

Trends in Imaging Studies for Flap Reconstruction Surgery: A Bibliometric Analysis

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Background: Imaging studies have become indispensable tools in the perforator flap surgeon's armamentarium, significantly enhancing operative outcomes and reducing complications. We conducted the first bibliometric analysis on imaging studies for flap reconstruction to characterize any emerging trends and assess the methodological quality of the field.

Methods: The 100 most-cited articles in imaging studies for flap reconstruction were identified on Web of Science, across all available journals and years (1950–2024). Study details, including the citation count, main subject, outcome measures, imaging type, and evidence level, were extracted.

Results: The most-cited articles involved 21,619 patients and amassed a total of 9689 citations. Citations per article ranged from 41 to 302. The evidence base relied heavily on level 3 (n = 37) and level 4 (n = 34) studies, reflecting the prevalence of retrospective cohorts and case series. Only 1 study was a randomized trial achieving level 1 evidence. Validated patient-reported outcome measures were reported in only 1 study. Imaging outcomes were the most explored, followed by flap anatomy and comparisons of imaging modality, with cost-effectiveness being the least investigated. Imaging was most frequently used for preoperative flap planning (n = 62), with fewer studies using intraoperative (n = 27) and postoperative (n = 19) imaging for perfusion assessment and complication detection. Computed tomography angiography, Doppler ultrasound, and indocyanine green ICG angiography were the most frequently used imaging modalities.

Conclusions: The most influential studies lacked randomization and were conducted by single-center efforts. Promoting global collaboration and incorporating patient-reported outcome measures into high-quality research can advance a more patient-centered, holistic evaluation of reconstructive success. (*Plast Reconstr Surg Glob Open* 2026;14:e7388; doi: [10.1097/GOX.00000000000007388](https://doi.org/10.1097/GOX.00000000000007388); Published online 6 January 2026.)

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The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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INTRODUCTION

Flap reconstruction surgery is a highly complex procedure that demands meticulous vascular assessment and optimization of perioperative strategies to achieve successful outcomes.^{1,2} Advanced imaging modalities have become integral to flap reconstruction surgery by providing precise preoperative vascular mapping, facilitating the identification of optimal recipient vessels, and predicting flap perfusion reliability.^{3,4} Evidence demonstrates that the use of preoperative imaging significantly reduces operative time, streamlines intraoperative decision-making, and minimizes the risk of flap failure.^{5–9} Postoperatively, imaging allows for the timely detection and management of complications such as ischemia and necrosis, further enhancing surgical success rates.^{10–13} Therefore, the integration of these technologies not only

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improves procedural efficiency but also directly impacts clinical outcomes.

In recent years, technological advancements have revolutionized flap reconstruction surgery, driving innovations in high-resolution imaging and data analytics.¹⁴ Developments such as dynamic contrast-enhanced imaging for precise vascular mapping and machine learning algorithms to predict flap survival have significantly enhanced surgical planning and outcomes.^{15,16} High-impact studies in the field have demonstrated how these innovations bridge the gap between technology and clinical practice, highlighting the transformative role of imaging in reconstructive surgery. These advancements underscore the synergistic relationship between innovative imaging technologies, clinical expertise, and academic research, contributing to improvements in patient care.

Despite a marked increase in publications on imaging techniques for flap reconstruction surgery, there remains a notable absence of comprehensive evaluations of publication trends, research productivity, and academic impact. This lack of synthesis obscures a clear understanding of how imaging advancements have influenced the field and limits insight into strategic directions for future research. Addressing this gap is critical to the future of imaging in reconstructive surgery.

This bibliometric analysis aims to address these gaps by systematically evaluating trends in imaging research related to flap reconstruction surgery. By focusing on the 100 most-cited studies, it identifies highly influential works and recurring themes, while recognizing their role in shaping clinical practice and academic priorities.^{17–19} Key metrics, such as citation counts, authorship patterns, and publication sources, will be analyzed to provide a targeted but impactful understanding of the field's progression.^{18,20,21} These findings will help refine research priorities, optimize funding strategies, and inform evidence-based policy development. Although this focused approach highlights landmark contributions, it also sets the stage for future analyses encompassing a broader range of studies to capture emerging innovations.

METHODS

A literature review was conducted to capture the 100 most-cited articles on imaging studies for flap reconstruction, according to a priori determined methodology, as previously illustrated by our team.^{22,23} All available journals on the Web of Science online database (version 5.35; Clarivate Analytics, Philadelphia, PA) were searched on August 2, 2024. The search strategy is detailed in Supplemental Digital Content 1, and the terms were searched as a “topic.” (See appendix, Supplemental Digital Content 1, which displays the search strategy, <https://links.lww.com/PRSGO/E576>.) The timespan set included all available years (1950–2024).

The search identified a total of 13,642 articles. These articles were subsequently ranked following a descending order of “times cited” to assemble the 100 most-cited articles. Studies of the same citation number were separated based on the mean number of citations per year, with

Takeaways

Question: What are the key trends and gaps in imaging studies for flap reconstruction?

Findings: Preoperative imaging dominated (62%), with fewer studies on intraoperative (27%) and postoperative (19%) imaging. The evidence base was mainly levels 3–4. Patient-reported outcome measures were reported in only 1 study. Imaging outcomes were most explored, followed by flap anatomy and comparisons of imaging modalities, with cost-effectiveness being the least studied. Computed tomography angiography and Doppler ultrasound were the most used modalities.

Meaning: Advancing reconstructive success requires greater global collaboration and integration of patient-reported outcome measures in high-quality research to enhance patient-centered evaluations.

more recent studies ranking higher. To ensure the articles are directly relevant to our topic, 2 independent authors (F.A. and H.R.K.M.) screened titles and abstracts until 100 articles were identified. Discrepancies and any remaining doubts were resolved by a consensus discussion with the senior author and reviewing the article's full text. A summary of the methods used and the reasons for exclusion are illustrated in Figure 1.

Five authors (M.A., F.A., G.R.K., Y.T., and I.R.) performed data extraction of the full-text articles. The extracted data were entered into a standardized Microsoft Excel (version 14.7.7) spreadsheet, and descriptive statistical analysis was performed. We extracted key study characteristics and outcomes as detailed in Figure 1. The level of evidence was assessed per the Oxford Centre for Evidence-Based Medicine (2011).²⁴ BIBLIO guidelines were consulted to inform outcome reporting.²¹

RESULTS

Analysis of Citations and Outcomes

The 100 most-cited articles involved a total of 21,619 patients and accumulated 9689 citations, with an average citation count of 96.89 per article. (See table, Supplemental Digital Content 2, which displays the complete citations for all 100 articles, <https://links.lww.com/PRSGO/E577>.) The number of citations per article spanned from 41 to 302, and the mean number of citations per article per year ranged from 1.66 to 17.64 (mean, 6.43) (Table 1). The most-cited article, by Blondeel et al,²⁵ critically highlighted the strengths and limitations of unidirectional Doppler and duplex ultrasound (DUS), marking a pivotal shift as DUS gained widespread adoption for its superior accuracy in perforator flap surgery.

Among the top 100 most-cited articles, imaging outcomes were the most frequently studied topic ($n = 66$), followed by research on the anatomy of flaps and perforators ($n = 16$) (see Fig. 2). Most studies ($n = 62$) used imaging preoperatively for mapping vascular anatomy and perforator selection. Intraoperative imaging was reported in a

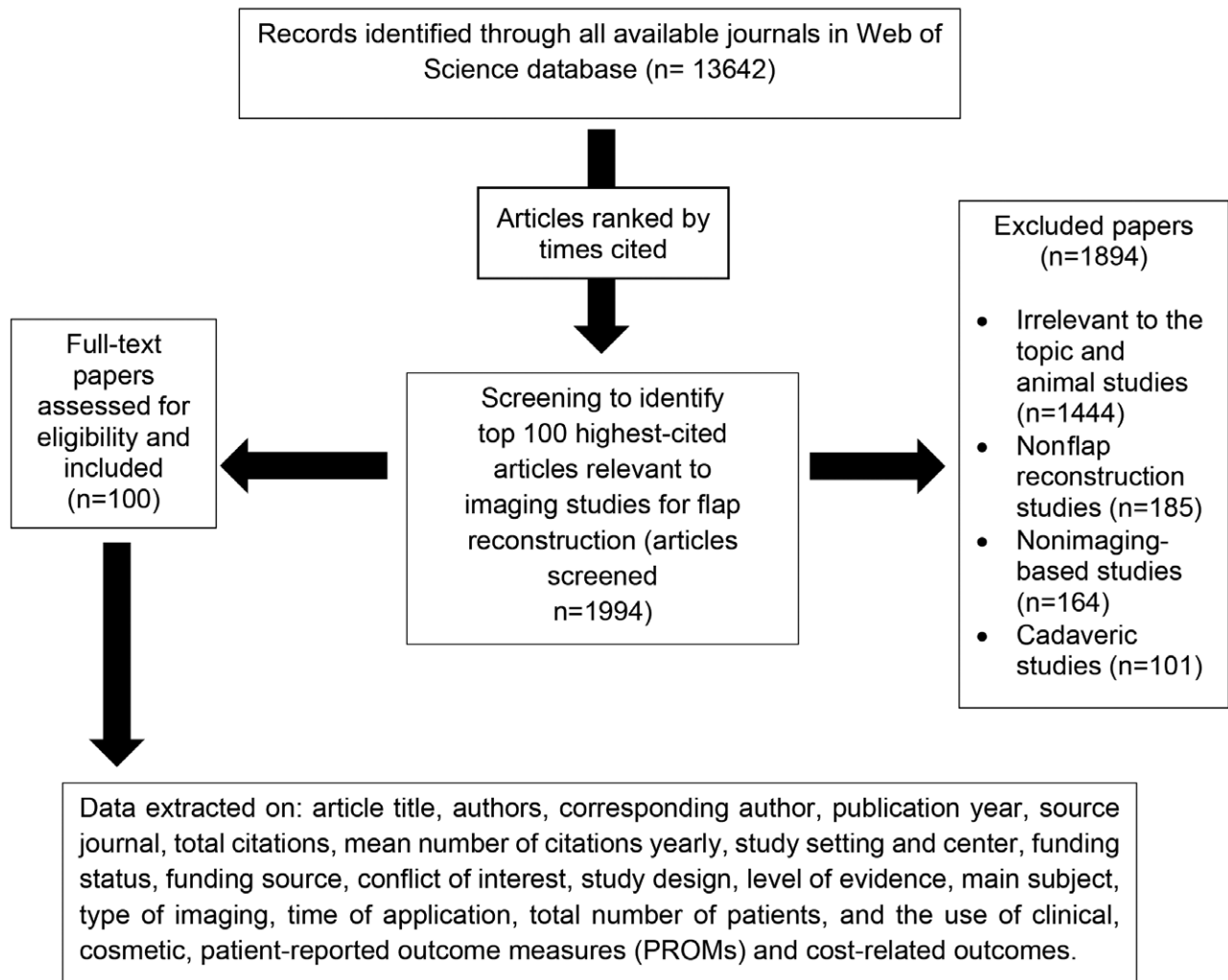


Fig. 1. Flow chart summarizing methodology.

smaller number ($n = 27$), assessing vessel patency and real-time flap perfusion. Postoperative imaging was the least common ($n = 19$), mainly used to monitor flap viability and detect complications such as fat necrosis.

Clinical outcome measures were used in all the most-cited studies; however, only 1 study incorporated patient-reported outcome measures (PROMs), namely the BREAST-Q. No studies assessed cosmetic outcomes. The cost of imaging studies was mentioned in 31 studies, but only 6 studies explored them in the context of potential cost savings, such as through reduced operating time.

Of the most used imaging modalities, computed tomography angiography (CTA) (including spiral computed tomography [CT], multidetector-row CT, 3-dimensional CT angiography) was the most frequently reported ($n = 41$), followed by Doppler ultrasound ($n = 36$) (including unidirectional Doppler, color DUS, laser Doppler flowmetry, and implantable Doppler). Indocyanine green angiography (laser-assisted, microscope-integrated) was used in 24 studies, and magnetic resonance angiography (MRA) was reported in 9 studies.

Deep inferior epigastric perforator (DIEP) flaps ($n = 52$) were most studied, mainly with CTA ($n = 24$), indocyanine green angiography ($n = 16$), and Doppler ($n = 14$). Anterolateral thigh flaps ($n = 21$) were primarily imaged with Doppler ($n = 10$). (See table, **Supplemental Digital Content 3**, which displays a detailed breakdown of flap types and the corresponding imaging, <https://links.lww.com/PRSGO/E578>.)

Publishing Journals and Timestamps

The top-cited studies were published across 30 journals spanning various specialties, with most published in 9 plastic surgery journals, followed by 6 radiology journals. Other fields included 4 surgery journals; 3 ear, nose, and throat journals; 3 maxillofacial journals; 2 vascular medicine/surgery journals; 2 oncology journals; and 1 trauma journal (Table 2).

With 29 articles, *Plastic and Reconstructive Surgery* (PRS) was the top-publishing journal, followed by the *Journal of Plastic, Reconstructive, and Aesthetic Surgery* with 16 and *Microsurgery* with 11. The *Journal of Reconstructive*

Table 1. The 100 Most-cited Articles on Imaging Studies for Flap Reconstruction Surgery, Sourced From Web of Science

Rank	Authors (if >2, Then et al)	Corresponding Author	Publication Year	Total Citations	Mean No. Citations per Year
1	P.N. Blondeel, G. Beyens, et al	Phillip N. Blondeel	1998	302	11.62
2	J. Masia, J. A. Clavero, et al	J. Masia	2006	298	16.56
3	Joseph J. Disa, Peter G. Cordeiro, et al	Joseph J. Disa	1999	261	10.44
4	R.E. Giunta, A. Geisweid, et al	Riccardo E. Giunta	2000	257	10.71
5	Ewa Komorowska-Timek, Geoffrey C. Gurtner	Geoffrey C. Gurtner	2010	247	17.64
6	Warren M. Rozen, Timothy J. Phillips, et al	Warren M. Rozen	2008	241	15.06
7	G.I. Taylor, M. Doyle, et al	G.I. Taylor	1990	221	6.50
8	Peirong Yu, Adel Youssef	Peirong Yu	2006	216	12.00
9	Geoffrey G. Hallock	Geoffrey G. Hallock	2004	203	10.15
10	A. Alonso-Burgos, E. García-Tutor, et al	A. Alonso-Burgos	2006	199	11.06
11	Hunter R. Moyer, Albert Losken	Hunter R. Moyer	2012	190	15.83
12	C. Holm, M. Mayr, et al	C. Holm	2002	187	8.50
13	Frank Hölzle, Denys John Loeffelbein, et al	Frank Hölzle	2006	164	9.11
14	Ivo A. Pestana, Brian Coan, et al	Michael Robert Zenn	2009	158	10.53
15	Naikhoba C.O. Munabi, Olushola B. Olorunnipa, et al	Jeffrey Ascherman	2014	155	15.50
16	James C. Yuen, Zuliang Feng	James Yuen	2000	151	6.29
17	Warren M. Rozen, Namrata S. Anavekar, et al	Warren M. Rozen	2008	147	9.19
18	Jeroen M. Smit, Angeliki Dimopoulou, et al	Rafael Acosta	2009	144	9.60
19	Gabriel M. Kind, Rudolf F. Buntic, et al	Gabriel M. Kind	1998	142	5.46
20	C. Holm, J. Tegeler, et al	Charlotte Holm	2002	137	6.23
21	Julia M. Toto, Eric I. Chang, et al	Neal S. Topham	2015	128	14.22
22	andrej repež, Dominika Oroszy, et al	andrej repež	2008	128	8.00
23	Daniel Z. Liu, David W. Mathes, et al	David W. Mathes	2011	123	9.46
24	Claire S. Duggal, Tarik Madni, et al	Albert Losken	2014	122	12.20
25	Martin I. Newman, Michel C. Samson, et al	Martin I. Newman	2010	112	8.00
26	T.J. Phillips, D.L. Stella, et al	Timothy John Philips	2008	112	7.00
27	H. Mothes, T. Döncke, et al	Olaf Bach	2004	112	5.60
28	M.I. Newman, M.C. Samson	Martin Newman	2009	111	7.40
29	M. Griffiths, M.P. Chae, et al	Matthew Griffiths	2016	110	13.75
30	A. Tsukino, K. Kurachi, et al	Akihiko Tsukino	2004	110	5.50
31	J.J. Rosenberg, B.D. Fornage, et al	Jason Rosenberg	2006	106	5.89
32	J. Masia, J. Larrañaga, et al	Jauma Masia	2008	104	6.50
33	R.P. Rand, M.M. Cramer, et al	R.P. Rand	1994	99	3.30
34	A. Cina, M. Salgarello, et al	Alessandro Cina	2010	99	7.07
35	G.G. Hallock	Geoffrey Hallock	1994	96	3.20
36	J.P. Guillemaud, H. Seikaly, et al	Jeffrey Harris	2008	94	5.88
37	W.M. Rozen, D.L. Stella, et al	Warren Rozen	2009	94	6.27
38	D.M. Young, P.P. Trabelsy, et al	David Young	1994	93	3.10
39	J. Still, E. Law, et al	J. Still	1999	89	3.56
40	B.T. Lee, M. Hutteman, et al	John Frangioni	2010	88	6.29
41	W.J. Casey, R.T. Chew, et al	William Casey	2009	85	5.67
42	J. Masia, D. Kosutic, et al	Jauma Masia	2010	84	6.00
43	C. Holm, M. Mayr, et al	Charlotte Holme	2009	84	5.60
44	L. Heller, L.S. Levin, et al	Bruce Klitzman	2001	83	3.61
45	N.T. Haddock, P. Greaney, et al	Nicholas Haddock	2012	83	6.92
46	W.M. Rozen, D. Chubb, et al	Warren Rozen	2009	83	5.53
47	G.D. Rosson, C.G. Williams, et al	Gedge D. Rosson	2007	83	4.88
48	J.R. Scott, D. Liu, et al	David Mathes	2009	82	5.47
49	W.M. Rozen, M.W. Ashton, et al	Warren Rozen	2008	80	5.00
50	W.M. Rozen, M.W. Ashton, et al	Warren Rozen	2008	80	5.00
51	L. de Weerd, J.B. Mercer, et al	Louis de Weerd	2006	78	4.33
52	A. Chatterjee, N.M. Krishnan, et al	A. Chatterjee	2013	76	6.91
53	R.S. Uppal, B. Casaer, et al	Rajan Uppal	2009	75	5.00
54	W.M. Rozen, M.W. Ashton, et al	Warren Rozen	2008	69	4.31
55	W.M. Rozen, E. Garcia-Tutor, et al	Warren Rozen	2010	68	4.86
56	H.S.P. Suh, H.H. Jeong, et al	Joon Pio Hong	2016	66	8.25

(Continued)

Table 1. (Continued)

Rank	Authors (if >2, Then et al)	Corresponding Author	Publication Year	Total Citations	Mean No. Citations per Year
57	U.D. Khan, J.G. Miller	U.D. Khan	2007	66	3.88
58	R.J. Mitnick, J.A. Bello, et al	Robin Mitnick	1995	65	2.24
59	J.J. Disa, P.G. Cordeiro	Peter Corderio	1997	65	2.41
60	E.F. O'Connor, W.M. Rozen, et al	Edmund Fitzgerald O'Connor	2016	63	7.88
61	A. Cina, L. Barone-Adesi, et al	A. Cina	2013	62	5.64
62	M.V. Schaverien, C.N. Ludman, et al	Stephen McCulley	2010	61	4.36
63	Mark K. Wax	Mark K. Wax	2014	60	6.00
64	Jorge de la Torre, William Hedden	Jorge de la Torre	2003	60	2.86
65	Diego Ribuffo, Matteo Atzeni	Diego Ribuffo	2009	60	4.00
66	Seven Weum, James B. Mercer	Seven Weum	2016	60	7.50
67	Florian Ensaf, Maria Babl, et al	Florian Ensaf	2012	60	5.00
68	Ingo Ludolph, Andreas Arkudas, et al	Justus P. Beier	2016	58	7.25
69	Kari A. Keys, Otway Louie	Kari A. Keys	2013	58	5.27
70	Shaoqing Feng, Peiru Min, et al	Yi Xin Zhang	2015	57	6.33
71	Georges Battega, Marine Hitier, et al	Georgis Battega	2016	56	7.00
72	Hideo Lida, Tadashi Umeda, et al	Hideo Lida	2003	56	2.67
73	Richard J. Shaw, Martin D. Batstone, et al	Richard J. Shaw	2010	54	3.86
74	S.Y. Chen, W.C. Lin, et al	S.Y. Chen	2010	54	3.86
75	Diego Ribuffo, Matteo Atzeni, et al	Diego Ribuffo	2008	53	3.31
76	Purificación Gacto-Sánchez, Domingo Sicilia Castro, et al	Purificación Gacto-Sánchez	2010	52	3.71
77	Lukas Prantl, K.P. Fister, et al	Lukas Prantl	2007	50	2.94
78	R. Varela, C. Casado-Sanchez, et al	Luis Landin	2020	50	12.50
79	A. Malhotra, N. Chhaya, et al	A. Malhotra	2013	50	4.55
80	David Dorfman, Lee L.Q. Pu	David Dorfman	2014	50	5.00
81	A. Ghattaura, J. Henton, et al	A. Ghattaura	2010	49	3.50
82	Gustave K. Diep, Jane Yuet Ching Hui, et al	Todd M. Tuttle	2016	49	6.13
83	Wen-Kuan Chiu, Wen-Chiung Lin, et al	Shyi-Gen Chen	2010	48	3.43
84	Ingo Ludolph, Raymond E. Horch, et al	Ingo Ludolph	2019	47	9.40
85	Victoria Chernyak, Alla M. Rozenblit, et al	Victoria Chernyak	2009	47	3.13
86	David Greenspun, Julie Vasile, et al	David Greenspun	2010	47	3.36
87	N.D. Futran, B.C. Stack, et al	N.D. Futran	1998	46	1.77
88	R.K. Devon, M.A. Rosen, et al	Mark Rosen	2004	45	2.25
89	A. Duymaz, F.E. Karabekmez, et al	Steven Moran	2009	45	3.00
90	C. Holm, U. Dornseifer, et al	C. Holm	2010	45	3.21
91	G.H. Mun, H.J. Kim, et al	G.H. Mun	2008	45	2.81
92	R.M. Nagler, J. Braun, et al	R.M. Nagler	1997	45	1.67
93	Katsuya Gorai, Keita Inoue, et al	Katsuya Gorai	2017	44	6.29
94	Moustapha Hamdi, Koenraad Van Landuyt, et al	Moustapha Hamdi	2009	44	2.93
95	F. Lorenzetti, A. Salmi, et al	F. Lorenzetti	1999	44	1.76
96	Winnie Mao Yiu Tong, Robert Dixon, et al	Winnie Mao Yiu Tong	2012	43	3.58
97	Grace T. Um, Jeff Chang, et al	Grace T. Um	2014	42	4.20
98	Amir Khosrow Bigdeli, Emre Gazyakan, et al	Christoph Hirche	2016	42	5.25
99	Michael R. DeLong, Duncan B. Hughes, et al	Michael R. DeLong	2014	42	4.20
100	A.A.K. Abdel Razek, A.T. Denewer, et al	A.A.K. Abdel Razek	2014	41	4.10
Total citations for the 100 studies				9689	

The table includes the rank based on total citations, authorship details, corresponding author, and the mean number of citations per year.

Microsurgery and *Annals of Plastic Surgery* also made significant contributions with 8 and 6 studies, respectively. All remaining journals published 3 or fewer articles.

The 100 top-cited articles were published between 1990 and 2020. The analysis by decade, presented in Figure 3 and Supplemental Digital Content 4, reveals that the 2000s were the most productive period, with the

highest number of publications (n = 44) and the greatest cumulative citation count (4926). (See table, Supplemental Digital Content 4, which displays the 100 most-cited articles decade analysis, <https://links.lww.com/PRSGO/E579>.) In contrast, the 1990s recorded the lowest number of publications and citations, despite featuring some highly influential articles.

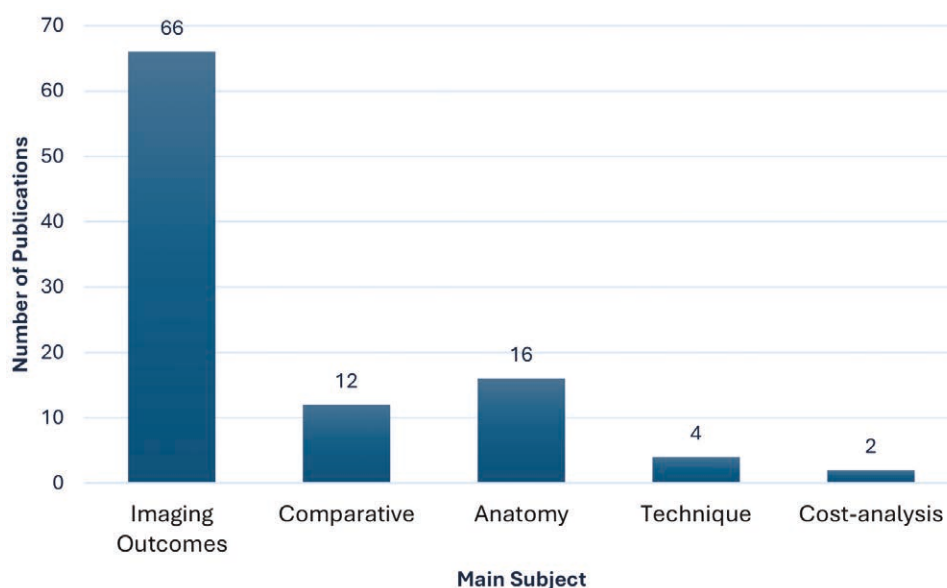


Fig. 2. Primary topics covered in the top 100 cited studies.

Levels of Evidence and Study Designs

When the top-cited articles were classified according to the Oxford Centre for Evidence-Based Medicine, only 1 study achieved level 1. Most studies fell into level 3 and level 4, encompassing 37 and 34 publications, respectively (see Table 3). Retrospective cohort studies ($n = 36$) and case series ($n = 34$) were the most common study designs (see Table 4).

Trends in Countries, Authors, and Funding Resources

The United States leads the field with a total of 41 publications. (See table, Supplemental Digital Content 5, which displays the countries contributing to the 100 most-cited articles, <https://links.lww.com/PRSGO/E580>.) Following behind, Germany exhibits a notable contribution with 12 studies to their credit. Australia, the United Kingdom, and Spain add to the research landscape with 10, 7, and 6 publications, respectively. Single-center studies are overwhelmingly prevalent ($n = 98$), with multi-center efforts being rare ($n = 2$).

Focusing on first and corresponding author roles, Rozen et al^{4,9,11,26–30} stand out as the most prolific contributors with 8 publications. Holm et al^{31–34} follow with 4 publications in these key positions.

In terms of funding status, only 7 studies acknowledged the receipt of funding, whereas the remaining studies either did not declare funding status ($n = 64$) or were unfunded ($n = 29$). Regarding conflict of interest, 6 studies disclosed potential issues, 34 stated no conflict existed, and 60 did not provide specific information. The sources of potential conflict of interest primarily involved authors serving as paid speakers or consultants for companies such as Novadaq, which manufactures imaging devices or provides the imaging system free of charge (eg, the SPY fluorescent angiography system). Funding sources were provided by academic/hospital institutions, such as the Head and Neck Oncology Program Fund at

Alberta University, or government-linked entities, such as the Andalusian Department of Health.

DISCUSSION

Our findings reveal that preoperative imaging for flap planning is the leading trend, with DUS and CTA most frequently used. Over time, the field has embraced a noticeable transition to more advanced and sophisticated imaging modalities, such as ICG and MRA. Consistent with prior bibliometric analyses, most studies were single-center, from the United States, and published in PRS. Only 1 study achieved level 1 evidence, and the use of PROMs was notably scarce.^{22,23,35–37}

Among the 100 most-cited articles identified in our analysis, 5 were featured in *Landmark Papers in Plastic Surgery*, reflecting their pivotal role in the field.³⁸ Landmark articles adhere to stringent criteria beyond citation counts; they introduce groundbreaking techniques or ideas, serve as catalysts for change, challenge the status quo, and leave a lasting impact on the field.³⁸

The first application of DUS in reconstructive surgery was a 1994 case report by Chang et al³⁹ demonstrating its utility in preoperative mapping of transverse rectus abdominis myocutaneous flap periumbilical perforators. The foundation for DUS's current applications was likely laid by 2 landmark articles.^{25,40} Rand et al⁴⁰ published the first large series using DUS to map DIEA and superior epigastric artery perforators, detailing their technique and offering guidance on flow velocities and selecting dominant perforators. Blondeel et al²⁵ published the most-cited DUS study ranking first in our analysis. They demonstrated DUS's superiority over handheld Doppler in perforator mapping, highlighting its precision, reduced intraoperative stress, and improved decision-making despite added time and cost. Despite its learning curve, DUS is now used both intraoperatively and postoperatively. Advances in

Table 2. Top Journals by Publication Count, With 2024 Impact Factors Retrieved From the Latest Clarivate Analytics Web of Science Database

Journal	No. Publications	Impact Factor
<i>Plastic and Reconstructive Surgery</i>	29	3.2
<i>Journal of Plastic, Reconstructive, and Aesthetic Surgery</i>	16	2.0
<i>Microsurgery</i>	11	1.5
<i>Journal of Reconstructive Microsurgery</i>	8	2.2
<i>Annals of Plastic Surgery</i>	6	1.4
<i>Radiology</i>	3	12.1
<i>Journal of Cranio-Maxillofacial Surgery</i>	2	2.1
<i>Plastic and Reconstructive Surgery—Global Open</i>	2	1.5
<i>Gland Surgery</i>	2	1.5
<i>Aesthetic Plastic Surgery</i>	1	2.0
<i>Aesthetic Surgery Journal</i>	1	3.0
<i>ANZ Journal of Surgery</i>	1	1.5
<i>Annals of Surgical Oncology</i>	1	3.4
<i>Annals of Vascular Surgery</i>	1	1.4
<i>Clinics in Plastic Surgery</i>	1	1.8
<i>International Journal of Oral and Maxillofacial Surgery</i>	1	2.2
<i>British Journal of Oral and Maxillofacial Surgery</i>	1	2.3
<i>BMC Medical Imaging</i>	1	2.9
<i>Clinical Hemorheology and Microcirculation</i>	1	2.1
<i>Clinical Radiology</i>	1	2.1
<i>European Journal of Surgical Oncology</i>	1	3.5
<i>European Radiology</i>	1	4.7
<i>RadioGraphics</i>	1	5.2
<i>Laryngoscope</i>	1	2.2
<i>JAMA Otolaryngology—Head & Neck Surgery</i>	1	6.0
<i>Head and Neck—Journal for the Sciences and Specialties of the Head and Neck</i>	1	2.3
<i>Surgical and Radiologic Anatomy</i>	1	1.2
<i>Surgical Innovation</i>	1	1.2
<i>The Journal of Trauma and Acute Care Surgery</i>	1	2.9
<i>Frontiers in Surgery</i>	1	1.6

ultrasound allow visualization of small vessels (<0.5 mm), making it an indispensable tool often called “the reconstructive surgeon’s stethoscope.”^{41–43}

Nagler et al⁴⁴ introduced CTA to survey external carotid branches in a landmark article, highlighting its advantages over conventional angiography—less invasive, cheaper, quicker, and easier to perform—but they did not anticipate it fully replacing angiography. It was published before the advent of multidetector row technology that solidified CTA’s prominence in flap surgery, but laid the groundwork by showcasing its ability to effectively map the size and location of small arterial branches. The fourth landmark article, ranked second in our analysis, by Masia et al,⁴⁵ used a 16-detector row CT scanner to create angiograms for DIEP flap breast reconstruction. CTA outperformed handheld Doppler, offering high-quality images, reducing operative time, and enhancing surgical safety. CTA will likely remain the primary imaging choice as methods evolve to reduce radiation while preserving image quality.^{46,47}

The fifth landmark article, ranked 13th, is a case series by Holm et al³² that was among the first clinical studies to validate ICG imaging for assessing blood flow in pedicled skin flaps, delineating axial and random blood supply patterns, and proving valuable for flaps exceeding the 3:1 length-to-breadth ratio. However, the first application of ICG in reconstructive flap literature was in a 1996 animal model by Eren et al,⁴⁸ providing a proof-of-concept for visualizing flow dynamics within the flap in real time, with rapid dye influx and efflux enabling serial assessments. This study was recognized as a landmark and provided a solid basis for ICG development, but it was excluded from our list because it was animal-based. The low toxicity, minimal adverse effects, and ease of use likely explain the increasing applications of ICG.⁴⁹ However, its preoperative use remains limited due to its limited penetration through soft tissue thicker than 15 mm.^{50,51}

Imaging costs, averaging \$250 for DUS, \$400 for CTA, and \$600 for MRA, vary widely but may be justified by savings in operative time and hospital stays, which can offset the initial expenses.^{4,27} CTA was found to save \$3900 per DIEP flap case in Rozen et al,⁵² with reduced operative time (90 min; \$3150) and a 1-day shorter hospital stay (\$750), far exceeding its \$490 cost. Among the top-cited studies, cost was acknowledged but rarely examined in terms of potential savings. With increasing emphasis on value-based healthcare, studies should incorporate cost-related outcomes alongside clinical endpoints and PROMs to support sustainable surgical practice and inform reimbursement and policy decisions.

By improving flap perfusion assessment and reducing complications such as fat necrosis, imaging can improve patient satisfaction. It can also inform intraoperative decision-making trade-offs such as choosing better-perfused tissue at the expense of scar placement or flap sensation, making PROMs essential for capturing patient-perceived benefits and evaluating whether these choices align with patient priorities. However, only 1 study on the list used a validated PROM. Varela et al⁵³ used ICG in DIEP flap reconstructions to guide selective excision of poorly vascularized areas, reducing fat necrosis while preserving flap dimensions. This resulted in improved BREAST-Q scores, particularly in sexual well-being, satisfaction with outcomes, and breasts.⁵³ The limited use of PROMs highlights a focus on technical over patient-centered outcomes; expanding their use would offer a holistic view of reconstructive success from the patient’s perspective.

BREAST-Q development set a benchmark for future plastic surgery PROMs by integrating patient input, expert consensus, and rigorous psychometric validation.⁵⁴ Given ongoing innovation and evolving patient expectations, continuous refinement is essential to validate existing PROMs across languages and cultures and to develop new disease-specific measures that address all areas of plastic surgery. These instruments must be valid, reliable, and responsive, with clearly established minimal clinically important differences to serve as meaningful comparative metrics in research and routine practice.⁵⁵

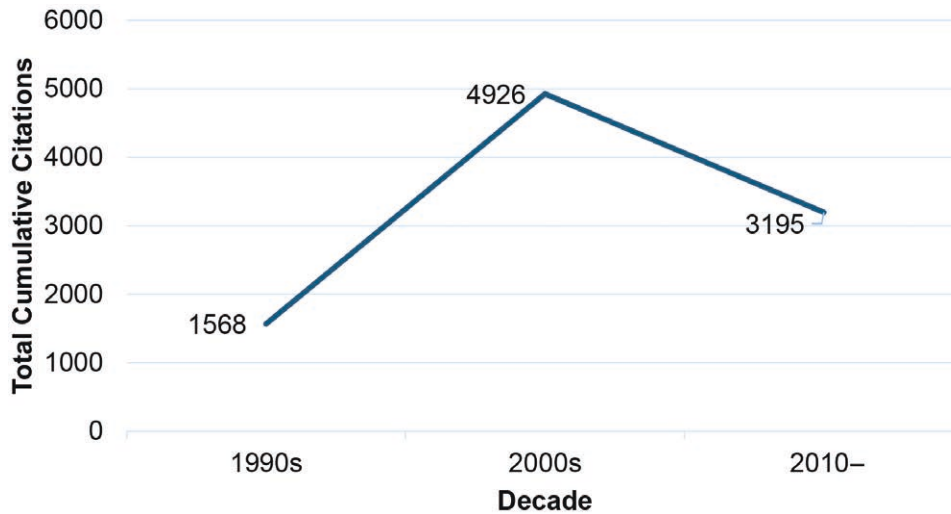


Fig. 3. A decade analysis of cumulative citations for the 100 most-cited articles.

Table 3. Level of Evidence of the 100 Most-cited Articles

Level of Evidence	No. Publications
Level 1	1
Level 2	24
Level 3	37
Level 4	34
Level 5	4

Table 4. Study Designs of the 100 Most-cited Articles

Study Design	No. Publications
Expert opinion and narrative review	4
Case series	34
Cost-effectiveness study	1
Retrospective cohort study	36
Prospective cohort study	24
Randomized controlled trial	1

The field relies heavily on level 3 and 4 evidence, mirroring trends in previous bibliometric analyses.^{22,33,37} Case series and retrospective cohort studies are vulnerable to selection biases and confounding variables, limiting their ability to establish robust guidelines. Their frequent use likely reflects feasibility over robustness given the challenges of randomized controlled trials.^{56,57} These include ethical concerns when assigning patients to less accurate imaging, difficulties with recruitment in small, heterogeneous populations, challenges in standardizing protocols, and limited funding, especially for costly modalities such as MRA.

In line with Bradford's law, most studies were concentrated in a few core journals, namely *PRRS*; *Journal of Plastic, Reconstructive, and Aesthetic Surgery*; and *Microsurgery*.^{58–61} These journals, known for their high visibility, prestige, and rigorous peer review, attract pioneering research, driving their high citation rates. The range of specialty journals shows the multidisciplinary relevance and the adaptable, evolving nature of imaging techniques, fueling innovations to enhance patient outcomes across diverse reconstructive scenarios.

Rozen et al^{9,11,29,30} emerged as the most prolific authors, focusing on enhancing operative and patient outcomes in autologous breast reconstruction through diverse imaging modalities, including Doppler ultrasound, CTA, MRA, and CT-guided stereotaxy. He serves as coeditor of a foundational textbook on imaging in plastic surgery and is credited with the original descriptions of CTA and MRA for vascular mapping in the preoperative planning of perforator flaps.^{9,62,63} Holm et al,^{31–34} the second most prolific author, has been instrumental in establishing ICG imaging as an essential intraoperative tool for real-time perfusion monitoring, improving flap viability and reducing complications.

Decade-by-decade analysis reveals the evolving landscape of the field. The 1990s saw foundational validation studies, whereas the 2000s and 2010s brought increased output, citation impact, and a rise in comparative studies. Comparable publication volumes in these later decades suggest the field may have plateaued as imaging became routine and well integrated into practice. The absence of post-2020 studies likely reflects the time required for articles to accumulate citations, with citation peaks typically taking 10–15 years, a timeline further disrupted by the COVID-19 pandemic.^{64–66}

Citation analysis is prone to conscious and unconscious biases.^{19,67} Authors may increase the apparent recognition of their work by citing themselves, colleagues, or mentors. Editors may favor articles with significant results, written in English, conducted in the United States, or citing their journal's work to influence the journal's citation metrics.⁶⁸ Biases such as in-house review, powerful person, bandwagon, and citation omission may distort this analysis. Older imaging such as Doppler ultrasound might have accumulated more citations due to longevity.^{58,69} Foundational studies, such as the transverse rectus abdominis myocutaneous flap described by Hartrampf, are often cited for historical context, illustrating how citation counts may reflect legacy rather than current relevance.⁷⁰

This review relied on the Web of Science and included English-only studies, potentially missing undindexed or non-English publications. The search terms focused on main imaging studies for flap reconstruction, leaving other modalities such as near-infrared spectroscopy and thermography underrepresented/not represented. Citation count does not necessarily equate to the study's quality, the popularity, or contemporary clinical utility of an imaging modality, but reflects its recognition within the scientific community. Other parameters, such as read/download frequency and the Altmetric Attention Score, were beyond this study's scope but remain important for gauging a study's broader influence.^{71–73} Although we only reported whether cost and potential cost savings were addressed, we did not evaluate the completeness of these analyses, which likely vary across healthcare systems and may omit components such as equipment, personnel, or radiologist fees.

Bibliometric analysis remains the gold standard for measuring scholarly output, valued for its quantitative and systematic approach, but its interpretation inherently carries a degree of subjectivity.^{73–75} Classifying imaging studies by flap type could have allowed for nuanced interpretations, but this was inconsistently reported, as were precision metrics and other outcomes. Therefore, developing core outcome sets through consensus methods is essential to foster methodological research in this field.^{76–78}

CONCLUSIONS

This extensive bibliometric analysis, the first in the literature, highlights the evolution of imaging studies for flap reconstruction across 3 consecutive decades, identifies true landmark articles, and offers valuable insights into the most frequently cited imaging modalities and their applications. The compiled list lacked standardized outcome reporting and high-quality randomized trials. To drive progress in the field, international collaboration, the development of core outcome sets, and the integration of PROMs into rigorous level 1 studies are imperative to address diverse patient populations and improve clinician–patient decision-making and overall satisfaction.

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