversion difficult, and puts the wall at risk of intimal tears, hence increasing the risk of thrombus formation. The studies done on arterial anastomosis are somehow scarce. Originally, older series did not show encouraging results, considering the small number of anastomoses reported. A good example is the series by Ahn et al in 1994, where the results showed only two (12.5%) successful arterial anastomoses out of 16.[5]

In more recent studies on arterial anastomoses in head and neck as well as in breast reconstruction, the success rates were much higher, reaching 97% and 100%, respectively. This shows that microvascular coupling is at least as efficient as the hand-sewn technique in arterial anastomoses, with a much shorter anastomosis time. A case study by Genther et al[14] reported that the coupler was very efficient in salvaging anastomoses in arteries after three consecutive failures with hand-sewn anastomosis, which demonstrates that arterial coupling can be used in difficult situations to salvage a flap. Although most studies present a higher failure rate for anastomoses on thicker or wider arteries, the use of an everter device may help overcome this difficulty.[19]

In our experience, arterial coupling retains a potentially interesting role in intraflap anastomoses (stacked or bipedicled flaps), as arterial run-offs generally have a more elastic wall than their main pedicles (for example, DIEA/V). However, contrary to venous coupling (where mismatch is not problematic and a smaller vein can generally be tightened up to a certain extent), we think that in arterial coupling, mismatch can be tolerated only if it does not imply intimal tears, which goes in line with previous experience.

Concerning arterial wall thickness, we agree that thick or rigid vessels walls (for example in smokers, or diabetic patients) retain a greater risk of tearing/breaking; and that manual sewing should be preferred, as it can better adapt to the vessels' specific features. In vessels with appropriate compliance, an arterial coupler can be used after proper dilatation of the edges, which reduces the tendency of the vessel to "jump out" of the pins. A second operator can often be useful in keeping the vessels walls steady on one pin, while the first operator continues to hook the vessel to the next pin. In lower limb free flap reconstruction, end-to-side arterial anastomoses are most often used, which reduces the potential application of arterial couplers. However, the growing development of perforator-to-perforator free flap transfer may extend the indication for coupler devices in lower limb reconstruction, considering the better elasticity of perforators and the potential for easier eversion over the pins.

In addition, a prospectively maintained study comparing arterial and hand-sewn anastomotic outcome could definitely help us in further assessing the role of these devices in arterial anastomosis.

Conclusion

Overall, this short review supports the use of MACD in arterial anastomosis. It demonstrates that the use of this device is an efficient and potentially less time-consuming alternative to the hand-sewn technique, provided that the selection of vessels is appropriate, and that the vessel diameter is large enough for the anastomosis to be done without any complication.

More studies are needed to consolidate the MACD as a better alternative to the hand-sewn technique in arterial anastomosis. Most surgeons still prefer to use the hand-sewn technique because of its lower cost and lower risk of intimal tear during eversion of the wall. The ultimate goal is to have a fully-coupled anastomosis with a very short anastomotic time, which reduces the duration of ischaemia, improves the flap survival rate, and is more cost-effective in the long run.

Conflict of interest

We have no conflicts of interest.

Ethics statement/confirmation of patients' permision

Neither is applicable.

References

1. Suarez EL, Jacobson II JH. Results of small artery endarterectomy-microsurgical technique. *Surg Forum* 1961;**12**:256–7.
2. Cusano A, Fernandes R. Technology in microvascular surgery. *Oral Maxillofac Surg Clin North Am* 2010;**22**:73–90.
3. Nakayama K, Tamiya T, Yamamoto K, et al. A simple new apparatus for small vessel anastomosisi (free autograft of the sigmoid included). *Surgery* 1962;**52**:918–31.
4. Ostrup LT, Berggren A. The UNILINK instrument system for fast and safe microvascular anastomosis. *Ann Plast Surg* 1986;**17**:521–5.
5. Ahn CY, Shaw WW, Berns S, et al. Clinical experience with the 3M microvascular coupling anastomotic device in 100 free-tissue transfers. *Plast Reconstr Surg* 1994;**93**:1481–4.
6. Gilbert RW, Ragnarsson R, Berggren A, et al. Strength of microvascular anastomoses: comparison between the unilink anastomotic system and sutures. *Microsurgery* 1989;**10**:40–6.
7. DeLacure MD, Kuriakose MA, Spies AL. Clinical experience in end-to-side venous anastomoses with a microvascular anastomotic coupling device in head and neck reconstruction. *Arch Otolaryngol Head Neck Surg* 1999;**125**:869–72.
8. Blair WF, Morecraft RJ, Steyers CM, et al. A microvascular anastomotic device: part II. A histologic study in arteries and veins. *Microsurgery* 1989;**10**:29–39.
9. Hallock GG, Rice DC. Use of a microvascular coupler for repair of major distal upper extremity artery injuries. *J Hand Microsurg* 2009;**1**:3–6.
10. Nakatsuka T, Harii K, Asato H, et al. Analytic review of 2372 free flap transfers for head and neck reconstruction following cancer resection. *J Reconstr Microsurg* 2003;**19**:363–9.
11. Grewal AS, Erovic B, Strumas N, et al. The utility of the microvascular anastomotic coupler in free tissue transfer. *Can J Plast Surg* 2012;**20**:98–102.
12. Shindo ML, Costantino PD, Nalbone VP, et al. Use of a mechanical microvascular anastomotic device in head and neck free tissue transfer. *Arch Otolaryngol Head Neck Surg* 1996;**122**:529–32.
13. Ross DA, Chow JY, Shin J, et al. Arterial coupling for microvascular free tissue transfer in head and neck reconstruction. *Arch Otolaryngol Head Neck Surg* 2005;**131**:891–5.
14. Genther DJ, Day AT, Rana K, et al. Salvage arterial anastomosis using a microvascular coupler in head and neck free flap reconstruction. *Laryngoscope* 2017;**127**:642–4.
15. Spector JA, Draper LB, Levine JP, et al. Routine use of microvascular coupling device for arterial anastomosis in breast reconstruction. *Ann Plast Surg* 2006;**56**:365–8.
16. Chernichenko N, Ross DA, Shin J, et al. Arterial coupling for microvascular free tissue transfer. *Otolaryngol Head Neck Surg* 2008;**138**:614–8.
17. Rad AN, Flores JI, Rosson GD. Free DIEP and SIEA breast reconstruction to internal mammary intercostal perforating vessels with arterial microanastomosis using a mechanical coupling device. *Microsurgery* 2008;**28**:407–11.
18. Rozen WM, Whitaker IS, Acosta R. Venous coupler for free-flap anastomosis: outcomes of 1,000 cases. *Anticancer Res* 2010;**30**:1293–4.
19. Sando IC, Plott JS, McCracken BM, et al. Simplifying arterial coupling in microsurgery-A preclinical assessment of an everter device to aid with arterial anastomosis. *J Reconstr Microsurg* 2018;**34**:420–7.