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Exploring the supremacy of microvascular coupling devices for arterial anastomosis in terms of added expeditiousness, safety concerns: A systematic review☆

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ABSTRACT

Background: Arterial anastomoses are still most commonly performed using orthodox hand sewing technique. Various rationale such as non-pliable, atherosclerotic, thick-walled or irradiated vessels limit the competency of coupler devices for arterial micro-anastomosis. Microvascular coupling devices (MCD) are well known for venous anastomoses but arterial MCD have relatively been less navigated in reported literatures. This review outlines the current applications, troubleshooting, safety and efficiency of arterial MCD in free flaps.

Methods: Comprehensive search of electronic databases (PUBMED/MEDLINE) in accordance with PRISMA guideline was performed. Data were extracted and collected in four groups of standardised variables.

Results: Out of a total of 263 identified articles, 38 studies were analysed and 16 amidst these were included in final data synthesis. Included studies contained a combined total of 2416 patients who went through 521 arterial and 2460 venous anastomoses using 3 M/Synovis coupling devices. Among all coupled arterial anastomoses, 407 were conducted in head and neck free tissue transfer and 114 were performed in breast reconstruction. The aggregate coupled arterial micro-anastomosis success rate reported was 90.01 % (469/521). Only 9.98 % (52 out of 521) manifested pooled incidence of troubleshooting, thrombosis or flap failure.

Conclusion: Microsurgeons are resisting the frequent use of arterial coupling devices owing to inherent arterial characteristics, but with suitable vessel selection, arterial coupling may be a powerful tool and can be executed in safe, expeditious and reliable fashion. This study embellishes collaborative suggestions and troubleshooting issues related to arterial coupling, however further assessment would be required with controlled trials.

Support

Nil.

1. Introduction

Head and neck oncological resection followed by reconstruction is indispensable and gold standard requisite. Micro-anastomosis of donor and recipient vessels during free tissue transfer necessitates rigorous approach with mindful vigilance and is critical for overall survival of the flap. Ascribed to the lengthy and exhaustive nature of micro-anastomosis procedure, it becomes necessary to bid for shortening overall surgical time which would sequentially ameliorate patient outcome.

In 1962, Nakayama et al. first designed a coupler device, incorporating 2 metallic rings along with twelve interlocking pins and

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corresponding holes.[1] It was created so that the ends of anastomosing vessels could be advanced easily via the ring which could further be pinned together to accurately interpose the ends of the vessels, and subsequently ensuing their intima contact, while keeping the lumen deprived of any foreign materials (suture) in to the lumen. Presently, application of couplers has become fascinating and is being mostly preferred in performing venous anastomosis.[2] However, the use of MCD for arterial anastomosis has not been extensively navigated and the published data also seems to be quite alarming. There are some technical obstacles associated with arterial couplers which include difficulty in manipulating too thick-walled arteries, non-pliable vessels as a result of fibrosis due to radiation or atherosclerotic calcification, and disparity in vessel diameter.[3] The focus of this systematic review is to assess all the validation on current applications, efficacy and troubleshooting of MCD in arterial micro-anastomosis.

1.1. Aims and Objectives

The primary intention of this systematic review is to evaluate troubleshooting issues associated with arterial anastomosis besides subsequently evaluating safety, potency and rapidity of microvascular coupling devices in performing the same during free tissue transfer. We anticipated to answer the following questions.

1. Is there any significant dissimilarity in time consumption, thrombotic events and overall flap survival rate using MCD for arterial anastomosis over hand suturing.
2. Unique troubleshooting/complications associated with MCD for arterial anastomosis in head & neck reconstruction.

2. Methods

2.1. Eligibility benchmark

This systematic review was accomplished using Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline. All available human studies in English language (randomized controlled trials, clinical trials, case series, case control and cohort study) were entitled for inclusion. There was no age bar or restriction on study size except for literatures on nonhuman subjects, cadaveric study, in-vitro study as well as non-English writings that could not be reliably interpreted were excluded.

2.2. Participants

Studies including tumor ablative surgeries where micro-anastomosis was performed either by MCD only or MCD and Hand sewing jointly were included. (studies acknowledging revascularization or reimplantation after amputation were not included).

2.3. Interventions

All the publications mentioning use of pin, ring and hole system MCD (3 M or Synovis) for micro-anastomosis were incorporated for evaluation. We thoroughly witnessed all the studies with the titles mentioning venous anastomosis or hand sewing and extracted all the inevitable details on arterial anastomosis.

2.4. Comparators

This study basically compares safety, reliability and troubleshooting of MCD in arterial v/s venous anastomosis. In addition to this, the study also compares efficacy and trustworthiness of MCD v/s hand suturing for arterial anastomosis. We have made sincere efforts to extract these details even if direct comparison has not been mentioned in the articles considered for review.

2.5. Outcomes and definitions

Primary outcome was assessment of significant time saving, manipulation difficulty and troubleshooting issues that required redo either by MCD or Hand sewing.

Secondary outcome was detailed estimation of difficulty associated with vessel geometry, coupler caliber, other mechanical failures and overall flap survival rate.

2.6. Search scheme and information origin

A panoramic exploration of relevant literature was conducted across PUBMED/MEDLINE, from its origin till May 2023. To identify studies, the detailed keywords strategy utilised on various databases were combination of “Microvascular anastomosis OR free tissue transfer OR free flap AND Coupling device OR couplers OR hand suturing OR hand sewn AND arterial”. Each denomination was explored prior to being integrated.

The medical subject headings (MeSH) terms were ((("microvascular"[All Fields] OR "microvascularity"[All Fields] OR "microvascularization"[All Fields] OR "microvascularized"[All Fields]) AND ("anastomosis, surgical"[MeSH Terms] OR ("anastomosis"[All Fields] AND "surgical"[All Fields]) OR "surgical anastomosis"[All Fields] OR "anastomosis"[All Fields])) OR ("free"[All Fields] AND ("tissue s"[All Fields] OR "tissues"[MeSH Terms] OR "tissues"[All Fields] OR "tissue"[All Fields]) AND ("transfer"[All Fields] OR "transferability"[All Fields] OR "transferable"[All Fields] OR "transferred"[All Fields] OR "transferring"[All Fields] OR "transferred"[All Fields] OR "transferring"[All Fields] OR "transfers"[All Fields])) OR ("free tissue flaps"[MeSH Terms] OR ("free"[All Fields] AND "tissue"[All Fields] AND "flaps"[All Fields]) OR "free tissue flaps"[All Fields] OR ("free"[All Fields] AND "flap"[All Fields]) OR "free flap"[All Fields])) AND ((("couple s"[All Fields] OR "coupled"[All Fields] OR "coupling"[All Fields] OR "couplings"[All Fields] OR "family characteristics"[MeSH Terms] OR ("family"[All Fields] AND "characteristics"[All Fields]) OR "family characteristics"[All Fields] OR "couple"[All Fields] OR "couples"[All Fields]) AND ("device s"[All Fields] OR "equipment and supplies"[MeSH Terms] OR ("equipment"[All Fields] AND "supplies"[All Fields]) OR "equipment and supplies"[All Fields] OR "device"[All Fields] OR "instrumentation"[MeSH Subheading] OR "instrumentation"[All Fields] OR "devices"[All Fields])) OR ("coupler"[All Fields] OR "coupler s"[All Fields] OR "couplers"[All Fields]) OR (("hand"[MeSH Terms] OR "hand"[All Fields]) AND ("suturability"[All Fields] OR "suturable"[All Fields] OR "sutural"[All Fields] OR "suturation"[All Fields] OR "suture s"[All Fields] OR "sutured"[All Fields] OR "sutures"[MeSH Terms] OR "sutures"[All Fields] OR "suture"[All Fields] OR "suturing"[All Fields])) OR (("hand"[MeSH Terms] OR "hand"[All Fields]) AND "sewn"[All Fields])) AND ("arterialization"[All Fields] OR "arterializations"[All Fields] OR "arterialize"[All Fields] OR "arterialized"[All Fields] OR "arterializing"[All Fields] OR "arterially"[All Fields] OR "arterials"[All Fields] OR "arterie"[All Fields] OR "arteries"[MeSH Terms] OR "arteries"[All Fields] OR "arterial"[All Fields] OR "arteris"[All Fields] OR "artery"[All Fields] OR "arterious"[All Fields] OR "artery s"[All Fields] OR "arterys"[All Fields])

A further manual search (for any missed publication) of citations in incorporated articles was also done which allowed for distinguishing relevant studies not encapsulated in primary search. These relevant studies were imported in to Zotero 6.0.26 (Corporation for Digital Scholarship) reference manager for evaluation and abolition of identical articles.

Screening was carried out at two levels (titles/abstract and full-text screening) by two independent investigators (AV and NS). In the instance of disagreements, the resolution was mediated by a third independent investigator (ND or SS) and final decision was made. The prime benchmark for full-text screening included literature delineating the use of MCD for anastomosis of any vessel (artery/vein). Articles

manifesting the use of couplers for anastomosis performed only in veins, experimental animal or cadaveric studies were excluded during data extraction along with non-English scholarly documentation and reviews. All possible rationalities for elimination beyond initial screening has been explained in PRISMA flow chart (Fig. 1).

2.7. Data extraction and analysis

All the articles which went across the twin stages of screening were listed in predefined Microsoft® Excel sheet for Mac 2018 and read thoroughly by two independent investigators (AV and NS).

Data were extracted and assembled in four categories of standardised variables: Characteristics of included studies, coupler anastomosis reported in Head & Neck and in Breast, and technical considerations. Data that were not intelligible in establishing their relevance to arterial anastomosis were recorded as 'Not reported'.

2.8. Quality assessment

MINORS criteria was applied for estimating the quality of evidence and probability of bias in the included study.[4] Since the studies included were retrospective in nature and there was lack of randomization added up with the scarcity of blinding with limited follow-up record, so the outcome fluctuated from five to eight which is indicative of high risk of bias.

3. Results

Initial search generated a huge number of titles (252) on electronic database in addition to 11 titles achieved from manual searching. In the concluding qualitative data synthesis, 16 manuscripts were incorporated. The principal criteria for exclusion after full-text eligibility evaluation of 38 manuscripts has been explained in PRISMA flow chart (Fig. 1).

Included studies contained a combined total of 2416 patients with age ranging from 16 to 92 years, who went through 521 arterial and 2460 venous micro-anastomoses using 3 M/Synovis MCD.

Extracted data and main attributes of included studies are outlined in Table 1. Out of all the studies included from 1995 to 2020 (year of publication), 8 took place in United States, 4 in China, 2 in New York, 1 each in California and Japan.

Out of 521 arterial coupled anastomoses, 407 were performed in head and neck free tissue transfer while 114 were conducted in breast reconstruction. The frequent free flaps coupled were the radial forearm

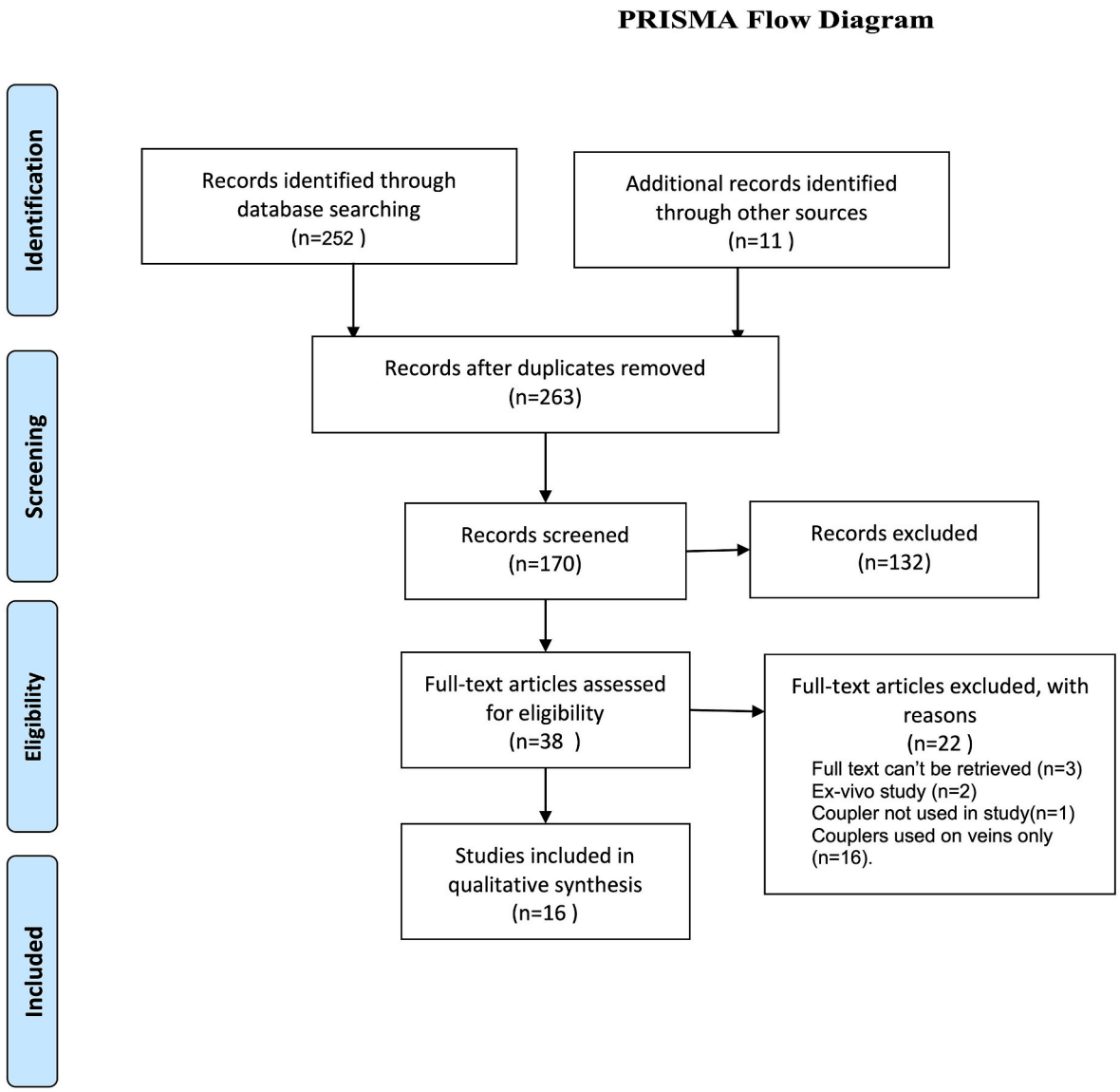

Fig. 1. PRISMA flow diagram.

Table 1
Characteristics of included studies (summary).

Year and Publication	Authors	Study design	Study country	No. of patients	Mean age/ range (years)	Region	No. of Anastomosis	
							Arterial	Venous
Am J Surg. 1995; 170: 521–523. **(1995)**	DeLacure et al.[18]	Retrospective case series	New York	29	49	Head & Neck	7	30
Arch Otolaryngol Head Neck Surg. 1996; 122:529–532. **(1996)**	Shindo et al.[2]	Retrospective case series	California	80	19–86	Head & Neck	17	88
Journal of reconstructive microsurgery/volume 16, number 7 October **(2000)**	Nishimoto et al.[5]	Retrospective case series	Japan	89	28–86	Head & Neck	NR	121
Arch Otolaryngol Head Neck Surg. 2005; 131:891–895 **(2005)**	Ross et al.[9]	Retrospective case series	United States	49	43–85	Head & Neck	50	100
Ann Plast Surg 2006; 56: 365–368 **(2006)**	Spector et al.[3]	Retrospective case series	New York	60	45.4	Breast	80	NR
Otolaryngology–Head and Neck Surgery (2008) 138, 614–618 **(2008)**	Chernichenko et al.[19]	Retrospective case series	United States	127	41–87	Head & Neck	124	NR
Laryngoscope, 118:2146–2150, 2008. **(2008)**	Chernichenko et al.[20]	Retrospective case series	United States	134	43–92	Head & Neck	1	173
Microsurgery 28:407–411, 2008. **(2008)**	Rad et al.[21]	Retrospective case series	United States	9	43–60	Breast	9	10
Plast. Reconstr. Surg. 125: 792, 2010. **(2010)**	Jandali et al.[22]	Retrospective case series	United States	730	NR	Breast	5	1000
J Reconstr Microsurg 2013; 29:433–436. **(2013)**	Patel et al.[23]	Retrospective case series	United States	66	NR	Head & Neck	NR	39
Int. J. Oral Maxillofac. Surg. 2015; **(2015)**	Wang et al.[24]	Retrospective case series	China	64	NR	Head & Neck	7	73
Br J Oral Maxillofac Surg (2017) **(2016)**	Assoumane et al.[13]	Retrospective case series	China	601	13–91	Head & Neck	100	754
Br J Oral Maxillofac Surg(2019) **(2019)**	Chen et al.[16]	Retrospective case series	China	45	18–71	Head & Neck	45	45
Head & Neck. 2020; 1–7. **(2020)**	Li et al.[25]	Retrospective case series	United States	106	52 and 80	Head & Neck	NR	NR
Int. J. Oral Maxillofac. Surg. 2019; **(2020)**	Guo et al.[14]	Retrospective case series	China	123	16–82	Head & Neck	56	27
J Reconstr Microsurg 2020-08-20 **(2020)**	McLaughlin et al.[26]	Retrospective case series	United States	104	18 and older	Breast	20	NR

Abbreviation: NR (not reported).

(n = 565), fibular (n = 244), anterolateral thigh (n = 289), muscle-sparing transverse rectus abdominis myo-cutaneous (n = 630) and deep inferior epigastric perforator (n = 346). The arterial coupling was done using Unilink Microvascular Anastomotic System (Synovis MCA, Birmingham, Ala) in 60.6 % (347 out of 521), The GEM microvascular anastomotic coupler system (Synovis Micro Companies Alliance Inc) in 20.15 % (105 out of 521), microvascular anastomotic coupler (Synovis Micro Companies Alliance, Baxter International) in 8.63 % (45 out of 521) and The Unilink/3 M Microvascular Anastomotic System (3 M Healthcare, St Paul, Minn) in 4.6 % (24 out of 521) of the patients (Table 2 and Table 3).

The overall reported success rate of MCD for arterial coupling was 90.01 % (469 out of 521) and merely 9.98 % (52 out of 521) were pooled incidence of troubleshooting, thrombosis or flap failure. These rates were estimated from technical perspective and hence are not indicative of anastomotic stability, patency or additional surgical consequences. Equivalent figures from hand sewn anastomosis were inadequate, therefore direct comparison is impractical to be established.

3.1. Complications related to arterial coupling

Overall 2.68 % (14 out of 521) events of Arterial thrombosis occurred intraoperatively or postoperatively (Table 4). The most frequently mentioned reason behind thrombosis was thick and stiff-walled arteries resulting in eversion error and thereby subsequently leading to small tear in intima. Also, the intima of an irradiated recipient vessel are at high risk to get separated from muscularis layer and may develop intimal flap which eventually leads to the possibility of thrombosis. In some flaps intraoperative thrombosis occurred in a vessel anastomosed by 2.0 mm size coupler which therefore required redo by 2.5 mm coupler. 6.5 % (34 out of 521) couplings were converted to hand suturing in exigent cases requiring immediate attention to deal with functional incompatibility of device, perfusion error or anastomotic leakage. 0.76 % (4 out of 521) flaps were not found fit enough to be salvageable due to the mixture of above mentioned troubleshooting issues.

3.2. Expeditiousness and safety concerns in arterial coupling

There was considerable variation regarding how anastomotic operating time was documented in every case. This led to significant heterogeneity in this data because exact time recorded differed in reported literatures. The anastomotic time generally ranges from 4 to 15 min. Authors of primitively reported literature were anxious about transfixion of thick and poorly pliable arterial vessels in to the tine. Despite the truncated documentation of evidence, this methodology shows eloquent application of coupling devices and authors have jointly proclaimed the conviction regarding use of MCD in executing considerable cases of arterial anastomosis.

4. Discussion

Anastomotic coupling devices have evolved into a manoeuvre gradually growing in demand for performing venous anastomoses. Vast majority of literature have documented the advantages of venous coupling. First and foremost, there is significant time saving as compared to hand sewing anastomosis. Secondly, the coupling device builds endothelial harmony while keeping the lumen free of any intraluminal foreign (suture) material, which theoretically validates reduced thrombotic events. To conclude with, anastomosis by couplers have been found to be 50 % more secure as compared to sutured anastomosis at four months post-surgery and this technique even might aid in scaffold effect of coupler rings which additionally avert the vessel walls from collapsing.[5–8]

Table 2
Coupler anastomosis reported in Head & Neck (illustrating procedure/Donor sites, failures from arterial coupler and anastomotic time).

Authors/ Year	Region	Procedures (Free flap donor sites)	Coupler Device	Anastomosis by coupler		Coupler size (mm)	Failures from arterial coupler			Flap loss in hand sewn anastomosis (artery/vein)	Mean anastomotic time for artery (minutes)
				Arterial anastomosis events	Venous anastomosis events		Conversion to hand sewing	Arterial thrombosis	Flap loss from arterial coupler		
DeLacure et al.[18] **(1995)**	Head & Neck	Radial forearm (n = 9), fibula (n = 7), scapula (n = 6), rectus abdominus (n = 3), jejunum(n = 1), latissimus dorsi (n = 1), gracilis muscle (n = 1) and iliac crest (n = 1).	3 M	7	30	1.5–2.5	2	0	NR	NR	5
Shindo et al.[2] **(1996)**	Head & Neck	Radial forearm (n = 28), Rectus abdominis (n = 27), fibula (n = 12), lateral thigh (n = 4), iliac crest (n = 3), gracilis muscle (n = 2), jejunum (n = 1), pectoral (n = 1) and lateral arm (n = 1).	3 M	17	88	NR	2	2	1	0	10
Nishimoto et al.[5] **(2000)**	Head & Neck	NR	3 M	NR	121	1.5–2.5	NR	NR	NR	0	5
Ross et al.[9] **(2005)**	Head & Neck	Radial forearm (n = 36), fibula (n = 12), and rectus abdominus (n = 2).	Synovis	50	100	2.0–3.0	1	1	0	0	7
Cherniche-nko et al.[19] **(2008)**	Head & Neck	Radial forearm (n = 90), fibula (n = 26), rectus abdominis (n = 9) and iliac crest (n = 2).	Synovis	124	NR	2.5–3.0	3	3	1	0	Not specified
Cherniche-nko et al.[20] **(2008)**	Head & Neck	Radial fore- arm (n = 76), fibula (n = 17) and rectus abdominis free flap (n = 3).	Synovis	Only 1 reported	173	2.5–3.5	0	NR	NR	0	NR
Patel et al.[23] **(2013)**	Head & Neck	Radial forearm free flap (n = 61).	Synovis	NR	39	1.5–3.5	0	0	0	2	4–15
Wang et al.[24] **(2015)**	Head & Neck	Fibula flap (n = 35), Iliac flap (n = 29).	Synovis	7	73	1.5–4.0	NR	1 (Arterial spasm)	0	0	5–8
Assouman-e et al.[13] **(2016)**	Head & Neck	Anterolateral thigh flap (n = 232), radial forearm flap (n = 223), fibula free flap (n = 78), and iliac crest flap (n = 68).	Synovis	100	754	1.0–4.0	NR	NR	NR	8	10
Chen et al.[16] **(2019)**	Head & Neck	radial forearm flap (n = 16), fibular flap (n = 18) and anterior lateral thigh free flaps flap (n = 11).	Synovis	45	45	1.5–2.5	1	1	1	NR	7
LI et al.[25] **(2020)**	Head & Neck	Anterolateral thigh flap, scapular tip osteo-cutaneous	Synovis	NR	NR	1.5 and 3.5	2	4	NR	1	NR

(*continued on next page*)

Table 2 (*continued*)

Authors/ Year	Region	Procedures (Free flap donor sites)	Coupler Device	Anastomosis by coupler		Coupler size (mm)	Failures from arterial coupler			Flap loss in hand sewn anastomosis (artery/vein)	Mean anastomotic time for artery (minutes)
				Arterial anastomosis events	Venous anastomosis events		Conversion to hand sewing	Arterial thrombosis	Flap loss from arterial coupler		
		flap and latissimus dorsi free flap. (Number not specified)									
Guo et al.[14] **(2020)**	Head & Neck	anterolateral thigh flap (n = 41), fibula flap (n = 39), radial forearm flap (n = 26), latissimus dorsi flap (n = 9), deep inferior epigastric perforator flap (n = 5), anteromedial thigh flap (n = 1), iliac flap (n = 1), and lateral upper arm flap (n = 1).	Synovis	56	27	1.5–3.5	0	0	1	1	8.06

Abbreviation: NR (not reported).

Table 3
Coupler anastomosis reported in Breast (illustrating procedure/Donor sites, failures from arterial coupler and anastomotic time).

Authors/ Year	Region	Procedures (Free flap donor sites)	Coupler device	Anastomosis by couplers		Coupler size (mm)	Failures from arterial coupler			Flap loss in hand sewn anastomosis (artery/vein)	Mean anastomotic time for artery (minutes)
				Arterial anastomosis events	Venous anastomosis events		Conversion to hand sewing	Arterial thrombosis	Flap loss from arterial coupler		
Spector et al.[3] **(2006)**	Breast	muscle-sparing TRAM (n = 47), DIEP flap (n = 22), and superior gluteal flap (n = 11).	Synovis	80	NR	2.0–2.5	18	1	0	0	5
Rad et al.[21] **(2008)**	Breast	DIEP flap (n = 8), SIEA flap (n = 1).	Synovis	9	10	1.5–3.0	0	0	0	NR	NR
Jandali et al.[22] **(2010)**	Breast	Muscle-sparing TRAM (n = 572), DIEP flap (n = 305), SIEA flap (n = 108), SGAP flap (n = 10) and IGAP flap (n = 5).	Synovis	5	1000	1.5–4.0	1	1	NR	0	3 (for vein)
McLaughlin et al.[26] **(2020)**	Breast	DIEP flap (n = 6), Muscle-sparing TRAM (n = 11), VUG flap (n = 1), Fleur de Lis Gracilis (n = 2).	Synovis	20	NR		4	NR	0	2	4–5

Abbreviations: NR (not reported), TRAM (transverse rectus abdominis myo-cutaneous), DIEP (deep inferior epigastric perforator), SIEA (superficial inferior epigastric artery), SGAP (superior gluteal artery perforator), IGAP (inferior gluteal artery perforator), VUG (vertical upper gracilis).

Table 4
Troubleshooting/failure, technical considerations, challenges and authors recommendation in application of arterial coupling device.

Author/Year	Troubleshooting/ failure		Technical considerations, challenges and comments	Authors recommendation
	Frequency	Rate		
DeLacure et al.[18] **(1995)**	2	28.5 %	If the selected coupler is found to be smaller than the optimal size for a particular vessel, it may result in evident uneven redundancy and pleating of vessel on ring. On the other hand, if selected coupler is larger than the optimal size for a particular vessel diameter, it may result in traumatic tearing of intima. So, both the above conditions will be predisposing to anastomotic failure. Previously irradiated operative fields generally have thickened and noncompliant arterial vessels which make coupler anastomosis very challenging.	The fundamental rule includes: • Minimal size discrepancy between donor and recipient vessel in addition to precise selection of coupler size. • Tension/torsion free anastomosis.
Shindo et al.[2] **(1996)**	5	29.4 %	One case of thrombosis occurred intraoperatively which necessitated redo by hand sewing. The reason behind thrombosis was vascular stiffness leading to difficulty in everting vessel wall which subsequently resulted in small tear in intima. Therefore, it is not advisable to anastomose thick-walled or calcified arteries by couplers.	Recommends technique to be safe and efficacious to use for microvascular anastomosis in head and neck free flap reconstruction. **Important elements of procedure:** • picking the correct size of coupler. • Making certain that the vessel is not twisted before placing it through the ring.
Nishimoto et al.[5] **(2000)**	NR	NR	In one patient anastomosis was reperformed using coupler because soon after completion of the procedure, the anastomosis was avulsed, though the coupling of two polyethylene rings remained firm and intact. In 2 of the cases, the coupler rings were palpated as subdermal induration which can be abhorred by shifting towards biodegradable ring materials.	The device demands tension free colligation and little more room during anastomosis. The technique is reliable and time sparing for end-to-end venous anastomosis in head and neck reconstruction.
Ross et al.[9] **(2005)**	2	4 %	The only arterial complication was breach of anastomosis on 12th postoperative day in steroid dependent renal transplant patient, which required ligation of vessel. (The coupler was found intact but the recipient artery had torn away from coupler pin allowing donor to bleed). One intraoperative thrombosis occurred in a vessel anastomosed by 2.0 mm size coupler requiring repeated coupling by 2.5 mm coupler. A single case of postoperative hematoma was also reported where 2.0 mm coupler did not provide adequate flow which further obligated the need of switching to hand sewn anastomosis.	Author recommends that the coupler is justifiable for arterial anastomosis as well and might evolve as a possible replacement of hand suturing.
Spector et al.[3] **(2006)**	19	23.7 %	In case of size disparity existing between recipient and donor vessels, the preferred coupler size should be in accordance with the smaller vessel. An elastic silicon strip (medline industries; mundelein, il) approximately 1 mm wide along with atraumatic forceps can be used for transfixion of vessels in to tine.	With appropriate vessel selection, arterial coupling may be accomplished in a safe, expeditious and reliable fashion specially for microvascular free flap reconstruction of bilateral breast.
Chernichenko et al.[19] **(2008)**	7	5.6 %	Couplers smaller than 2.5 mm were more likely to limit blood flow, because intraoperative thrombotic event was detected in one of the patients in	Although in the beginning, literature shows concern over transfixion of thick and poorly pliable arterial vessels in to the tine, but eventually down the line, authors

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Table 4 (*continued*)

Author/Year	Troubleshooting/ failure		Technical considerations, challenges and comments	Authors recommendation
	Frequency	Rate		
			which 2.0 mm coupler was used.	developed enough conviction regarding use of coupling devices for carrying out extensive majority of arterial anastomosis.
Chernichenko et al.[20] **(2008)**	0	0 %	On 2nd postoperative day, a patient developed signs of venous congestion. Therefore, salvage thrombectomy was planned followed by re-anastomosis with a 2.5 mm coupler. To evade the obligation of switching to hand sewing, the thickened tunica adventitia was dissected off and thin intimal wall was selected for better transfixion into the coupler.	This massive reported case series of end-to-side venous anastomosis expresses the feasibility and potency of coupling devices in head and neck reconstruction.
Rad et al.[21] **(2008)**	0	0 %	When the size disparity exists between flap and recipient vessel, then the coupler selected should be matching with the size of smaller diameter out of the above two. The intima of an irradiated recipient vessel are endangered to get separated from muscularis layer and may develop intimal flap which subsequently leads to risk of thrombosis.	This methodology shows dynamic and eloquent application of coupling devices in microvascular free flap reconstruction of breast.
Jandali et al.[22] **(2010)**	2	40 %	This study introduced a vessel measuring gauge to regulate the selection of correct coupler size. (if the diameter of vessel equals 3.0 mm mark on the measuring gauge, then 2.5 mm diameter coupler should be used)	The author was condemned regarding practice of this faster and more productive technique, for shifting the residents and fellow from basic hand sewn micro-anastomosis to use of couplers. But, finally it was believed that this study was an exact contemplation of what other microsurgeons should expect with the use of couplers for the venous anastomosis.
Patel et al.[23] **(2013)**	0	0 %	There were 2 cases that needed re-exploration, one for suspected thrombosis (which was negative), and another one for suspected hematoma (which also turned up negative).	It was acknowledged that while the couplers may simplify the process of venous anastomosis but it still called for a learning curve for using the coupling system.
Wang et al.[24] **(2015)**	1	14.2 %	No coupler was discarded due to the device being broken, but two couplers were abandoned due to ring falling off the instrument. Because of twist seen in vein intraoperatively, 2 couplers were discarded and hand suturing anastomosis was performed further. In still another case, one venous anastomosis required redo using coupler because of leak.	The fundamental rules for 100 % flap survival include the following key points: • Firstly, there should be no tension in the vessels during anastomosis. • Secondly, there ought to be no adventitia around the nozzle of vessels. • Thirdly, vascular pedicle should lack any sort of torsion • Finally, there got to be least size disparity between donor and recipient vessel.
Assoumane et al.[13] **(2016)**	NR	NR	Eight patients suffered from suture dehiscence following hand-sewn anastomosis that were further salvaged using couplers.	Author superseded in using coupler for arterial anastomosis in head and neck reconstruction in 4 different free flaps and also proposed usage of couplers for micro-anastomosis of arteries as well as vein, as he found no detrimental consequences with implantation of couplers.
Chen et al.[16] **(2019)**	3	6.6 %	There was one event of thrombosis detected during immediate postoperative period in a 67 years old hypertensive and diabetic male, in which arterial micro-anastomosis was done using 2.0 mm coupler. The case was further retrieved by hand suturing.	Author recommends following key points: • The assistant must be expeditious to fix the arterial wall on tine beside the part that the surgeon is holding. • Another skill is to hang the arterial wall far from the handle to prevent ring slipping.

(*continued on next page*)

Table 4 (*continued*)

Author/Year	Troubleshooting/ failure		Technical considerations, challenges and comments	Authors recommendation
	Frequency	Rate		
				Moreover, adequate extent of skills and expertise is definitely a prerequisite for the use of couplers besides the fact that coupling for arterial anastomosis should be used only after appropriate selection of vessels.
Li et al.[25] **(2020)**	6	NR	The study focussed on variance of approach for second attempt of micro-anastomosis. Initial attempts should be made to recognize the source of thrombosis and focus on: • Inadvertent creation of intimal flap. • Overt anastomotic twisting or compression It is judicial to attempt redo and reorient the anastomosis to ameliorate the imprecision.	Author recommended that arterial coupling is definitely a convenient technique for microvascular surgeons, but still each and every arterial anastomosis should preferably be hand sewed first. The idea behind this which author proposed was that it is paramount to maintain basic hand sewing micro-anastomosis skills so that a surgeon can shift to hand suturing wherever arterial coupler is unsuitable.
Guo et al.[14] **(2020)**	1	1.7 %	One flap failed on 6th postoperative day due to concurrent arterial and venous thrombosis which was prospected but the flap was beyond the possibility of recovery.	Author suggested that if the diameter of selected coupler is below 2.0 mm or above 3.0 mm, it is preferable in such circumstances to conclude the anastomosis by traditional hand sewing.
McLaughlin et al.[26] **(2020)**	4	20 %	This study manifested use of couplers to be strenuous to utilize in patients with small luminal diameter (less than 1.5 mm) or large size mismatch (greater than 1.5:1) and even in end-to-side anastomosis. Out of 6 coupled micro-anastomoses, four were converted to hand sewing and amidst 10 hand sewn anastomoses, two were shifted to	Author did not support the idea that arterial coupling should replace traditional hand sewn technique or training, but instead recommended that a coupled micro-anastomosis can only supplement the field of microsurgery. For an expertized surgeon, it may undoubtedly become a definitive adjunct

Table 4 (*continued*)

Author/Year	Troubleshooting/ failure		Technical considerations, challenges and comments	Authors recommendation
	Frequency	Rate		
			coupled anastomosis. One flap was originally anastomosed by coupling device, then hand sewn and eventually needed revision by coupler.	to hand sewn anastomosis in the context of standardization and pace.

Abbreviation: NR (not reported).

4.1. Vessel geometry and coupler configuration (calibre, wall thickness, luminal disparity)

The vessel wall is obligated to be thin and pliable to facilitate uncomplicated eversion over the spike system for the rings to join. The early literatures have mutually accredited couplers usefulness in venous micro-anastomosis, owing to the fact that thin and more pliable inherent character of vein naturally lends itself to easy eversion and the device reinforces the colligation open to preserve venous collapse and perpetuate venous return.[2]

In our understanding and perception, the excessive vessel wall thickness to lumen ratio in arteries when integrated with a non-expansile coupler ring leads to the development of narrow luminal space in contrast to venous anastomosis. This non-expansile nature of coupler rings can obstruct the arterial pulsatile flow, which in due course induces instability and thrombosis, whereas hand sewn anastomosis can preserve the palpitating nature of vessel wall and maintain arterial flow. Because of these inherent arterial property (thick, non-pliable), which does not allow eversion over coupler pin, it become mandatory for microsurgeons to switch to hand sewn anastomosis. In reaction to these lacunae, authors have considerably prospected the advantages of adventitiectomy in order to thin down vessel from exterior so as to lessen the wall thickness prior to vessel anastomosis.[9–12] The data began to be significantly noticeable with the first comprehensive study done by Spector et al.[3] which was further continued by Assoumane et al.[13] supporting increased success rate, reduced blood loss and operating time.[14]

Considering that delamination of intimal lining of endothelial cells from the supporting elastin and collagen scaffold makes coupler anastomosis arduous in patients with peripheral vascular disease, therefore to cope up with this delamination developing as a result of damage of elastin and cholesterol deposition within tunica media, authors have advocated pinning up the fragile intima against the media in an inside to outside fashion to avert additional delamination and facilitate vessel positioning on the anastomotic line[14] (Table 4).

4.2. Technical consideration and authors recommendation

One of the exclusive benefits of a MCD is its efficiency to anastomose vessels with a size disparity of even up to 50 %. Arterial coupling obligates manipulation to amend vessel size discrepancies between donor and recipient location. To integrate larger coupler device, there are numerous technical proposals to deal with vessel disparity such as, enlarging the narrow artery lumen following adventitiectomy, longitudinal slitting of arterial wall in order to widen its circumference and lumen dissection with additional caution to avoid intimal injuries. An elastic everting device and elastic silicon strip (1.0 mm wide) also assists safe eversion and atraumatic pinning.[3,14,15]

Chen et al.[16] recommends wall thickness of <0.4 mm, intact intima, arterial diameter greater than or equal to 1.5 mm and discrepancies of

less than 0.5 mm between vessels as suitable criteria for coupling through arterial anastomosis. The author has also highlighted the significance of educating and practicing hand sewn anastomosis and further advocated that microsurgeon must be skilled in the use of venous couplers before progressing to arterial coupling.

Apparently the chief privileged aspect of using an arterial MCD is remarkable curtailment in anastomosing time as well as overall surgical time. Microvascular free flap procedures are generally time consuming in nature and it is validated in earlier studies that patient end results are adverse with longer surgical time.[17] Judicial elucidation of this point is based on the fact that the cut in intraoperative time reduces the possibility of free radical generation and hence flap loss which might happen as a repercussion of increased ischemic time.[2] Hence, it has an implication to prospect manoeuvres that can nick surgical time without any detrimental effect on flap survival.

The result of this systematic review should be decoded cautiously as it has several restrictions due to significant heterogeneity and variability in included studies that make quantitative data synthesis challenging. As illuminated, the calibre of evidence is shallow, together with high risk of reporting bias in the identified literature which in addition to retrospective character of all included studies, carries high risk of selection bias. However, we have tried to be impeccable to the best of our knowledge and belief regarding inclusion of every single study that had anastomosis by coupler but concurrently acknowledging the fact that since the sample size for our study is relatively small as compared to similar systematic reviews for venous coupler, this necessitates further assessment for arterial coupling in this new era of microvascular surgery.

5. Conclusion

Practice of mechanical coupling devices has evolved into being safe and potent alternative to hand sewn anastomosis in carefully selected patients. But its application is making headway progress mainly in the field of venous anastomoses as compared to arterial anastomoses. Although practice of arterial couplers has been evident in the past but only a few literatures have been documented in support of its execution. On the other hand, there is a vast majority of literature justifying the countless advantages of venous couplers. The fact which cannot be disregarded is that microsurgeons are still quite skeptical towards routine use of current widespread coupler devices for arterial anastomosis owing to the reported risk of arterial thrombosis. This is mainly attributable to the fundamental differences of arteries as compared to veins in certain areas for instance, wall thickness, intactness of intima, lumen diameter, size discrepancies between donor and recipient vessel, etc. However, with certain guidelines and protocols in mind, arterial anastomosis can also be frequently practiced using couplers. Nonetheless, it is strongly advised that one should be skilled in the use of venous couplers before progressing to arterial coupling. Yet after all, the benefit of knowledge of traditional hand sewn anastomosis still cannot be overlooked since caution is strongly advised and switching to hand sewn anastomosis might be inevitable in certain situations such as, non-pliable vessels stiffened by atherosclerotic calcification or radiation induced fibrosis, existing discrepancy of more than 1.5:1 ratio in luminal diameter of donor and recipient arteries. Adventitiectomy can be equally efficacious in reducing failure incidents in certain cases. Though logistically arduous, a randomized controlled trial may be helpful in further evaluating the safety and practicability of coupler use in arterial anastomosis compared to routine hand-sewn technique. Moreover, subsequent advancements might be imperative particularly in the sphere of specified instrumentation, superior techniques and splendid coupler devices which would further facilitate the routine arterial coupling in a relatively unchallenging way and transfer the benevolent outcomes of microvascular coupling to arterial microvascular anastomosis.

Conflicts of interest

None.

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