(Jurnal Plastik Rekonstruksi, 2024; Vol 11, No 2, 50-66) RECONSTRUCTIVE

Article

THE OUTCOME OF KEYSTONE FLAP FOR LOWER EXTREMITY DEFECTS: A SYSTEMATIC REVIEW

Kevin Varian Marcevianto[1], Aditya Wardhana[2], & Nandita Melati Putri[2]

1. Department of Surgery, Faculty of Medicine Universitas Indonesia – Cipto Mangunkusumo Hospital, Jakarta, Indonesia
2. Division of Plastic, Reconstructive and Aesthetic Surgery, Department of Surgery, Faculty of Medicine Universitas Indonesia – Cipto Mangunkusumo Hospital, Jakarta, Indonesia

ABSTRACT

Introduction : Lower extremity defect poses a significant challenge in reconstructive surgery due to the limited usability of soft tissue. The keystone flap which utilizes fasciocutaneous perforators, has emerged to be a potential technique in fixing soft tissue defects. However, scientific evidence, specifically on its effectivity and complication rate in lower extremity defect is lacking. Therefore, this systematic review aims to assess the outcome and potential complications correlated to the use of Keystone Flap in repairing lower extremity defect.
Method : This systematic review was done in accordance to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA). Literature searching was conducted using four databases, which is PubMed Central, Embase, Scopus and Cochrane Library.
Result : A grand total of sixteen studies were included in the review. Among it, fourteen studies were case series. The others were cohort prospective and single arm interventional studies. Out of the 662 keystone flaps used, a total of 129 complications (19.5%,) were recorded, with the majority being infection or cellulitis (5%, n=33), delayed healing (4.5%, n=30), wound dehiscence (4.3%, n=28), and partial flap loss or necrosis (2%, n=13).
Conclusion: The keystone flap could be an alternative for lower extremity defect with a realtively low complication rate.

***Key words**: Keystone flap, Lower extremity defect, Reconstructive surgery, Soft tissue repair, Complications*

Latar Belakang: Defek ekstremitas bawah merupakan tantangan signifikan dalam bedah rekonstruksi karena keterbatasan jaringan lunak yang dapat digunakan. Keystone flap, yang memanfaatkan perforator fasciokutaneus, telah muncul sebagai teknik potensial untuk memperbaiki defek jaringan lunak. Namun, bukti ilmiah, khususnya terkait efektivitas dan tingkat komplikasinya pada defek ekstremitas bawah, masih terbatas. Oleh karena itu, tinjauan sistematis ini bertujuan untuk menilai hasil dan potensi komplikasi yang berkaitan dengan penggunaan keystone flap dalam memperbaiki defek ekstremitas bawah.
Metodologi: Tinjauan sistematis ini dilakukan sesuai dengan pedoman *Preferred Reporting Items for Systematic Review and Meta-Analysis* (PRISMA). Pencarian literatur dilakukan menggunakan empat basis data, yaitu PubMed Central, Embase, Scopus, dan Cochrane Library.
Hasil: Sebanyak enam belas studi dimasukkan dalam tinjauan ini. Empat belas di antaranya adalah *case series*, sementara sisanya merupakan studi kohort prospektif dan studi intervensi dengan satu kelompok. Dari total 662 keystone flap yang digunakan, tercatat 129 komplikasi (19,5%), dengan mayoritas berupa infeksi atau selulitis (5%, n=33), penyembuhan tertunda (4,5%, n=30), dehiscence luka (4,3%, n=28), dan kehilangan flap parsial atau nekrosis (2%, n=13).
Kesimpulan: Keystone flap dapat menjadi alternatif untuk memperbaiki defek ekstremitas bawah dengan tingkat komplikasi yang relatif rendah.

***Kata Kunci:** Keystone Flap, Defek Ekstremitas Bawah, Bedah Rekonstruksi, Perbaikan Jaringan Lunak, Komplikasi*

Conflicts of Interest Statement:
The author(s) listed in this manuscript declare the absence of any conflict of interest on the subject matter or materials discussed.

Received: 17-03-2024, Revised: 26-08-2024, Accepted: 16-09-2024

 P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

INTRODUCTION

Lower extremity defects often arise from trauma, tumors, or chronic illnesses.[1] Problems with these defects might arise, especially in the lower leg, due to the thin nature of the soft tissue, which lacks expandability.[2,3] For thigh defects as well as those in the proximal and middle thirds of the leg, local muscle flaps are used in traditional reconstructive procedures for lower limb defects.[2] Because full-thickness skin transplants have significantly greater metabolic demands than split-thickness grafts, split-thickness grafts have traditionally been utilized as the preferred reconstructive technique for cutaneous lesions on the distal lower limbs that cannot be fully healed. Utilizing these grafts has certain downsides, including morbidity at the donor site and the normal maturation-related graft manifestations of atrophy, depression, and hypopigmentation at the recipient site.[4] Lower extremity wound applications of grafts are associated with considerable risks of graft failure.

Fasciolocutaneous flaps, which are the current trend, are closely followed by perforator flaps in an effort to reduce difficulties at the donor site.[3] These types of flaps preserve muscle function and reduce complications at the donor site, representing a new trend in reconstruction. The Keystone flap is a novel advancement flap that transfers nearby tissue with enough flexibility to addredss soft tissue abnormalities using sporadic fasciocutaneous perforators.[5] It can be used as a primary reconstructive option or as a supplementary technique for additional soft tissue coverage. By being aware of the areas of high perforator density, the keystone flap can be founded on a number of random fasciocutaneous perforators without necessitating dissection of the primary feeding artery. This technique requires minimal microsurgical expertise, shortens the surgical process, and reduces the risk of pedicle disruption and kinking.[6]

The Keystone flap gets its name from the curvilinear trapezoid-shaped center stone of a Roman arch, which was first reported by Behan in 2003. Two opposing V-Y flaps that are placed parallel to the defect's long axis make up the flap.[7] The defect should be elliptical in form, with the long axis running parallel to the cutaneous nerves, veins, and known perforators, in order to enhance vascularity and perhaps preserve cutaneous sensitivity.[8] Most commonly, the defects often have a 3:1 long-to-short axis ratio.

The use of the keystone design perforator island flap in the lower extremities has been the subject of many studies.[2–5] However, scientific evidences regarding its usage for lower extremity defects are still lacking. Therefore, this systematic review is aimed to examine the effectiveness and complications associated with keystone flaps in the repair of lower extremity defects.

METHOD

This study was reported in accordance with the principles stated in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[9] The protocol of this systematic review was registered in the international prospective register of systematic reviews (PROSPERO) with registration number CRD42023442246. Being a systematic review, ethical approval or patient consent was not necessary for this study.

Inclusion and exclusion criteria

We included all published original studies that documented the utilization of keystone flaps for lower extremity defects. We excluded duplicate studies, incomplete data of study, as well as review articles, technical report, editorials, commentaries, and letters. If multiple publications covered the same study or aspects of a study, we checked that the data from a single study were not counted repetitively. Articles not in English or Bahasa Indonesia were also excluded from the study.

Search strategy

A systematic literature search was conducted in electronic databases, including PubMed Central, Embase, Scopus and Cochrane Library. We tried to identify articles published from January 2003 (the year of the initial description of the keystone flap technique) until current year. The search employed appropriate English-language keywords combined with Boolean logical operators. No limitations were set on the search. The identified studies were

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

recorded in Microsoft Excel 2020 along with their relevant details.

Data extraction and study appraisal

The authors conducted independent data extraction. The following information was extracted from the included studies: duration of study, country of study, study design, duration of follow up, number of subjects, sex, age, etiology of the defect, flap location, number of flaps performed, the type of technique performed, flap size, complications, and other specific outcomes. The level of evidence for each article was determined according to the criteria outlined by the Oxford Centre for Evidence-Based Medicine.[10]

Critical appraisal for each study was done according to the appropriate tool for each study design. The Newcastle Ottawa Scale was used for cohort studies. It examines studies from its selection of cohorts, comparability of cohorts, and validity of outcomes.[11] The JBI Checklist for Case Series for was used for case series. It is a 10-number tool which examines studies from its methodology and reporting.[12] Finally, the Critical Appraisal of Intervention Studies by Guyatt & Rennie was used for interventional studies. It examines the validity, importance, and applicability of the results.[13]

RESULTS

Search selection and characteristics

Figure 1 shows the flow of literature search. A total of 66 records were initially identified from the databases.[8,14–29] **Table 1** shows the number of hits acquired using the respective keywords used on each database. After further screening and assessment, ultimately 16 studies were included. One study was retrospective cohort studies, fourteen were a case series, and one was a single arm conventional study. Furthermore, detailed characteristics of each study are described in **Table 2** and **Table 3**.

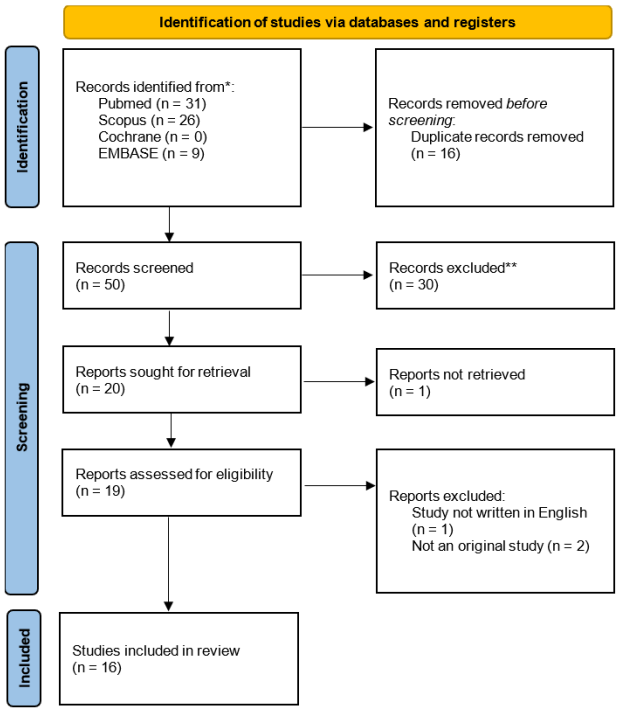

Figure 1. PRISMA flow diagram of the literature search

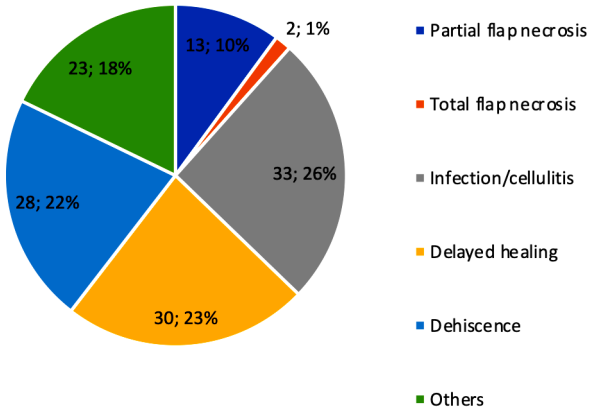

Figure 2. Complications of keystone flap

In the sixteen studies, 662 keystone flaps were utilized in 639 patients with various types of defects. The majority of the flaps, totaling 471 (71.15%), were conducted on the lower limb. The most frequent etiology of the defect was oncologic causes (78.9%, n=504).

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

Table 1. Keywords used for each database with corresponding hits

Database	Keywords	Hits
PubMed	(lower extremity [mesh]) AND (keystone flaps [mesh]) AND (surgical reconstruction [mesh])	31
EMBASE	lower limb' AND 'keystone flap' AND 'reconstructive surgery'	9
Scopus	lower AND extremity AND keystone AND flaps AND reconstruction	26
Cochrane	(lower extremity) AND (keystone flaps) AND (surgical reconstruction)	0

Table 2. Study characteristics and population

Author (year), country	LoE	Design	Duration of Study	Subjects	Sex	Age (years)	Etiology of Defect
Moncrieff et al.[14] (2008), Australia	2b	Prospective cohort	July 2003 – June 2007	176	Female = 123 (69.9%) Male = 53 (30.1%)	Median: 57 (21–93)	Primary cutaneous melanoma = 176 (100%)
Stone et al.[22] (2015), Canada	4	Case series	Not mentioned	30	Female = 19 (63.3%) Male = 11 (36.7%)	59±18	Melanoma = 22 (70%) Dermatofibrosarcoma protuberans = 2 (6%) Full-thickness burn = 2 (6%) Basal cell carcinoma = 2 (6%) Squamous cell carcinoma = 2 (6%) Merkel cell carcinoma = 1 (3%) Angiosarcoma = 1 (3%)
Mohan et al.[8] (2016), United Kingdom & Australia	4	Case series	January 2020 – December 2014	36	Female = 17 (47.2%) Male = 19 (52.8%)	60 (8–86)	Malignant melanoma = 14 (38.9%) Soft tissue sarcoma = 12 (33.3%) Benign pathologic condition = 6 (16.7%) Nonmelanoma skin cancer = 4 (11.1%)
Turin et al.[23] (2017), United States	4	Case series	December 2015 – March 2017	6	Female = 3 (50%) Male = 3 (50%)	57.5 ± 12	Basal cell carcinoma = 1 (16.6%) Squamous cell carcinoma = 1 (16.6%) Melanoma = 1 (16.6%) Dermatofibrosarcoma protuberans = 1 (16.6%) Scalp wound secondary to craniotomy = 2 (33.3%)
Lanni et al.[24] (2017), United States	4	Case series	January 2012 – August 2016	60	Female = 19 (31.7%)	Mean age 55.7 (46–57)	Basal cell carcinoma = 7 (11.7%) Squamous cell carcinoma = 4 (6.7%)

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

Author (year), country	LoE	Design	Duration of Study	Subjects	Sex	Age (years)	Etiology of Defect
					Male = 41 (68.3%)		Melanoma = 29 (48.3%) Sarcoma = 9 (15%) Trauma = 3 (5%) Other = 8 (13.3%)
Pripotnev & White[25] (2017), Canada	4	Case series	2 years	37	Female = 14 (37.8%) Male = 23 (62.2%)	49–89	Basal cell carcinoma = 22 (56.4%) Squamous cell carcinoma = 11 (28.2%) Melanoma = 5 (12.8%) Dermatofibroma = 1 (2.6%)
Cogolludo et al.[26] (2018), Spain	4	Case series	2014 – 2017	10	Female = 7 (70%) Male = 3 (30%)	76 ± 11.9	Squamous cell carcinoma = 6 (60%) Basal cell carcinoma = 3 (30%) Dermatofibrosarcoma protuberans = 1 (10%)
Fang et al.[27] (2020), China	4	Case series	September 2014–March 2017	31	Female = 15 (48.4%) Male = 16 (51.6%)	43.8 (30–72)	Trauma = 2 (6.45%) Benign/malignant tumour = 21 (67.74%) Chronic ulcer = 8 (25.8%)
Petukhova et al.[29] (2020), United States	4	Case series	2016–2018	73	Female = 37 (50.7%) Male = 36 (49.3%)	71.1 ± 1.5	Squamous cell carcinoma = 39 (45.3%) Basal cell carcinoma = 33 (38.4%) Melanoma = 8 (9.3%) Atypical nevus = 3 (3.5%) Others = 3 (3.5%)
Al-Mousawi et al.[15] (2020), Italy	4	Case series	May 2015 – May 2017	12	Female = 5 (41.7%) Male = 7 (58.3%)	63 (35–74)	Osteomyelitis type II = 7 (48.3%) Osteomyelitis type III = 5 (41.7%)
Srivastav et al.[16] (2020), India	4	Case series	October 2017 – December 2019	50	Female = 11 (22%) Male = 39 (78%)	38.5 (18–65)	Trauma = 25 (50%) Tumor resection = 10 (20%) Abscess debridement = 15 (30%)
Kong et al.[17] (2021), South Korea	4	Case series	December 2017 – June 2020	6	Female = 2 (33.3%) Male = 4 (66.7%)	41.67 ± 22.42	Trauma = 5 (83.3%) Burns = 1 (16.7%)
Guern et al.[18] (2021), France	4	Case series	2010 – 2019	25	Female = 17 (68%) Male = 8 (32%)	67.5 (19–95)	Squamous cell carcinoma = 6 (24%) Basal cell carcinoma = 9 (36%) Melanoma = 9 (36%) Bowen's disease = 1 (4%)

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

Author (year), country	LoE	Design	Duration of Study	Subjects	Sex	Age (years)	Etiology of Defect
Torto et al.[19] (2021), Italy, United Kingdom, and Peru	2 b	Single-arm interventional	March 2019 – December 2019	72	Female = 23 (32%) Male = 49 (68%)	76.2 (65–91)	Oncologic wounds = 15 (20.8%) Non-oncologic wounds = 15 (20.8%)
Kumbla et al.[20] (2021), United States	4	Case series	January–July 2018	6	Not mentioned	Mean age 44.7	Donor for anterolateral thigh free flap = 6 (100%)
Ribeiro et al.[21] (2022), Brazil	4	Case series	February 2017–January 2020	9	Female = 6 (67%) Male = 3 (33.3%)	Mean age 52.7	Basal cell carcinoma = 1 (11.1%) Squamous cell carcinoma = 1 (11.1%) Melanoma = 4 (44.4%) Sarcoma = 3 (33.3%)

Table 3. Study intervention and outcome

Author (year), country	Duration of follow-up	Intervention				Outcome
		Technique	Size (Flap)	Flap Location	Flaps Performed	
Moncrieff et al.[14] (2008), Australia	3 months	Standard = 106 (60.2%) Modified = 65 (36.9%) Double-opposing keystone = 5 (2.8%)	Not mentioned	Lower limb = 176 (100%)	176	1. Total flap loss: 1 (0.6%) 2. Partial flap necrosis: 1 (0.6%) 3. Incomplete excision: 2 (1.1%) 4. Early local recurrence: 1 (0.6%) 5. Infection: 2 (1.1%) 6. DVT: 1 (0.6%) 7. Transient neuralgia: 4 (2.3%) 8. Minor wound problem: 3 (1.7%) 9. Seroma: 1 (0.6%)
Stone et al.[22] (2015), Canada	33 weeks	Type I = 12 (37.5%) Type IIA = 17 (53.1%) Type IIB = 1 (3.1%) Others = 2 (6.3%)	1.2×1.2 cm to 9.0 × 25.0 cm^2	Lower limb = 24 (70%) Torso = 3 (9.38%) Upper limb = 5 (15.63%)	32	1. Delayed healing: 3 (9%) 2. Cellulitis: 2 (6%) 3. Minor flap dehiscence: 1 (3%) 4. Partial/total flap loss: 0 (0%) 5. Majority of patients were discharge home following surgery
Mohan et al.[8] (2016), United Kingdom & Australia	30 days	Single keystone flap = 30 (71%) Bilateral keystone flap = 12 (29%)	344 cm^2 Range: 5–1350 cm^2	Lower limb = 19 (52.8%) Upper limb = 19 (52.8%)	42	1. Partial/total flap necrosis: 0 (0%) 2. Delayed healing and wound dehiscence: 10 (28%)

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

Author (year), country	Duration of follow-up	Intervention				Outcome
		Technique	Size (Flap)	Flap Location	Flaps Performed	
				Groin/hips/buttock = 6 (16.7%) Perineum = 1 (2.8%) Trunk = 6 (16.7%)		3. The mean time to mobilization was 1.8 days 4. The mean length of stay was 6.8 days
Turin et al.[23] (2017), United States	201 days	Original keystone flap = 6 (100%)	167.2 cm^2	Lower limb = 6 (100%)	6	1. Cellulitis: 0 (0%) 2. Flap necrosis: 0 (0%) 3. Edema/swelling: 0 (0%) 4. Delayed wound healing: 1 (16.6%) 5. Shorter time needed to perform surgery 6. There were no difficulties with ambulation and range of motion
Lanni et al.[24] (2017), United States	719 days	Majority were Behan's type IIA Other methods used were Type III, IV, and combination between type III/IV	405.6 cm^2 (251 to 500 cm^2)	Lower limb = 25 (41.7%) Trunk = 20 (33.3%) Upper limb = 5 (8.3%) Head and neck = 10 (16.7%)	60	1. Numbness: 2 (3.33%) 2. Wound healing problem: 16 (26.7%) 3. DVT: 1 (1.7%) 4. Infection: 7 (11.7%) 5. Hypertrophic scarring: 1 (1.7%) 6. Contour deformity: 3 (5%)
Pripotnev & White[25] (2017), Canada	2–3 weeks	Original keystone flap = 39 (100%)	Not mentioned	Lower limb = 25 (64.1%) Upper limb = 8 (20.5%) Back = 4 (10.3%) Neck = 2 (5.1%)	39	1. Partial dehiscence: 2 (5.4%) 2. Infection: 1 (2.7%) 3. Seroma: 1 (2.7%)
Cogolludo et al.[26] (2018), Spain	Not mentioned	Original keystone flap = 10 (100%)	Not mentioned	Lower limb = 10 (100%)	10	1. Flap necrosis: 0 (0%) 2. Large hemorrhage: 0 (0%) 3. Wound infections: 0 (0%) 4. Edema/swelling: 0 (0%) 5. Difficulty walking: 0(0%)

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

Author (year), country	Duration of follow-up	Intervention				Outcome
		Technique	Size (Flap)	Flap Location	Flaps Performed	
						6. Shorter time needed to perform surgery 7. Good functional results
Fang et al.[27] (2020), China	6–24 months	Modified keystone flap / boat shaped flap by adding a V shape along the lateral arc = 31 (100%)	3×5 to 10×15 cm^2	Lower limb = 5 (16.13%) Upper limb = 6 (19.35%) Trunk = 18 (58.07%) Face = 2 (6.45%)	31	1. Superficial infection: 1 (3.23%) 2. Partial flap necrosis: 1 (3.23%)
Petukhova et al.[29] (2020), United States	26 weeks	Modified keystone flap / V-Y hemi-keystone advancement flap	53.5 ± 4.2 cm^2	Lower limb = 75 (87.2%) Upper limb = 9 (10.5%) Trunk = 2 (2.3%)	86	1. Infection: 2 (2.3%) 2. Dehiscence: 1 (1.2%) 3. Infection + dehiscence: 3 (3.5%) 4. Hematoma: 0 (0%) 5. Hemorrhage: 0 (0%) 6. Flap failure: 0 (0%) 7. High rates of flap survival 8. Minimize incision area and increase efficiency
Al-Mousawi et al.[15] (2020), Italy	16 months	Type I = 4 (33.3%) Type IIA = 3 (25%) Type IIB = 1 (8.3%) Type III = 1 (8.3%) Type IV = 2 (16.7%) Freestyle = 1 (8.3%)	Not mentioned	Lower limb = 12 (100%)	12	1. Partial flap necrosis: 1 (8.3%) 2. Wound discharge with recurrent osteomyelitis: 1 (8.3%)
Srivastav et al.[16] (2020), India	Not mentioned	Not specified	Not mentioned	Lower limb = 30 (60%) Upper limb = 10 (20%) Torso = 10 (20%)	50	1. Partial flap necrosis: 2 (4%) 2. Wound infection leading to dehiscence: 3 (6%)
Kong et al.[17] (2021), South Korea	4–7 months	Modified keystone flap Omega variation (OV) = 1 (16.7%)	3×6 to 8×17 cm^2	Lower limb = 6 (100%)	6	1. Marginal maceration: 1 (16.6%) 2. Infection: 0 (0%) 3. Hematoma: 0 (0%)

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

Author (year), country	Duration of follow-up	Intervention				Outcome
		Technique	Size (Flap)	Flap Location	Flaps Performed	
		Sydney melanoma unit modification (SMUM) = 1 (16.7%) OV + SMUM = 66.7%)				
Guern et al.[18] (2021), France	6 months	Original keystone flap = 19 (76%) Simplified version = 6 (24%)	12 cm^2	Lower limb = 25 (100%)	25	1. Total flap necrosis: 1 (4%) 2. Partial flap necrosis: 1 (4%) 3. Partial flap dehiscence: 2 (8%)
Torto et al.[19] (2021), Italy, United Kingdom, and Peru	6 months	Type I = 42 (58.3%) Type IIA = 13 (18%) Type III = 16 (22.2%) Type IV = 1 (1.4%)	Torso = 107.51 cm^2 (35–244 cm^2) Upper limb = 33.3 cm^2 (26–42 cm^2) Lower limb = 32.5 cm^2 (16–110 cm^2)	Lower limb = 22 (30.6%) Upper limb = 4 (5.6%) Torso = 46 (63.6%)	72	1. Partial flap necrosis: 7 (9.7%) 2. Total flap necrosis: 0 (0%) 3. Wound dehiscence: 5 (6.9%) 4. Wound infection: 3 (4.2%)
Kumbla et al.[20] (2021), United States	Not mentioned	Not specified	12.2×22.5 cm^2	Lower limb = 6 (100%)	6	1. Seroma: 1 (16.7%) 2. Partial wound dehiscence: 1 (16.7%) 3. Average operative time was 528.3 minutes 4. Mean hospital stay was 11.7 days
Ribeiro et al.[21] (2022), Brazil	Not mentioned	Original keystone flap = 9 (100%)	52.6 cm^2	Lower limb = 5 (55.6%) Torso = 3 (33.3%) Face = 1 (11.1%)	9	1. Dog ear: 1 (11.1%)

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

Table 4. Critical appraisal of included cohort studies

Study / Domain	S1	S2	S3	S4	C1	O1	O2	O3	Total	Quality
Moncrieff et al.[14] (2008)	□		□	□	□	□	□	□	7	Good

S: selection, C: comparability, O: outcome

Conversion to Agency for Healthcare Research and Quality (AHRQ) standards:

- Good quality : 3 or 4 stars in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome/exposure domain
- Fair quality : 2 stars in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome/exposure domain
- Poor quality : 0 or 1 star in selection domain OR 0 stars in comparability domain OR 0 or 1 stars in outcome/exposure domain

Table 5. Critical appraisal of interventional study

Question	Torto et al.[19] (2021)
Validity	
1. Were participants randomized?	No
2. Was randomization concealed?	N/A
3. Were participants analyzed in the groups to which they were randomized?	N/A
4. Were participants in each group similar with regard to known prognostic variables?	N/A
5. Were participants aware of group allocation?	N/A
6. Were clinicians aware of group allocation?	N/A
7. Were outcome assessors aware of group allocation?	N/A
8. Was follow-up complete?	Yes, 6 months
Importance	
1. How large was the treatment effect?	N/A
2. How precise was the estimate of the treatment effect?	N/A
Applicability	
1. Were study participants similar to my own situation?	Yes
2. Were all clinically important outcomes (harms and benefits) considered?	Yes

Table 6. Critical appraisal of case series (1)

	Question	**Stone et al.[22] (2015)**	**Mohan et al.[8] (2016)**	**Pripotnev & White[25] (2017)**	**Turin et al.[23] (2017)**	**Lanni et al.[24] (2017)**	**Cogolludo et al.[26] (2018)**	**Srivastav et al.[16] (2018)**
1.	Were there clear criteria for inclusion in the case series?	Yes	Yes	No	Yes	No	No	Yes
2.	Was the condition measured in a standard, reliable	Yes	Yes	Yes	Yes	Yes	No	Yes

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

	Question	Stone et al.[22] (2015)	Mohan et al.[8] (2016)	Pripotnev & White[25] (2017)	Turin et al.[23] (2017)	Lanni et al.[24] (2017)	Cogolludo et al.[26] (2018)	Srivastav et al.[16] (2018)
	way for all participants included in the case series?							
3.	Were valid methods used for identification of the condition for all participants included in the case series?	Yes	Yes	Unclear	Yes	Yes	Yes	Unclear
4.	Did the case series have consecutive inclusion of participants?	Yes	Yes	Unclear	Yes	Yes	Yes	Yes
5.	Did the case series have complete inclusion of participants?	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes
6.	Was there clear reporting of the demographics of the participants in the study?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7.	Was there clear reporting of the clinical information of the participants?	Yes	Yes	Yes	Yes	Yes	No	Yes
8.	Were the outcomes or follow-up results of cases clearly reported?	Yes	Yes	Yes	Yes	Yes	Yes	No
9.	Was there clear reporting of the presenting sites'/clinics' demographic information?	No	No	No	No	No	No	No
10.	Was statistical analysis appropriate?	Not applicable	Not applicable	Not applicable	Not applicable	Yes	Not applicable	Not applicable

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

Table 6. Critical appraisal of case series (Continue)

	Question	Fang et al.[27] (2020)	Petukhova et al.[29] (2020)	Al-Mousawi et al.[15] (2020)	Kong et al.[17] (2021)	Guern et al.[18] (2021)	Kumbla et al.[20] (2021)	Ribeiro et al.[21] (2022)
1.	Were there clear criteria for inclusion in the case series?	Yes	Yes	Yes	Yes	Yes	No	No
2.	Was the condition measured in a standard, reliable way for all participants included in the case series?	Unclear	Yes	Yes	Yes	Yes	No	Yes
3.	Were valid methods used for identification of the condition for all participants included in the case series?	Unclear	Yes	Yes	Yes	Yes	Unclear	Yes
4.	Did the case series have consecutive inclusion of participants?	Yes	Yes	Yes	Yes	Yes	Yes	Unclear
5.	Did the case series have complete inclusion of participants?	Yes	Yes	Yes	Yes	No	Yes	Unclear
6.	Was there clear reporting of the demographics of the participants in the study?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7.	Was there clear reporting of the clinical information of	Yes	Yes	Yes	Yes	Yes	No	Yes

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

	Question	Fang et al.[27] (2020)	Petukhova et al.[29] (2020)	Al-Mousawi et al.[15] (2020)	Kong et al.[17] (2021)	Guern et al.[18] (2021)	Kumbla et al.[20] (2021)	Ribeiro et al.[21] (2022)
	the participants?							
8.	Were the outcomes or follow-up results of cases clearly reported?	Yes	Yes	Yes	Yes	Yes	Yes	Unclear
9.	Was there clear reporting of the presenting sites'/clinics' demographic information?	No	No	No	No	No	No	No
10.	Was statistical analysis appropriate?	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable

There were complications in 19.5% (n=129) of cases, with the most common being infection (5%, n=33), delayed healing (4.5%, n=30), and wound dehiscence (4.3%, n=28). Only 0.3% (n=2) of cases reported complete flap necrosis, while partial flap necrosis was reported in 2% (n=13) of cases. Figure 2 and Table 2 provide further details on these complications.

Critical appraisal

The studies were critically appraised according to their study designs. Table 4 contains the critical appraisal of the cohort study. Meanwhile, Table 5 and Table 6 details the critical appraisal of the interventional study and case series studies respectively

DISCUSSION

The studies included are mostly case series studies (14 out of 16 studies). Based on Oxford Centre for Evidence-Based Medicine criteria, these studies are designated as level 4 evidence. Meanwhile, the rest of the studies include one cohort and one single-arm interventional studies which are designated as level 2b. Upon conducting a thorough critical appraisal, the cohort study by Moncrieff et al. (2008) was found to be good in quality. Out of the fourteen case series studies, only Lanni et al. (2017) performed statistical analysis, while the majority did not. Most studies have included all participants with consecutive sampling and clearly reported the demographics and outcomes. However, some studies did not clearly state the inclusion criteria. In several studies, it was not stated whether the condition was measured in a standard and reliable manner for all participants, and whether valid methods were utilized for identifying the condition. The sole interventional study included in this study was doubtful in validity as it was a non-randomized study. Although no randomization was done, follow-up was still completely done in 6 months. While no statistical analysis was conducted in the study, the study results were still deemed applicable.

Across all studies, there was a total of 639 subjects. However, only 633 had their sex reported, which was composed by 315 males and 318 females. The other 6 subjects were from the case series by Kumbla et al. Central tendency of the age was reported with mean or median. The youngest mean age was 38.5 years (Srivastav et al.) in which 50% of defect was caused by trauma.

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

The oldest mean age was around 76 years which was reported by Cogolludo et al. and Torto et al. The defects in both studies were mostly caused by oncologic wounds. One study only reported the age range. Pripotnev & White reported an age range of 49–89 in 37 subjects, with a majority of defects caused by malignancy.

The majority of defects, totalling 504 (78.9%) cases, were caused by cancer-related diseases. Cancer can lead to deformities as tumours grow physically, with benign bone tumours and tumour-like lesions commonly associated with limb length discrepancies. The discrepancy may be attributed to the disturbance of bone growth and development due to the presence of a tumour, particularly in younger patients.[30] The primary objective in managing this condition is tumour removal, which can be achieved through various procedures such as excision with wide margins or radical removal.[31] While tumour removal surgery aims to be conservative, secondary surgery may still be necessary post-operation to address any resulting deformities. Guern et al. demonstrated that keystone flaps are effective in repairing defects related to cancer surgeries.[18] Although the majority of lower limb deformities included in this review were caused by tumors, other etiologies, including trauma and burns, can also lead to deformities. While these conditions have different mechanisms in creating deformities, keystone flaps have proven useful in correcting resulting deformities. Therefore, it is reasonable to assume that the use of Keystone Flap could aid in fixing leg deformities caused by various etiologies.

Across 16 studies, 662 keystone flaps were used to cover a range of defects in 639 patients. Follow-up was done in a timeframe of two weeks to two years. The majority of these flaps (71.15%, n=471) were performed on the lower limbs. The majority of flaps utilized the Behan's keystone flap technique, with only three studies opting for a modified version of the keystone flap. In their research, Fang et al introduced a modified keystone flap known as the "boat-shaped flap" that features a V shape along the lateral arc.[28] In order to seal the defect and minimize tissue incision, Petukhova et al. designed a simplified V-Y hemi-keystone advancement flap that entails cutting the curvilinear part of the flap on one side.[30] In a research by Kong et al, small to moderate-sized defects were covered using a modified keystone flap with the omega variant (OV) and Sydney melanoma unit modification (SMUM).[18]

A total of 129 complications out of 662 total flaps (19.5%) were recorded, with the majority being infection or cellulitis (5%), delayed healing (4.5%), wound dehiscence (4.3%), and partial flap loss or necrosis (2%). Infections are common in surgical procedures, with a study indicating that 5–20% of post-operative patients experience some form of infection, of which up to 60% is highly preventable. Preventing post-operative infection, including in keystone flap procedures, involves prioritizing proper hygiene, using correct equipment, informing patients, and being well-prepared.[32] Petukhova et al stated that most infections occurred on lower extremities, indicating that healing is more difficult on the lower extremities due to minimal skin laxity, skin fragility, and decreased vascular supply.[30] While infection, delayed healing, and dehiscence are considered minor complications, partial loss or necrosis is considered major.[14] Another important complication that island flap procedures, including keystone flap, should be cautious about is total flap loss or necrosis. The study's results in **Table 3** showed that total flap necrosis occurred in only 2 (0.3%) cases, indicating its relative rarity. This finding aligns with a review conducted by Rini et al., which suggests that keystone flap has the lowest risk of total flap necrosis compared to other island flap procedures. This could be attributed to its shorter operative time, lower technical difficulty, and reduced donor-site morbidity.[33] Typically, keystone flap surgery requires 20-90 minutes, depending on the wound's size and complexity, and patients usually stay for 3 days post-operation before recovery.[16] However, these values may change during complications, emphasizing the importance of preventing complications to achieve better patient outcomes, improved mobilization, and shorter hospital stays.[14]

The main limitation of this review lies in the limited variety of study types included. The majority of studies incorporated were in the form of case series studies. Inclusion of other study types could enhance the analysis and provide a more comprehensive perspective. Moreover, there were also a few studies excluded due to language barrier, which may potentially affect the final data gathered. Another limitation lies in the review being restricted to lower extremity cases. As keystone flap are applicable to other body parts, it may be beneficial to broaden the scope to explore its effectivity in other body parts as well. By addressing these limitations and

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

incorporating a wider range of study types and body regions, future research can aid in the strengthening of evidence surrounding efficacy of keystone flap.

CONCLUSION

Based on the findings of our systematic review, the keystone flap method can be considered as an alternative of safe and effective operative procedure for managing lower extremity defects, exhibiting a relatively low rate of complications. Notably, the majority of complications identified were minor, suggesting they can be managed with relative ease. These favorable outcomes highlight the viability of keystone flap in reconstructing lower extremity defect.

Correspondence regarding this article should be addressed to:
Kevin Varian Marcevianto. Department of Surgery, Faculty of Medicine Universitas Indonesia – Cipto Mangunkusumo Hospital, Jakarta, Indonesia.
Postal address: RSCM A Building, 4th floor. Diponegoro Street 71st. Central Jakarta, Indonesia. E-mai: kevin.varian21@office.ui.ac.id

ACKNOWLEDGEMENT

N/A

REFERENCES

1. Soltanian H, Garcia RM, Hollenbeck ST. Current concepts in lower extremity reconstruction. Plast Reconstr Surg. 2015 Dec;136(6):815e-829e. https://doi.org/10.1097/PRS.0000000000001807.
2. Hallock G. A paradigm shift in flap selection protocols for zones of the lower extremity using perforator flaps. J Reconstr Microsurg. 2013 Mar;29(04):233–40. https://doi.org/10.1055/s-0032-1328919.
3. AlMugaren FM, Pak CJ, Suh HP, Hong JP. Best local flaps for lower extremity reconstruction. Plast Reconstr Surg - Glob Open. 2020 Apr;8(4):e2774. https://doi.org/10.1097/GOX.0000000000002774.
4. Martinez J-C, Cook JL, Otley C. The keystone fasciocutaneous flap in the reconstruction of lower extremity wounds. Dermatologic Surg. 2012 Mar;38(3):484–9. https://doi.org/10.1111/j.1524-4725.2011.02239.x.
5. Khouri JS, Egeland BM, Daily SD, Harake MS, Kwon S, Neligan PC, et al. The keystone island flap: use in large defects of the trunk and extremities in soft-tissue reconstruction. Plast Reconstr Surg. 2011 Mar;127(3):1212–21. https://doi.org/10.1097/PRS.0b013e318205f36f
6. Rodriguez-Unda NA, Abraham JT, Saint-Cyr M. Keystone and rerforator flaps in reconstruction: modifications and updated applications. Clin Plast Surg. 2020 Oct;47(4):635–48. https://doi.org/10.1016/j.cps.2020.06.014.
7. Pohl MJ. The keystone perforator island flap, concept. ANZ J Surg. 2013 Jul;83(7–8):589–589. https://doi.org/10.1111/ans.12337.
8. Mohan AT, Rammos CK, Akhavan AA, Martinez J, Wu PS, Moran SL, et al. Evolving Concepts of Keystone Perforator Island Flaps (KPIF): Principles of Perforator Anatomy, Design Modifications, and Extended Clinical Applications. Plast Reconstr Surg [Internet]. 2016 Jun;137(6):1909–20. Available from: https://journals.lww.com/00006534-201606000-00044 doi: 10.1097/PRS.0000000000002228.
9. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. https://doi.org/10.1136/bmj.n71.
10. Phillips B, Ball C, Sackett D, Badenoch D, Straus S, Haynes B, et al. Oxford Centre for Evidence-Based Medicine: Levels of Evidence (March 2009) [Internet]. 2009 [cited 2022 Nov 19]. Available from: https://www.cebm.ox.ac.uk/resources/levels-of-evidence/oxford-centre-for-evidence-based-medicine-levels-of-evidence-march-2009 .
11. Wells GA, Shea B, O'connell D, Peterson J, Welch V, Losos M, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. [Internet]. Ottawa Hospital Research Institute. 2014. Available from: http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp .
12. Munn Z, Barker TH, Moola S, Tufanaru C, Stern C, McArthur A, et al. Methodological quality of case series studies. JBI Database

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

Syst Rev Implement Reports [Internet]. 2019 Sep 23;18(10):2127–33. Available from: https://journals.lww.com/10.11124/JBISRIR-D-19-00099 doi: 10.11124/JBISRIR-D-19-00099.
13. Guyatt G, Rennie D, Meade MO, Cook DJ. Users' Guides to the Medical Literature: A manual for Evidence-Based Clinical Practice [Internet]. 2nd ed. New York: McGraw Hill; Available from: https://bmjopen.bmj.com/lookup/doi/10.1136/bmjopen-2019-033516 doi: 10.1036/0071590382.
14. Moncrieff MD, Bowen F, Thompson JF, Saw RPM, Shannon KF, Spillane AJ, et al. Keystone Flap Reconstruction of Primary Melanoma Excision Defects of the Leg—The End of the Skin Graft? Ann Surg Oncol [Internet]. 2008 Oct 16;15(10):2867–73. Available from: http://link.springer.com/10.1245/s10434-008-0018-8 doi: 10.1245/s10434-008-0018-8.
15. Al-Mousawi A, Sanese G, Baljer B, Lo Torto F, Hausien O, Perra A, et al. Use of the Keystone Perforator Island Flap in the treatment of chronic lower extremity wounds complicated by osteomyelitis. Injury [Internet]. 2020 Mar;51(3):744–9. Available from: https://linkinghub.elsevier.com/retrieve/pii/S002013831930779X doi: 10.1016/j.injury.2019.12.010.
16. Srivastav S, Gupta S, Sharma A. Keystone Flap as a Reconstructive Option for selected areas; A Prospective Study. J Clin Orthop Trauma [Internet]. 2020 Oct;11:S871–5. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0976566220302526 doi: 10.1016/j.jcot.2020.06.019.
17. Kong YT, Kim J, Shin HW, Kim KN. Keystone Flap with Omega Variation and Sydney Melanoma Unit Modification to Cover Small- and Moderate-Sized Defects in the Anterior Lower Leg. J Wound Manag Res [Internet]. 2021 Jun 30;17(2):94–101. Available from: http://jwmr.org/journal/view.php?doi=10.22467/jwmr.2020.01452 doi: 10.22467/jwmr.2020.01452.
18. Le Guern A, Wiart T, Modiano P, Lebas D. The keystone flap and its simplified version for malignant skin tumor defects of the lower limbs: A review of 25 cases. Ann Dermatol Venereol [Internet]. 2021 Dec;148(4):241–5. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0151963821000557 doi: 10.1016/j.annder.2021.04.006.
19. Lo Torto F, Frattaroli JM, Kaciulyte J, Mori FLR, Troisi L, Ciudad P, et al. The keystone flap: A multi-centric experience in elderly patients treatment. J Plast Reconstr Aesthetic Surg [Internet]. 2022 Jan;75(1):226–39. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1748681521004290 doi: 10.1016/j.bjps.2021.08.043.
20. Kumbla PA, Thorburn AQ, Makwana S, Mino M, Zakhary J, Myers RP. Use of the Keystone Perforator Flap Closure for the Anterolateral Thigh Free Flap Donor Site. Craniomaxillofacial Trauma Reconstr Open [Internet]. 2021 Jan 1;6:1–5. Available from: http://journals.sagepub.com/doi/10.1177/24727512211032867 doi: 10.1177/24727512211032867.
21. Ribeiro RDA, Pagotto VPF, Clivatti GM, Takahashi GG, Busnardo F de F, Gemperli R. Versatility and reliability of the Keystone flap in oncological reconstructions. Rev Bras Cir Plástica – Brazilian J Plast Sugery [Internet]. 2022;37(03). Available from: http://www.rbcp.org.br/details/3165/en-US/versatility-and-reliability-of-the-keystone-flap-in-oncological-reconstructions doi: 10.5935/2177-1235.2022RBCP.575-en.
22. Stone JP, Webb C, McKinnon JG, Dawes JC, McKenzie CD, Temple-Oberle CF. Avoiding Skin Grafts. Plast Reconstr Surg [Internet]. 2015 Aug;136(2):404–8. Available from: http://journals.lww.com/00006534-201508000-00034 doi: 10.1097/PRS.0000000000001449.
23. Turin SY, Spitz JA, Alexander K, Ellis MF. Decreasing ALT donor site morbidity with the keystone flap. Microsurgery [Internet]. 2018 Sep;38(6):621–6. Available from: https://onlinelibrary.wiley.com/doi/10.1002/micr.30317 doi: 10.1002/micr.30317.
24. Lanni MA, Van Kouwenberg E, Yan A, Rezak KM, Patel A. Applying the Keystone Design Perforator Island Flap Concept in a Variety of Anatomic Locations. Ann Plast Surg [Internet]. 2017 Jul;79(1):60–7. Available from: https://journals.lww.com/00000637-201707000-00014 doi: 10.1097/SAP.0000000000000995.

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373

25. Pripotnev S, White C. The Keystone Flap—A Case Series Demonstrating Practical Design, Use, and Applications. Plast Surg [Internet]. 2017 Aug 25;25(3):184–7. Available from: http://journals.sagepub.com/doi/10.1177/2292550317716121 doi: 10.1177/2292550317716121.
26. Colorado Cogolludo L, Conde-Taboada A, González-Guerra E, Fueyo Casado A, López Bran E. Keystone flap used on the legs: case series. Clin Exp Dermatol [Internet]. 2019 Aug 11;44(6):691–3. Available from: https://academic.oup.com/ced/article/44/6/691/6597458 doi: 10.1111/ced.13860.
27. Fang S, Li Y, Tang W, Zhu W, Zhuang W, Xing X, et al. The use of modified keystone flap in periarticular or large superficial tumor resection surgery. J Surg Oncol [Internet]. 2020 Jun 3;121(7):1090–6. Available from: https://onlinelibrary.wiley.com/doi/10.1002/jso.25879 doi: 10.1002/jso.25879.
28. Alam A, Sree Ram M, Sahu S. Lipoma of the Corpus Callosum : Diagnosis Using Magnetic Resonance Imaging. Med J Armed Forces India [Internet]. 2006 Jul;62(3):299–300. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0377123706800328 doi: 10.1016/S0377-1237(06)80032-8.
29. Petukhova TA, Navrazhina K, Minkis K. V-Y Hemi-keystone Advancement Flap: A Novel and Simplified Reconstructive Modification. Plast Reconstr Surg - Glob Open [Internet]. 2020 Feb;8(2):e2654. Available from: https://journals.lww.com/10.1097/GOX.0000000000002654 doi: 10.1097/GOX.0000000000002654.
30. Reif TJ, Matthias J, Fragomen AT, Rozbruch SR. Limb Length Discrepancy and Angular Deformity due to Benign Bone Tumors and Tumor-like Lesions. JAAOS Glob Res Rev. 2021 Mar;5(3). https://doi.org/10.5435/JAAOSGlobal-D-20-00214.
31. Bloodgood JC. CONSERVATIVE OPERATIONS ON BONE TUMORS, BASED ON THE CLINICAL AND PATHOLOGIC STUDY OF THE RELATIVE DEGREE OF MALIGNANCY. J Am Med Assoc [Internet]. 1908 Feb 1;L(5):325. Available from: http://jama.jamanetwork.com/article.aspx?doi=10.1001/jama.1908.25310310001001 doi: 10.1001/jama.1908.25310310001001.
32. Andersen BM. Prevention of Postoperative Wound Infections. In: Prevention and Control of Infections in Hospitals. Cham: Springer International Publishing; 2019. p. 377–437. https://doi.org/10.1007/978-3-319-99921-0_33.
33. Rini IS, Gunardi AJ, Marsaulina RP, Aryandono T, Dachlan I, Dwiprahasto I. A systematic review of the keystone design perforator island flap in the reconstruction of trunk defects. Arch Plast Surg. 2020 Nov;47(06):535–41. https://doi.org/10.5999/aps.2020.00094.

P-ISSN 2089-6492; E-ISSN 2089-9734 | DOI: 10.14228/jprjournal.v11i2.373