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REVIEW

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Systematic review of microvascular coupling devices for arterial anastomoses in free tissue transfer

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Abstract

Background: Coupling devices have become commonplace in performing venous anastomoses during microvascular free tissue transfer (FTT). However, arterial anastomoses are still most commonly performed using traditional microvascular suture techniques.

Objective: To describe the safety and feasibility of using microvascular coupling devices for free flap arterial anastomosis.

Methods: A systematic review of English language literature was performed for studies that investigated the use of an arterial coupler for microvascular FTT in human patients. A comprehensive search of MEDLINE (January 1948 to August 2018), EMBASE (January 1974 to August 2018), and Web of Science was performed.

Results: Fifteen studies were included. All studies were retrospective case series. A combined total of 395 arterial anastomoses were attempted with a coupling device. All studies except for one used the 3M Unilink/Synovis coupling device. One study used a novel absorbable coupling device. The coupling device was aborted and converted to a suture technique in 8.4% of attempted anastomoses. Rupture of the anastomotic device was reported in only 1 patient (0.3%). Thrombosis was also infrequent at 1.9%. The quality assessment showed a high risk of bias in all studies.

Conclusion: In selected patients, coupling devices for arterial anastomoses have a good success rate with low rates of thrombosis based on limited quality evidence.

KEYWORDS

arterial coupler, free tissue transfer

1 | INTRODUCTION

Microsurgical anastomosis of blood vessels during free flap reconstructive surgery requires meticulous technique with careful attention and is crucial to the overall success of the operation. During lengthy free flap procedures, it is desirable to try and reduce the overall surgical time and subsequently improve patient outcomes. Nakayama et al first described use of a coupler in 1962 where they developed a device consisting of two metal rings with 12 interlocking pins and corresponding holes.[1] It was designed so that the ends of donor and recipient vessel could be passed through the rings which could then be pinned together, subsequently anastomosing the vessel. This

concept was later modified in 1986 by Ostrup and Berggren.[2] With their coupler, they reported no adverse effects even after 3 years postoperatively. Since then, couplers have become popular for performing venous anastomoses. However, couplers are not routinely used for arteries. Technical challenges associated with arterial couplers include difficulty manipulating thicker vessel walls, decreased pliability, and the presence of intimal plaques or calcifications. However, potential advantages over traditional microvascular suture technique include decreased operative time, improved maneuverability when working in difficult anatomic areas, improved tensile strength, better vessel eversion, and decreased adventitial exposure.

2 | METHODS

Research methods were documented in a study protocol a priori. The PRISMA guidelines for systematic reviews were followed. MEDLINE (January 1948 to August 2018), EMBASE (January 1974 to August 2018), and Web of Science were comprehensively searched for studies using coupling devices for arterial anastomosis in free flap surgery. The following search terms (including Medical Subject Headings and keywords) were combined to identify studies: anastomosis (anastomotic/anastomoses), microsurgery, microvascular, coupler (coupling/coupled), free tissue flap, free flap. Studies using nonhuman subjects, couplers used for vessel trauma (non-free flap surgery), and noncoupling devices were excluded. All anatomic sites were included. Subset analysis of specific body sites was planned but not performed due to lack of specifically reported outcomes based on anatomic site in the included studies. There was no age cutoff. Only English language studies were included. Outcomes included success of arterial coupler anastomoses, coupler failures, reasons for the failure, type of coupler used, average time for anastomosis, and coupler size. We used MINORS criteria for assessing the quality and risk of bias in the included studies.[3] Two reviewers (A. R. G., Y. J. B.) independently assessed and extracted data from all the studies included in the review. Disagreements were resolved with discussion, with a third reviewer (P. E.) available for arbitration if needed. Meta-analysis was planned for any outcomes in which there was a direct comparison

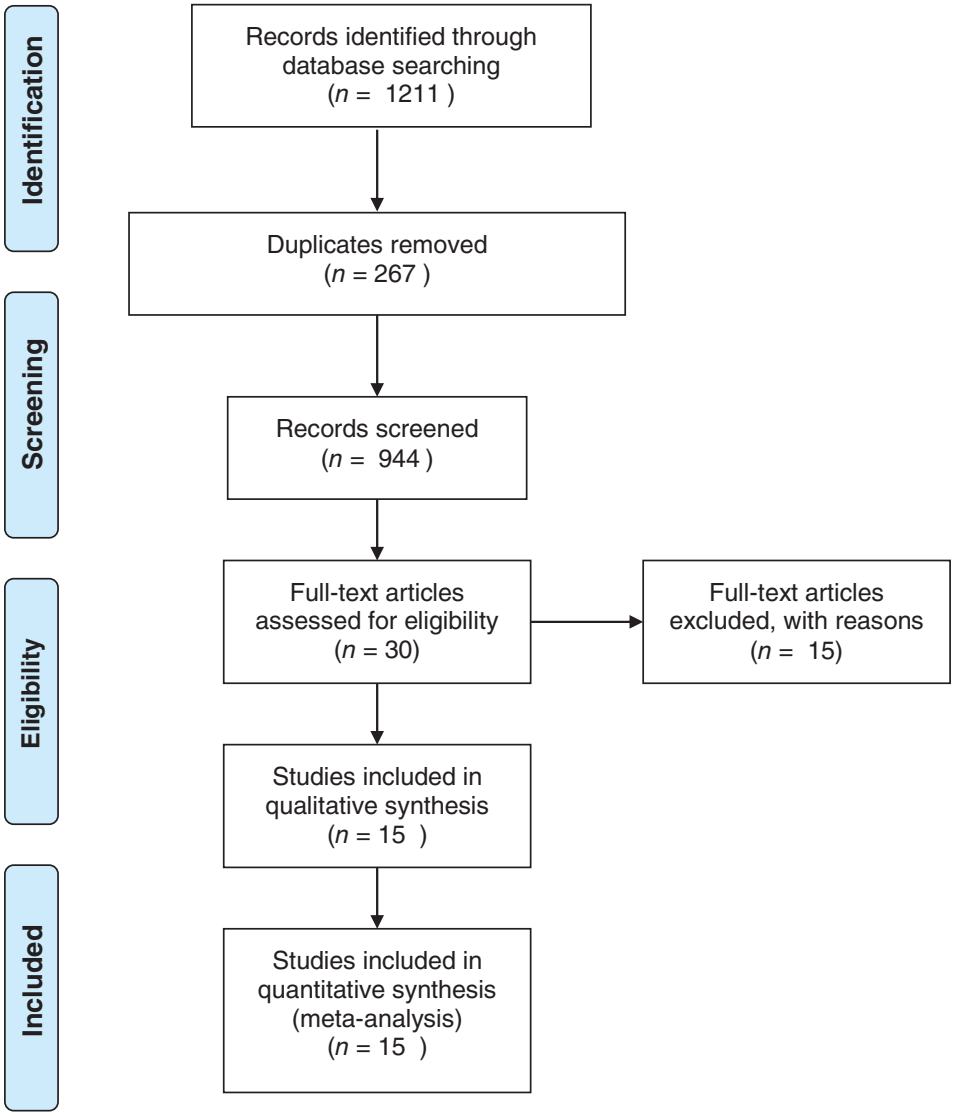

FIGURE 1 PRISMA flow diagram

between hand-sewn and coupler-assisted anastomoses if there was appropriate heterogeneity.

3 | RESULTS

The initial search identified 1211 records, out of which 267 duplicates were deducted. After screening 944 titles/abstracts, 30 full-text articles were reviewed. Out of these, 15 studies were included in the final analysis (Figure 1). All of the studies reviewed were retrospective studies. None of the included studies provided an appropriate comparison directly between coupler-assisted and hand-sewn anastomoses. Therefore, statistical meta-analysis was deemed inappropriate and not performed. The data for the outcomes of interest was pooled for aggregate percentages to summarize the data.

We identified 395 total arterial anastomoses in combined analysis. Table 1 shows that, of the 15 studies included, there were seven studies involving free tissue transfer (FTT) in the head and neck region, whereas the rest of the studies included FTT in various other regions of the body. There were 264 FTT in the head and neck, 90 in the breast region, and 41 in other body systems. Most of the studies used the 3M Synovis coupler, whereas one study by Daniel et al used an absorbable coupler made up of polyglactin.[14]

Most studies were small case series with less than 10 patients. Chernichenko et al had the largest series identified in this review.[5] They reported a series of 127 attempted arterial anastomoses for head and neck reconstruction patients. The coupler was successfully applied in 93.7% of attempted anastomoses. Success rate was 96.0% when the coupler was applied. The coupler was abandoned and converted to a hand-sewn technique in 3 patients (2.4%). Reasons for conversion included inadequate flow, inadequate vessel pliability, and

TABLE 1 Summary data of included studies

Studies	Site	Arterial anastomosis events	Conversion to suture	Mechanic al failure	Thrombosis	Average time (min)	Coupler size (mm)	Average age (y)
Assoumane et al[4] 2017	H&N	100	NR	0	0	NR	1-4	53
Chernichenko et al[5] 2008	H&N	127	3	0	3	NR	2.5	66
Cope et al[6] 2000	H&N, Breast	5	1	0	0	NR	NR	NR
Delacure et al[7] 1995	H&N	7	2	0	0	5	2.5	46
Shindo et al[8] 1996	H&N	17	2	2	2	10	NR	19-86[a]
Genther et al[9] 2016	H&N	1	0	0	0	NR	NR	NR
Wang et al[10] 2015	H&N	7	0	0	0	NR	1.5-2.5	60
Ahn et al[11] 1994	Various	29	5	0	0	4	1.5-2.0	44
Berggren et al[12] 1993	Various	5	NR	0	1	NR	1.5-2.0	NR
Camara et al[13] 2009	Breast	1	NR	0	0	NR	2-2.5	NR
Daniel et al[14] 1984	Various	2	NR	0	0	5	NR	NR
DeBrujin et al[15] 1996	Various	4	2	0	0	NR	NR	44
Rad et al[16] 2008	Breast	9	0	0	0	NR	NR	NR
Spector et al[17] 2006	Breast	80	18	0	0	NR	2-2.5	45.9
Zeebregts et al[18] 2002	Various	1	0	0	0	NR	2.0	54
Total	–	395	33	2	6	–	–	–

Abbreviations: H&N, head and neck; NR, not reported.
[a]Only range reported, average not available.

pseudoaneurysm formation. Thrombosis rate was 3.2%. Mechanical failure (rupture) occurred in 1 (0.8%) patient.

The second largest study was reported by Assoumane et al. This study included 100 patients undergoing head and neck reconstruction. They reported a 100% success rate; no specific mention was made of thrombosis, rupture, or need for conversion to hand-sewn methods.[4] Spector et al reported the third largest series with 80 attempted anastomoses in breast reconstruction patients. The coupler was successfully applied in 62 (77.5%) patients. There were no reported anastomotic or flap failures.[17]

Age, coupler size, and time taken to perform the anastomosis were reported in an inconsistent manner. Although age is a potentially important factor, it was not reported in seven studies. Only a few studies reported the size of coupler used, ranging from 1.0 to 4.0 mm. The average time for anastomosis was reported in four studies and it ranged from 4 to 10 minutes. Combined analysis of the included studies showed that of the 395 attempted anastomoses, 8.4% were unsuccessful intraoperatively and subsequently converted to a hand-sewn technique. The reasons for the conversion included thick-walled vessels, small sized vessel, vessel size discrepancy, or calcified stiff arterial walls. Intraoperative conversion to a hand-sewn technique was not reported in four studies.

Of the 362 successfully applied coupler anastomoses, success was very good with a low rate of subsequent complications. Thrombosis occurred in 1.9% of anastomoses. Rupture of the anastomosis was rare (0.3%). Mechanical failure occurred in 2 cases (0.5%). Out of six thrombotic events, four were salvageable; three were restored by replacement of the coupler and one was converted to hand-sewn technique. The size of the couplers used for salvage was increased by 0.5 mm in each instance. There was one event of rupture of the donor vessel at the coupler end that occurred in a patient with steroid-dependent immunosuppression. One case involved a mechanical failure that was due to a tear of the tunica intima while everting the vessel.

There were various reasons cited in different studies for conversion to a hand-sewn technique. In Ahn et al, there were five arterial anastomotic failures. It was observed intraoperatively that there was no flow or diminished flow after eversion of the arterial edge in four cases.[11] The fifth failure was due to the traumatic tear of the vessel. Brujin et al also noted that the failure in their only two arterial anastomoses were due to thick arterial walls.[15] Furthermore, Delacure et al reported failure of couplers due to thick arterial walls, decreased pliability, and inadequate eversion of the arterial walls for revascularization.[7] In general, the most common reasons of abandonment stated were thickened arterial walls, small vessel size, and atherosclerotic plaques. Not all studies reported reasons for coupler failure.

Shindo et al[8] reported a 12.5% arterial coupler failure rate. They described one failure that was seen in an irradiated vessel, which was caused due to an intimal tear while everting thick walls. They concluded that the use of the coupler for arterial anastomosis is suboptimal in the head and neck region due to thick-walled and irradiated vessels.

One case report by Genther et al suggested that couplers could be considered as an alternative in the setting of repeated failure with hand-sewn anastomoses.[9] They successfully demonstrated the use of a coupling device in a case involving a salvage arterial anastomosis.

MINORS criteria were used to assess the quality and risk of bias in the studies included.[3] The score ranged from 5 to 8 which was suggestive of a high risk of bias. The reasons included lack of randomization, lack of blinding, retrospective nature, and a lack of follow-up data.

4 | DISCUSSION

Since the initial description in 1962 by Nakayama et al, coupling devices have become a mainstay in microvascular FTT.[1] However, this use is predominantly for the venous anastomoses; coupler use for the arterial anastomosis is not a common practice. In this study, we reviewed the evidence behind couplers for arterial anastomosis in FTT. Overall, the data suggests that arterial coupler use is reasonably safe with a low rate of complications and a good success rate based on low quality evidence.

There are a number of variables to consider when using a coupler on an artery. Spector et al suggested that the ratio of lumen size between the two vessels should not exceed 1:1-1.5.[17] If the ratio exceeds this, then size discrepancy may increase the chance of kinking and thrombosis. Additionally, flow through the anastomosis may be impaired if the arterial lumen is significantly larger than the coupler. There were a range of coupler sizes used in the studies identified in this review, although a number of studies did not specify coupler size. Successful coupler use was reported in sizes as small as 1 mm.

Thrombosis was overall a rare complication seen in 1.9% of anastomoses in this review. One of the theoretical arguments for arterial coupler use is that less exposure of the adventitia and avoidance of foreign material in the vessel lumen can reduce this risk of thrombosis compared to manually placed sutures. The low thrombosis rate in this study would support this; however, there is no direct scientific proof to support this theory.

Vessel pliability is a major factor when considering arterial coupler use. Compared to veins, the increased thickness and elasticity of arteries can make placement of the coupler technically challenging. Additional factors such as atherosclerotic disease and fibrosis due to radiation therapy can significantly reduce the pliability of arteries, further increasing the difficulty of placing an artery over the coupler pins. These diseased vessels may be at increased risk for tears or ruptures. Technical inability to place an arterial coupler is therefore a concern. In contrast, the studies by Chernichenko et al and Delacure et al state that the preoperative radiation dose not impact the anastomotic failure and hence should not be considered a contraindication for coupler use.[5,7] In our review, 8.4% of anastomoses were unsuccessful intraoperatively and were converted to a hand-sewn technique. This number is also likely under reported, as several studies may have excluded these occurrences from their final retrospective analysis. Although the anastomosis can usually be converted to a hand-sewn technique,

critical vessel length may be lost in the process and additional surgical time is added. Furthermore, hand-sewn techniques may be responsible for unequal spacing and unrecognized back walling with potential for thrombosis, luminal stenosis, and intimal injury.[9]

Probably the most attractive feature of using an arterial coupler is a potential decrease in surgical time. Microvascular free flap cases are often lengthy in nature. Previous studies have shown that patient outcomes are worse with prolonged surgical time.[19] Therefore, measures that can decrease surgical time without negatively impacting outcomes are worth exploring. In this systematic review, arterial anastomotic time was noted in some studies but not all. Of the four studies that did report the average time to anastomose, most authors reported favorable times. However, this data is at high risk for reporting bias and should be interpreted carefully. Such results also may not account for failed attempts at coupler placement with subsequent conversion to a hand-sewn anastomosis.

Age of the patient is another important consideration in arterial coupler use. Atherosclerotic disease and fibrosis are more frequent in older patients, and carry inherent technical challenges as mentioned above. Average age or age range was not reported in many of the studies. Although it seems prudent to avoid coupler use in patients with suspected severe atherosclerotic disease or poor vessel pliability, quality issues and inconsistent reporting of data from the included studies prevent any conclusions from being drawn regarding arterial coupler use based on patient age.

The results of this systematic review should be interpreted cautiously. As described, the quality of the evidence is low, particularly given the high risk of bias in the identified studies. The retrospective nature of all the included studies carries an inherent selection bias. Additionally, there is a high risk of reporting bias.

5 | CONCLUSION

Coupler use appears to be a safe technique for arterial anastomosis in microvascular free flap reconstruction in carefully selected patients based on low quality evidence. Conversion to a hand-sewn technique may be necessary. Caution is strongly advised in the setting of small diameter arteries, significant atherosclerotic burden, and thick-walled vessels. Though logistically challenging, a randomized controlled trial may be helpful in further assessing the safety and feasibility of coupler use in arterial anastomoses compared to a hand-sewn technique.

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