Loupes-Only Microsurgery is a Safe Alternative to the Operating Microscope: An Analysis of 1,649 Consecutive Free Flap Breast Reconstructions

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Abstract

Background Loupes-only microsurgery challenges the paradigm that free flap surgery requires an operating microscope. We describe our loupes-only microsurgery experience with an emphasis on rates of intraoperative anastomotic revision and total flap loss.
Methods We identified all patients having breast reconstruction with muscle-sparing transverse rectus abdominis myocutaneous (ms-TRAM) or deep inferior epigastric perforator (DIEP) flaps over 7 years. We examined rates of intraoperative anastomotic revision and total flap loss as markers of technical quality. For one high-volume surgeon who started loupes-only microsurgery while at our institution, we examined rates of intraoperative anastomotic revision and total flap loss rates over time to evaluate for a learning curve.
Results We performed 1,649 ms-TRAM or DIEP flaps in 1,063 patients. For 1,649 flaps, the rate of artery anastomotic revision was 2.2% (36 arteries) and venous anastomotic revision was 2.2% (37 veins). Any microvascular revision was performed in 3.5% (58 flaps). Total flap loss rate was 1.2% (20 flaps).
For the “learning curve” analysis, there were no clinically relevant differences in rates of any intraoperative anastomotic revision or total flap loss during the first 60 months after loupes-only microsurgery was adopted. Total flap loss during this surgeon’s first 60 months of loupes-only microsurgery was 1.6% (10 of 638 flaps).
Conclusions Loupes-only microsurgery is a safe alternative to the operating microscope for free flap breast reconstruction using the deep inferior epigastric system. Our total flap loss rate of 1.2% in 1,649 flaps is at the low end of published flap loss rates.

Keywords
► loupes
► microscope
► free flap
► breast reconstruction
► TRAM
► DIEP

The first microsurgical free tissue transfer, a free omental flap to a scalp wound, was performed in 1972 by McLean and Buncke.[1] Since that time, the field of microsurgery has grown exponentially. Free tissue transfer is now recognized as a safe and reliable reconstructive technique, with anastomotic patency rates over 97% being the norm.[2–7]

Microsurgery is typically performed using loupe-aided magnification to dissect the flap and recipient vessels, and operating microscope-aided magnification to perform the arterial and venous anastomoses. Proponents of microscope-aided anastomosis cite multiple advantages, including superior lighting, a more stable operative field, and improved

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visualization for novice surgeons, among others.[8] However, in 1995, two landmark articles published by Serletti et al at the University of Rochester and Shenaq et al at the Baylor College of Medicine[9,10] presented the concept of loupes-only microsurgery, in which $\times$3.5 or higher surgical loupes were used for microsurgical anastomosis, in addition to flap harvest and recipient vessel dissection. Both studies reported free flap survival rates of over 98% without the operating microscope.

In 1995, Serletti et al reported that 78% of free tissue transfers performed at community hospitals were done with loupes, and noted that "the routine use of loupes has enabled us to extend the boundaries of microsurgery beyond the traditional academic center."[9] This expansion also applies to resource-poor areas, where the cost of purchasing a microscope is prohibitive. In these settings, loupe-aided microsurgery is the only feasible means to offer patients the highest rung on plastic surgery's reconstructive ladder.

Since the initial publications in 1995, several other studies that examine feasibility and safety of loupes-only microsurgery have been published.[7,11–13] Small studies have shown flap survival over 97% with loupe-aided microsurgery.[9–12] Small comparative studies have shown no differences in flap outcomes with loupe-aided versus microscope-aided anastomoses.[9,12] At present, there are limited data available regarding the technical quality of anastomoses performed using loupes-only microsurgery. In addition, there are no data on the "learning curve" for this technique, and it remains unknown whether initiation of loupes-only microsurgery will result in substantially increased rates of free flap loss.

Here, we will describe our experience with loupes-only microsurgery in free flap breast reconstruction, with an emphasis on intraoperative anastomotic revision and total flap loss as markers of technical quality. Additionally, we will examine flap survival rates of surgeons as they transitioned to loupes-only microsurgery to assess for a "learning curve."

Methods

Before beginning this study, approval was obtained from our institution's Institutional Review Board.

The Division of Plastic Surgery at the University of Pennsylvania prospectively maintains a database of free flap breast reconstruction patients. Available variables include demographic information, comorbid medical conditions, intraoperative anastomotic details, and flap outcomes. We identified consecutive female patients who underwent abdominal-based free flap breast reconstruction at our institution between 2005 and 2012. Multiple authors agree that the microscope is preferable for vessel size < 1.5 mm, pediatric cases, distal replantations, and nerve repairs.[8–10,13] The arterial diameter for superficial inferior epigastric artery flaps (SIEA) flaps is commonly below 1.5 mm[14,15] and we occasionally use the operating microscope for these cases. Thus, we limited our population to free flap breast reconstruction based on the deep inferior epigastric vessels. Specifically, we considered reconstruction using free muscle-sparing transverse rectus abdominis myocutaneous (ms-TRAM) flap or free deep inferior epigastric perforator (DIEP) flaps. The reported study is a case series. This analysis is particularly relevant as the abdomen remains the first-line donor site for free flap breast reconstruction, and overall rates of SIEA flaps, even in large series, remains low.[16]

All surgeries were performed by one of three attending surgeons (S. J. K., L. C. W., or J. M. S.). At our institution, attending surgeons are assisted by a microsurgical fellow or senior resident for free flap breast reconstruction. The trainee, directly supervised by the surgeon, performs the anastomoses in over 90% of the cases. Venous anastomoses are performed using a coupling device. Arterial anastomoses are handsewn. Anastomotic revisions, when required, are performed using loupe magnification.

Outcomes of Interest

Outcomes of interest for this study included markers of technical quality for the anastomosis. Specifically, we included the following: (1) anastomotic revision of the artery or vein during the initial operation and (2) total flap loss. We did not consider rates of partial free flap loss, as this is typically a problem related to flap design or flap dissection, not a problem with the vascular anastomosis. We did not examine rates of return to the operating room, as factors unrelated to the vascular anastomosis (such as hematoma) could be the proximate cause. Our dataset did not contain information on why return to the operating room was indicated.

Data Acquisition and Storage

Study data were warehoused using the web-based REDCap (Research Electronic Data Capture) platform. REDCap is a secure, web-based application designed to support data capture for research studies, providing the following: (1) an intuitive interface for validated data entry; (2) audit trails for tracking data manipulation and export procedures; (3) automated export procedures for data downloads to common statistical packages; and (4) procedures for importing data from external sources. REDCap is currently used at 1,176 institutions in 85 countries to support data acquisition for research endeavors.[17,18] Patient-level demographic data and intraoperative details were uploaded by the operating surgeon or resident/fellow on the day of surgery. Retrospective chart review allowed data capture for postoperative complications and long-term outcomes including flap losses.

Analysis

Deidentified data were extracted from REDCap and were analyzed using the Stata11 statistical package (Stata Corp., College Station, TX). Bilateral mastectomy is increasingly common. As bilateral breast reconstruction has become increasingly common,[19] demographics of flap use and flap complications were considered at the flap, not patient, level. Descriptive statistics were generated for patient-level and flap-level demographics. Rates of intraoperative anastomotic revision, stratified by artery or vein, were calculated. Rates of total flap loss were calculated at the flap, not patient, level.

For one high-volume surgeon (L. C. W.) who initiated loupes-only microsurgery after starting at our institution, we performed a stratified analysis of any intraoperative thrombosis and total flap loss rates over time. This surgeon used the microscope exclusively during the board collection period for the American Board of Plastic Surgeons examination. Subsequently, this surgeon transitioned exclusively to loupes-only microsurgery for free flap breast reconstruction based on the deep inferior epigastric system. After their board collection period had ended, this surgeon exclusively utilized loupes-only microsurgery when a flap based on the deep inferior epigastric vessels was used for free flap breast reconstruction. For stratified analysis, block 1 was months 9 to 14 of independent practice, block 2 was months 15 to 20 of independent practice, block 3 was months 21 to 26 of independent practice, block 4 was months 27 to 32 of independent practice, block 5 was months 33 to 38 of independent practice, block 6 was months 39 to 45 of independent practice, block 7 was months 46 to 51 of independent practice, block 8 was months 52 to 57 of independent practice, block 9 was months 58 to 63 of independent practice, and block 10 was months 64 to 69 of independent practice. These time blocks correlated to months 1 to 6, 7 to 12, 13 to 18, 19 to 24, 25 to 30, 31 to 36, 37 to 42, 43 to 48, 49 to 54, and 55 to 60 of loupes-only microsurgery, respectively. As number of outcome events was low, Fischer exact test was used to compare the proportion of intraoperative thrombosis or total flap loss rates between time blocks.

Results

We identified 1,649 consecutive free ms-TRAM or DIEP flaps in 1,063 patients over 7 years. Patient demographics were representative of breast reconstruction patients seen in a northeastern academic medical center. Our patient's mean age was 50.2 years (range, 29.4–76.7 years) and mean body mass index was 27.5 kg/m^2 (range, 18.3–61.2 kg/m^2). Nearly 70% of our patients were white, non-Hispanic. Major comorbid conditions were rare (►**Table 1**). The majority of our patients had immediate breast reconstruction. Anastomoses were most commonly performed in an end-to-end fashion with the internal mammary vessels (►**Table 2**).

Table 1 Patient demographics

Characteristic	Percentage of cohort ($N = 1,096$)
Ethnicity	
Caucasian	69.1% (757)
African American	14.8% (162)
Hispanic	1.9% (21)
Asian	2.1% (23)
Other or unknown	12.1% (133)
Chronic obstructive pulmonary disease	1.2% (13)
Diabetes mellitus	6.4% (70)
Hypertension	25.4% (278)
Coronary artery disease	1.6% (18)
Peripheral vascular disease	0.7% (8)
Dyslipidemia	17.2% (189)
Lymphedema	5.7% (62)
Smoking history	
Never	60.0% (654)
Current	10.6% (116)
Previously quit	27.7% (303)
Unknown	2.1% (23)

Among 1,649 free flaps, the total rate of intraoperative anastomotic revision was 3.5% (58 flaps). Intraoperative arterial revision was performed in 2.2% (36 flaps) and intraoperative venous revision was performed in 2.2% (37 flaps). The total flap loss rate was 1.2% (►**Table 3**; 20 flaps).

Subgroup analysis was performed to examine intraoperative revision and total flap loss rate per 6 month interval for one high-volume breast surgeon who began loupes-only microsurgery after starting at our institution. Total flap loss rate during this period was 1.6% (10 of 638 flaps). Ten patients (1.6%) required an intraoperative anastomosis revision. ►**Figs. 1** and **2** demonstrate rates of any intraoperative revision and total flap loss over time. Block 7 appeared to be an outlier for total flap loss. With this exception, there were no significant differences between intraoperative revision and total flap loss between time blocks. Patients were not more likely to require intraoperative revision or experience total flap loss in earlier time blocks (all comparisons $p > 0.05$).

Discussion

Loupes-only microsurgery challenges the paradigm that free flap surgery requires an operating microscope. Here, we have shown that loupes-only microsurgery results in rates of intraoperative anastomotic revision (2.2% for arterial revision and 2.2% for venous revision) and total flap loss rate (1.2%) that are within the acceptable, published range for free flap breast reconstruction.[4–7] Importantly, the technique appears to be easily adoptable, as no "learning curve" was seen in one surgeon who transitioned to loupes-only microsurgery while in independent practice. Unfortunately, this trend could only be examined in one surgeon, and thus the presence of a "learning curve" among all surgeons who adopt this technique remains unknown.

Loupes-only microsurgery is appealing on multiple levels, and theoretic advantages can be discussed at the patient, institution, and access levels. To provide a well-rounded argument, we also discuss disadvantages inherent to loupes-only microsurgery, including ergonomics and magnification.

Patient-Level Advantages

The operating microscope has a fixed viewing angle. Real-time adjustment of this angle necessitates repositioning of the microscope, which invariably stalls the operative procedure. As arterial sutures are placed, the vessel must be manipulated and turned to visualize the stitch within the

Table 2 Intraoperative details stratified by side

Characteristic	Ipsilateral (N = 1,096)	Contralateral (N = 598)
Reconstructive timing		
Immediate	76.4% (837)	85.5% (511)
Delayed	22.9% (251)	13.9% (83)
Not recorded	0.7% (8)	0.7% (4)
Mastectomy type		
Simple	31.7% (347)	50.8% (304)
Modified radical	21.6% (237)	1.5% (9)
Skin sparing simple	20.8% (228)	32.4% (194)
Skin sparing modified radical	8.6% (94)	0.5% (3)
Nipple sparing	0.6% (7)	10.9% (65)
Unknown	2.1% (21)	3.9% (23)
Reconstruction type		
ms-TRAM	69.8% (765)	72.1% (431)
DIEP	27.2% (298)	26.9% (155)
SIEA	3.0% (33)	2.0% (12)
Recipient artery and vein		
Internal mammary	70.4% (771)	73.9% (442)
Thoracodorsal	19.7% (216)	14.9% (89)
Other	0.3% (3)	0.3% (2)
Not recorded	9.7% (106)	10.9% (65)
Arterial anastomosis		
End-to-end	90.0% (985)	89.0% (532)
End-to-side	0.3% (3)	0.2% (1)
Not recorded	9.9% (108)	10.9% (65)
Venous anastomosis		
End-to-end	90.1% (987)	89.0% (532)
End-to-side	0.1% (1)	0.2% (1)
Not recorded	9.9% (108)	10.9% (65)

Abbreviations: DIEP, deep inferior epigastric perforator; ms-TRAM, muscle-sparing transverse rectus abdominis myocutaneous; SIEA, superficial inferior epigastric artery flaps.

lumen. In contrast, loupes are affixed to the surgeon's head and the viewing angle can be adjusted in real time. A change in head position can allow direct visualization of the lumen with decreased need to manipulate the vessel. This change can be made in real time as the stitch is placed and operative flow is not interrupted. Decreased vessel manipulation and decreased vascular trauma have been suggested as factors that contribute to improved anastomotic patency.[20–22]

Loupes-only anastomoses during free flap breast reconstructions are typically performed with the surgeon and assistant on the same side of the operating table. This allows the reconstructive team to perform recipient vessel exposure and free flap vascular anastomoses during the contralateral mastectomy. One author (L. C. W.) will occasionally have a flap reperfused on the ipsilateral internal mammary vessels before the contralateral mastectomy is completed. This ability to work simultaneously with the resecting surgeons can save time in the operating room.

Institutional-Level Advantages

Nonreliance on the microscope allows a plastic surgery group to have multiple free flap breast reconstruction rooms running simultaneously. At our institution, it is not uncommon to have three free flap breast reconstruction rooms running at the same time. Loupes-only microsurgery avoids the bottleneck that would invariably occur if surgeons were required to share a microscope, and eliminates the need for an institution to purchase multiple operating microscopes to avoid this bottleneck.

Although a less important contributor to cost-savings, the cost of the operating microscope drape, as well as time saved by not draping the operating microscope, also deserve

Table 3 Rates of anastomotic revision and total flap loss stratified by side

	Ipsilateral ($N = 1,063$)	Contralateral ($N = 586$)
Anastomotic revision		
Arterial	2.5% (27)	1.5% (9)
Venous	2.5% (26)	1.9% (11)
Any microvascular revision	3.9% (41)	2.9% (17)
Total flap loss	1.2% (13)	1.2% (7)

mention. This improved efficiency of operating room resources can theoretically shorten operating room times.[23]

Access

The operating microscope is heavy and expensive. Loupes are (relatively) inexpensive and portable. Loupes-only microsurgery allows microsurgical reconstruction to be performed outside of the bounds of the traditional academic medical center, including community hospitals or resource-poor environments.[9] Free-flap breast reconstruction is commonly performed within our hospital system at locations, where an operating microscope is not immediately available. Loupes' portability also theoretically permits microsurgical reconstruction during medical missions or in resource-poor environments.[13] However, an evaluation of that environment's ability to provide postoperative care would be necessary before undertaking such an endeavor. Of note, we have not performed loupes-only free flaps during medical mission work.

Ergonomics and Occupational Health

Microsurgeons are prone to cervical spine problems. Published survey data has demonstrated that 24% of plastic surgeons and 28% of hand surgeons complain of cervical disc or root pain.[24] Poor posture, incorrect table height, bad lighting, and the "peculiar, nonergonomic positions for plastic surgeons requiring hyperflexion and twisting of the neck" have been implicated as causal factors.[24–26] Use of both surgical loupes and a headlight, with which the surgeon is constantly trying to optimize both focal length and beam position, can be particularly damaging.[25] Case series of plastic surgeons with cervical disc disease requiring corpectomy and titanium cage fixation have been published.[26]

As loupes increase in magnification past ×2.5 a prismatic, as opposed to compound, lens design is needed. This increases weight by 30 to 40%, and the surgical telescope length is also increased.[23,27] The combination of more weighty loupes and a longer rotation arm can substantially increase the weight transferred to the nasal dorsum. Prolonged and repeated loupe wear on the uninitiated nose can cause pressure ulcers with superficial ulcerations. This phenomenon, which has been experienced by many new microsurgery fellows at our institution, typically resolves within 2 months (Christopher Pannucci, MD, personal experience; Christopher Bibbo, MD, personal oral communication).

The operating microscope has improved ergonomics when compared with surgical loupes. The microscope forces surgeons to sit up and allows them to perform anastomoses with the head in neutral position. Surgical loupes narrow the field of view, and neck movement, not extraocular movement, becomes the primary mechanism for field adjustment.[27,28] When compared with thyroid surgery using surgical loupes, use of the operating microscope significantly increases

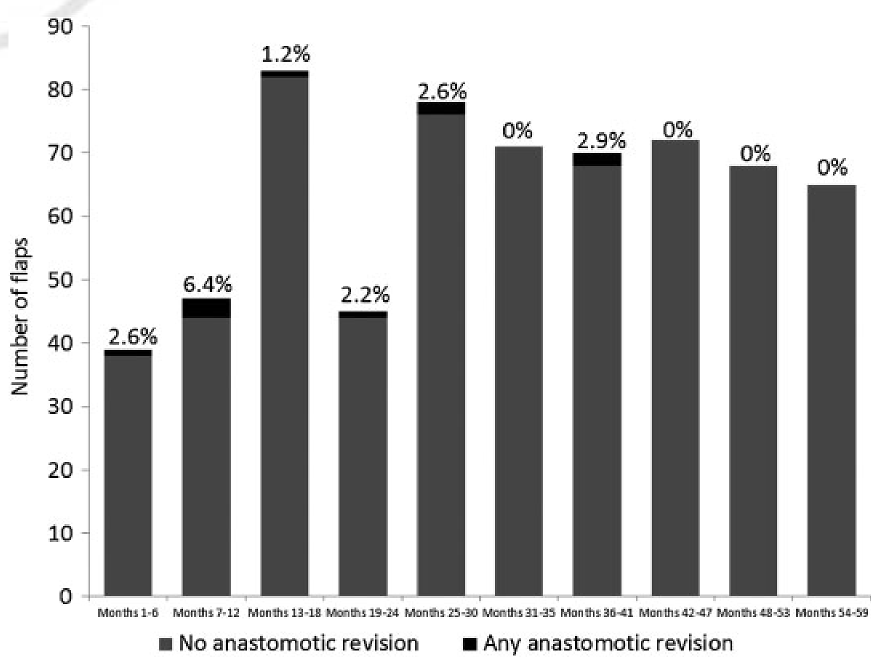

Fig. 1 Rates of any intraoperative anastomotic revision over time. Percentages represent the total anastomotic revision rate during the specified time block.

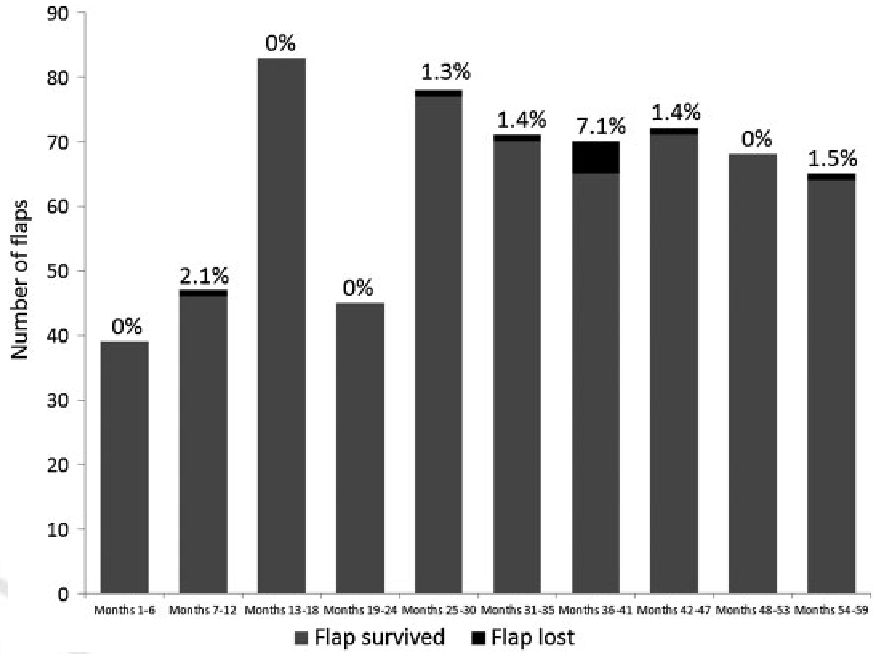

Fig. 2 Rates of total flap loss over time. Percentages represent the total flap loss rate during the specified time block.

operating time by 20%.[28] Surgical loupes are a necessity for flap elevation and recipient vessel selection.

Although microvascular anastomoses can be performed using surgical loupes or the operating microscope, it is worth noting that the majority of a free flap surgery is performed using surgical loupes. Use of the operating microscope may spare the surgeon approximately 60 minutes of loupe wear during a unilateral free flap breast reconstruction, or approximately 120 minutes of loupe wear during a bilateral case.

Degree of Magnification

The operating microscope has substantially better magnification ($\times$6–40) than surgical loupes. The standard surgical loupe used for this study was $\times$3.5 magnification, although loupes up to $\times$8 magnification are available. Increased magnification comes at the expense of shorter depth of field and smaller field of view. Loupes with increased magnification have a corresponding increase in weight; this is not true for the operating microscope.[23] Studies have shown that vascular anastomoses performed by novice microsurgeons in a basic skills laboratory are of higher quality when an operating microscope is used, compared with $\times$2.5 loupes. However, only 75 to 80% of anastomoses performed on 1.5 mm vessels using the microscope were patent; this underscores the experience level of the study groups.[29,30] For anastomoses $>$ 2.5 mm, anastomosis quality, measured by the Gorman scale,[31] was not significantly different for $\times$2.5 loupes versus the operating microscope.[29] Our study, which tracked revision and failure rates of experienced microsurgeons in 1,649 consecutive free flaps using $\times$3.5 loupe magnification, seems to refute the laboratory data.

Limitations

This study's generalizability is limited by the cases we chose to include. We examined flap loss rates among a selected population of free-flap breast reconstructions. All flaps were based on the deep inferior epigastric vessels and were anastomosed to either the thoracodorsal or internal mammary system. These vessels are typically larger than 2.0 mm. We explicitly excluded SIEA flaps as the artery is routinely smaller than 1.5 mm.[14,15] Other studies[10,32] have reported on loupe use for replantation or toe to thumb transfer with success rates over 79%. We do not report experience with loupes-only microsurgery for hand surgery. Loupes-only microsurgery may be inappropriate for vessels $<$ 1.5 mm, for distal replantations, for supermicrosurgery, or in pediatric patients.[9,10,13,23,33] Major nerve repairs may benefit from use of the operating microscope, as its superior magnification can assist with precise alignment. Additionally, the consequences of poorly performed nerve coaptations are often not known for weeks or months, when revision surgery becomes substantially more difficult.[13] Of note, there are no studies that examine the feasibility of loupes-only microsurgery for these type of small-vessel anastomoses or coaptations. Based on our data, we can confidently say that loupes-only microsurgery is a safe and effective way to perform deep inferior epigastric vessel-based free flaps for breast reconstruction. Finally, we were able to perform a "learning curve" analysis for one surgeon only in this study. Although rates of intraoperative revision and total flap loss did not vary over time, this analysis does not necessarily reflect trends that would be seen in a population of surgeons adopting this technique, instead of a single surgeon. This represents an important direction for future research.

Conclusions

For free flap breast reconstruction based on the deep inferior epigastric vessels, loupes-only microsurgery is safe and effective. In this series of 1,649 consecutive free flap breast reconstructions, the overall rate of intraoperative anastomotic revision was 3.5% and the rate of total flap loss was 1.2%. For one surgeon, there did not appear to be a "learning curve" with this technique, as rates of any intraoperative revision and total flap loss were similar over the first 60 months after loupes-only microsurgery was adopted. This finding is not necessarily generalizable to the overall population of surgeons adopting this technique, and warrants further investigation.

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