TITLE:

Clinical Application and Outcomes of Reconstructive Microsurgery in Africa: A Systematic Review and Meta-analysis

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Financial Disclosure Statement
The authors have no financial interest to declare in relation to the content of this article. No funding was received for this work.

Prior Presentation

None

Short Running Title:

Outcomes of Microsurgery in Africa

ABSTRACT

Background

Reconstructive microsurgical free flap techniques are often the treatment of choice for a variety of complex tissue defects across multiple surgical specialties. However, the practice is underdeveloped in low and middle-income countries. The aim of this systematic review was to evaluate the clinical application and outcomes of reconstructive microsurgery performed in Africa.

Methods

Seven databases (PubMed, Web of Science, MEDLINE, CINAHL, Academic Search Complete, Embase and Google Scholar) were searched for studies reporting microsurgical procedures performed in Africa. Risk of bias was assessed using the Joanna Briggs Institute Critical Appraisal Tools and quality of evidence using the GRADE approach. Meta-analysis was performed using a random effects model to estimate the pooled proportion of events with 95% confidence intervals. The primary outcome was free flap success rate, and the secondary outcomes were the complication and flap salvage rates.

Results

Ninety-two studies were included in the narrative synthesis and nine in the pooled meta-analysis. In total 1,376 free flaps in 1,327 patients from 1976 to 2020 were analyzed. Head and neck oncologic reconstruction made up 30% of cases while breast reconstruction comprised 2%. The pooled flap survival rate was 89% (95% CI: 0.84, 0.93), complication rate 51% (95% CI: 0.36, 0.65) and free flap salvage rate was 45% (95% CI: 0.08, 0.84).

Conclusion

This meta-analysis showed that the free flap success rates in Africa are high and comparable to those reported in high-income countries. However, the comparatively higher complication rate and lower salvage rate suggest need for improved perioperative care.

Review Registration

Registered with the International Prospective Register of Systematic Reviews (PROSPERO) on 25th September 2020, ID: CRD42020192344.

KEY WORDS

Free flap survival; Free flap surgery; Microsurgery; Africa; Low middle income country; Complications; Free flap success; Outcomes; Global Surgery; Free tissue transfer

INTRODUCTION

Microsurgical techniques have revolutionized reconstructive surgery and form an essential component of the modern reconstructive surgeons' armamentarium. At present, reconstructive microsurgery services are poorly developed in low and middle-income countries (LMIC), particularly in Africa despite the high burden of several endemic complex conditions that may require microsurgical intervention including cancer, road traffic injuries, noma, lymphedema and post burn scarring and contracture, with children and young adults worst affected.[1–3]

A few local and visiting surgeons have reported performing free tissue transfers often using surgical loupes and basic microsurgical instruments in local hospitals amidst significant staff and resource challenges.[4–13] This approach, coupled with the perceived poor outcomes in Africa has raised pertinent ethical questions about the efficacy and safety of performing microsurgery in this setting.[12,14,15] In turn, some teams and charities have opted to transport patients abroad, at great expense, to undergo microsurgical reconstruction in high-income countries (HIC), following which they are returned to Africa.[12,14–18]

This systematic review aimed to summarize the evidence on the application and outcomes of microsurgery performed in Africa. Recently, substantial progress has been made in addressing the surgical workforce deficit in Africa through enhanced regional and international collaborative efforts in surgical training.[19–21] Accompanying this growth has been the need for locally derived evidence to understand and overcome the challenges of clinical practice on the continent. This review focused exclusively on patients treated in Africa because there is a paucity of literature comprehensively assessing the practice, safety and outcomes of this approach in the unique African setting.[13] While the results of successful microsurgical reconstruction are transformative, complications such as free flap failure can have devastating consequences on patient health, leaving them with the original defect that required reconstruction, loss of healthy donor tissue, and potential additional donor site morbidity. We therefore aimed to evaluate both the evolution of microsurgical practice over time, and the resulting outcomes.

METHOD

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[22] PRISMA and Meta-analyses Of Observational Studies in Epidemiology (MOOSE)[23] Checklists are included in *Appendix 1 and 2*.

Eligibility Criteria

We included English language studies describing patients who had reconstructive microsurgery and perioperative care relating to the procedure in Africa. Procedures not including microvascular reconstruction such as neurosurgical dissections were excluded. Non-vascularized nerve repairs were excluded as clinical outcomes are difficult to measure. Study designs included original research articles, technical reports, case series and case reports. Conference abstracts, reviews, meta-analyses, and letters were excluded.

Outcome Measures

The primary outcome measurement was free flap success rate (free flap survival rate). Secondary outcomes were the complication rate and the free flap salvage rate (following flap compromise[24]). Complications were further classified as major; requiring return to theater or further invasive treatment, and minor; not requiring any invasive treatment.

Search Methods for Identification of Studies

A systematic search was conducted independently by two reviewers using PubMed, Web of Science, MEDLINE, CINAHL, Academic Search Complete and Embase. Secondary searches were performed using Google Scholar. The search strategy included combining MeSH terms and free text words relating to microsurgery with free text words relating to Africa and the respective countries. The full search strategy is available in *Appendix 3*.

Mendeley was used to screen for duplicates, after which two reviewers (C.H.B and G.O) independently screened the titles and abstracts for relevance using Rayyan[25]. The remaining articles underwent full-text reading by two independent reviewers (C.H.B and G.O) for eligibility with a third reviewer (C.M.M) responsible for resolving conflicting decisions. In cases where essential data was missing, the study authors were contacted, and additional data obtained.

Quality Assessment

Risk of bias and quality of evidence assessments were performed independently by two reviewers (C.H.B and D.T.G) with a third reviewer (E.M) resolving disagreements. Risk of bias in individual studies was assessed using the Joanna Briggs Institute Critical Appraisal Tools for Systematic Reviews. Quality of evidence was evaluated using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach with respect to reporting the outcome – Complication Rate.[26]

Data Extraction

Data extraction was performed independently by two reviewers (C.H.B and D.T.G) with a third reviewer (C.M.M) presiding over disagreements.

Data Synthesis and Statistical Analysis

A qualitative synthesis of patient characteristics, indications, surgical techniques and postoperative follow-up was used to evaluate clinical application. Pearson Chi-square and goodness-of-fit tests were performed to examine the relationship between patients, surgeons and the procedures performed.

Meta-analysis was performed using a random effects model to estimate the pooled proportion of the outcomes with 95% confidence intervals. Sensitivity analysis was conducted to evaluate the influence of including high risk-of-bias studies in the pooled meta-analysis.[27] Heterogeneity was assessed using the I^2 statistic and Cochran's Q test. Heterogeneity was considered low if I^2 was 0%-50%, moderate 50%-75% and high 75%-100%. Statistically significant heterogeneity was defined as $I^2 > 50\%$ or Cochran's Q test $p < 0.05$.[28,29] Binary logistic regression analysis was then performed to evaluate the association between the type of free flaps performed and free flap success.

Analyses were performed using SPSS 26 (IBM Corp. Released 2019. Armonk, NY) and STATA v16 (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC). Statistical significance was defined as $p < 0.05$.

RESULTS

Study Selection and Quality Appraisal

A total of 5,125 articles were identified from the database search. The study selection is summarized in Figure 1 and the reasons for study exclusion in *Appendix 4*. Ninety-two studies met the inclusion criteria and were included in this systematic review (*Appendix 5*). The risk of bias in individual studies and quality of evidence assessment are summarized in *Appendix 6 and 7*. Most of the studies included were case series (77.2%) with only 15 (21.1%) reporting complete inclusion of patients and 21 (29.6%) reporting consecutive patients all together indicating a general deficiency in inclusion completeness, low reliability and possible selection bias. Postoperative clinical follow-up was inadequately reported in 31 (43.7%) case series and 8 (47.1%) case reports introducing further bias. As a result, most of the case reports and case series retained their Low-GRADE or were downgraded to Very Low. One cohort study and 5 case series were upgraded from Low to Moderate and one case series (Citron, 2016) upgraded from Low to High for large effects and adequately reporting confounding factors.[30] One randomized controlled trial (Bassiouny, 2005), had unclear study design, follow-up, and data analysis reporting and was downgraded from High to Moderate due to indirectness of evidence.[31] Therefore, the overall evaluation of quality of evidence resulted in 2 studies graded as High, 7 Moderate, 42 Low and 36 Very Low with 5 studies being borderline Low to Moderate.

Sensitivity analysis comparing the pooled flap success rate of all studies against only Moderate and High-GRADE studies showed a substantially different estimate of effect and study heterogeneity (*Appendix 16*). This suggested possible publication bias with most of the observational studies and case reports predominately reporting successful free flap outcomes. Therefore, we excluded the high risk-of-bias studies from the quantitative meta-analysis of outcomes and included only the Moderate and High-GRADE studies.[27] Assessment of publication bias with statistical analysis of funnel plot asymmetry was not appropriate due to the low number of studies included in the final meta-analysis.

Patient Characteristics

A total of 1,367 flaps in 1,327 patients were reviewed in studies published between 1976-2020 (Figure 2). The patient age ranged from 1 year 2 months to 83 years and the follow-up duration ranged from 2 months to 10 years. The number of microsurgical procedures tripled in the last 10 years of the period studied with 1,000 flaps (73.2%) reported from 2010-2020 (*Appendix 8)*.

Surgeon Characteristics

Local surgeons performed 91.4% of the cases, visiting surgeons 7.8% and 0.9% did not report the lead surgeon. The proportion of cases performed by visiting surgeons was significantly higher ($p < 0.001$) in sub-Saharan Africa 18.3% compared to North Africa 0%. There was no significant difference in the proportion of cases performed by local surgeons compared to visiting surgeons in 2010-2020 compared to 1976-2009 ($p = 0.644$).

Indications

Head and neck tumors 405 (29.6%) and lower limb trauma 206 (15.1%) were the most common indications (Table 1, *Appendix 9-11*). Noma accounted for 90.4% of the procedures performed by visiting surgeons. In contrast, local surgeons operated on a more diverse spectrum of defects. There was a significant increase in other less common indications such as lymphedema and facial paralysis in 2010-2020 compared to 1976-2009 ($p < 0.001$). However, breast and upper limb trauma reconstruction declined.

Procedures Performed

Free fibulas (26.4%), anterolateral thigh (ALT) (16.0%) and radial forearm free flaps (RFFF) (14.6%) were the leading flaps performed (Table 2, *Appendix 12-14*). RFFF was utilized more frequently in sub-Sahara and by visiting surgeons, with loupes used for most procedures. Surgeons in North Africa recorded a higher proportion of free gracilis and free jejunum procedures compared to sub-Sahara. Parascapular flaps were the leading flap performed by visiting surgeons accounting for 41.1% of the total cases performed by visiting surgeons.

Magnification method was recorded in 25 studies including 637 (46.6%) of the total procedures. Loupes were used in 51.2% of the cases and the operating microscope in 48.8%. A significantly higher ($p < 0.001$) proportion of visiting surgeons (67.3%) used the microscope compared to local surgeons (44.2%) who reported more cases using loupes (55.8%). Utilization of loupes was significantly higher in sub-Sahara (60.1%) compared to North Africa where the microscope was used instead in 78.4% of cases ($p < 0.001$). However, there was no significant change ($p = 0.108$) in magnification method over time with a near even usage of both methods.

Outcomes of Microsurgery

Nine studies with Moderate and High-GRADE accounting for 529 (38.7%) of the total procedures in the study met the criteria for inclusion in the meta-analysis (Table 3).[1,30–37] Patient age ranged from 2 to 83 years and the follow-up period ranged from 3 to 104 months.

The pooled free flap success rate was 89% (95% CI: 0.84, 0.93) (Figure 3) with moderate heterogeneity ($I^2 = 52.21\%$, $p = 0.03$). Sub-group analysis showed no statistically significant difference in free flap success rates in sub-Sahara compared to North Africa ($p = 0.41$) and between loupes and microscopes ($p = 0.38$). Free flap success remained consistent at 89% for the period before and after 2010 ($p = 0.97$). Only one study (Citron, 2016) reported free flap survival of cases performed by visiting surgeons therefore, there was insufficient data for detailed analysis of this group.[30]

Binary logistic regression showed that the type of flap was not significantly associated with free flap success, Wald Test (8) = 5.000 ($p = 0.66$) (*Appendix 17*). The recipient site of the failed flaps was reported in only 50 (9.4%) cases and the reason for failure in 22 (4.2%). The head and neck region 30 (60%) was the most common recipient site for failed flaps followed by the lower limb 14 (28%). The most frequent reported reasons for flap failure were venous thrombosis 9 (40.9%) and arterial thrombosis 7 (31.8%).

Return to the operating room for flap salvage was attempted in 6% (95% CI: 0.04, 0.09) of the total flaps performed (*Appendix 18*). The pooled free flap salvage rate was 45% (95% CI: 0.08, 0.84) with moderate heterogeneity (I^2 = 67.88%, p = 0.03). There was insufficient data reported on the types of flaps salvaged and the timing of the salvage procedures for further detailed analysis.

The pooled total complication rate was 51% (95% CI: 0.36, 0.65) with high heterogeneity (I^2 = 90.08%, p = 0.00) (Figure 4). Major complications accounted for 38.9% and minor complications 61.1%. The pooled complication rate excluding free flap total and partial loss was 37% (95% CI: 0.25, 0.49). Subgroup analysis showed no significant difference in the complication rates by region (p = 0.20), time period (p = 0.24), and magnification method (p = 0.05).

DISCUSSION

Summary of Evidence

This systematic review and meta-analysis of 92 studies evaluated the clinical practice and outcomes of microsurgery performed in Africa over a 44-year period from 1976-2020. The study found that microsurgery is increasingly being utilized for a broad variety of defects in the African setting. Meta-analysis revealed a pooled free flap success rate of 89%, complication rate of 51% and a flap salvage rate of 45%. To the best of our knowledge, our study is the first large scale systematic review and meta-analysis investigating microsurgery outcomes in a low resource setting. We used mixed methods synthesis resulting in the study having two main components, a qualitative evaluation of microsurgery practice and a quantitative meta-analysis of outcomes. These two complimentary aspects are essential for wholistic understanding and interpretation of the study result in view of the vast inequality in clinical practice between HIC, from which most of the current literature is derived, and LMIC, in which the overwhelming majority of the global population live.

Evolution of Microsurgery Practice

Our study showed that surgeons in Africa were among the pioneers of the microsurgery revolution, reporting some of the earliest procedures such as toe-to-hand transfers by Chait in the 1970s.[38] However, the practice declined and only remerged in the early 2000s with the advent of loupes-only microsurgery and the availability of affordable operating microscopes.[39] In the last 10 years of the period studied, we found an exponential increase in both the number of free flaps performed and the diversity of indications, spurred by emerging local teams across more countries such as Kenya and Uganda (*Appendix 8*). While this can partly be attributed to the general global rising trends in microsurgery, we believe the primary reason behind the rising success is the equally parallel exponential growth in the number of trained surgeons on the continent.[19,20,40–42] This growth trend in microsurgery practice is likely to continue as global surgery targets are attained and the standards of healthcare on the continent continue to improve.

Patient Selection

Head and neck pathology was the leading indication with the case mix highlighting the key differences in both disease burden and surgical priority in comparison to HIC. While the higher proportion of noma, post burn reconstruction and chronic osteomyelitis all of which are endemic to Africa was expected, breast reconstruction accounted for a disproportionately low number of cases. Breast cancer is the most common invasive cancer in women worldwide and second most common cancer in women in Africa.[43] Improved quality of life and psychosocial benefits have made breast reconstruction an integral component of breast cancer management.[44] However, breast reconstruction accounted for only 1.9% (25 TRAM, 1 DIEP) of the 1,367 free flaps. In contrast, breast reconstruction was the leading indication for free tissue transfer in the United Kingdom from 2015-2019 accounting for 50.1% of all free flaps performed, with DIEP flaps utilized in over 77% of the cases.[45] Whilst non-microsurgical breast reconstruction may partially account for this disparity, this result more likely reflects deficiencies in the overall breast cancer care in Africa.[43,46]

Surgical Technique

The flaps utilized from 2010-2020 were similar to that of HIC with the workhorse flaps; free fibular, ALT and RFFF being the most common donor flaps used.[45] A notable exception was the lower usage of the DIEP. There was an overall even split in the usage of operating microscopes and loupes with loupe usage significantly higher in sub-Sahara. This preference is not unique to sub-Saharan Africa, with several units worldwide also widely utilizing loupes-only microsurgery.[47–49] However, the primary reason for their wide-spread use in LMIC is the low cost and low maintenance required.[50–52] In contrast, visiting surgeons from HIC and those in well-established tertiary centers in Egypt showed significantly higher preference for the microscope. We found no statistically significant difference in free flap success and complication rates between the two magnification methods in agreement with several previous studies that have also shown equivalent outcomes.[48,49] However, modern operating microscopes offer the advantages of improved lighting, superior magnification and video-photography, combined with the increasingly advanced fluoroscopic imaging and augmented reality features making them more suitable for some applications such as supermicrosurgery.[39] This wider repertoire of applications was demonstrated in our study with the microscope being used for a broader variety of procedures such as finger replantations.

Short-term Surgical Missions

The study revealed the important role played by visiting surgeons in addressing the reconstructive surgery burden particularly in sub-Saharan Africa. We found that the same team would often visit the same site repeatedly and perhaps more importantly, unlike the microsurgical services offered by local surgeons, nearly all of which were performed in major cities, visiting teams concentrated their work in much smaller and much poorer rural areas such as in Sokoto, Nigeria (Noma Children's hospital) and in Malindi, Kenya (Tawfik Hospital and Malindi District Hospital), all of which are located over 700km away from the commercial capital.[5,11,53–61] The study also revealed significant differences in patient selection and flaps performed by visiting surgeons compared to local teams. Noma reconstruction was the primary focus of surgical missions with visiting surgeons performing 94.3% of all noma microsurgical reconstruction in the entire period studied from 1976-2020. Infamously referred to as the 'face of poverty'[62], the characteristic mixed extensive bone and soft-tissue defects encompassed by scarring and contracture make noma microsurgery exceptionally technically challenging, let alone when performed in a resource limited setting.[18,59,62] In addition, extensive preoperative planning, biomaterials, perioperative care and postoperative rehabilitation are often also required. Giessler et al and Rodgers et al reported using a variety of sequential chimeric osteofasciocutaneous and folded free flaps in Ethiopia and Nigeria with relatively modest aesthetic and functional results.[4,5,53,54] This approach has placed microsurgical noma reconstruction at the heart of the debate on the ethics of short-term reconstructive surgical missions in LMIC.[14,15] In reality, many patients in rural sub-Saharan Africa simply cannot afford to make the long trip to the city to receive treatment. Without the supporting care of visiting missions, such patients may have to endure a lifetime of disability, disfigurement, and ostracization. Additionally, the broader infrastructure support and training of local surgical staff by visiting teams also benefits LMIC health systems.[63]

Microsurgery Outcomes

Interestingly, the overall free flap success rate of 89% (95% CI: 0.84, 0.93) found in this study was equivalent to the 85%-100% range reported in HIC.[24,64–67] The relatively lower success rate of 76.3% reported by Citron et al in Uganda was attributed to learning curve by the authors of that study who further showed the flap success rate rising to 93%-95% in the final two years of their case series, consistent with the other results in our study (*Appendix 18*).[30]

In contrast, the complication rate of 51% (95% CI: 0.36, 0.65) was higher than the reported 18%-50% in HIC.[24,64,65] The high heterogeneity ($I^2 = 90.08\%$) could partly be attributed to a possible outlier study by Ghoneimy et al that reported a 95% total complication rate.[35] In contrast to the other studies, the majority of the complications reported in this study were long-term complications such as nonunion due to inadequate fixation, limb length inequalities and long-term fractures that occurred several months to years following microsurgical reconstruction in an oncologic setting.[35] The pooled complication rate with exclusion of this study was 44% (*Appendix 18*).

In a recent systematic review of 44,031 flaps by Shen et al, 5.8% of free flaps required return to the operating theater for salvage with a flap salvage rate of 64.1%.[68] Similarly, a recent meta-analysis by Newton et al showed attempted salvage in 6.55% of flaps with a pooled salvage rate of 50% (95% CI: 0, 0.89) when clinical flap monitoring was used.[69] Though an equivalent 6% (95% CI: 0.04, 0.09) of flaps were returned to theater for attempted salvage in our study, the comparatively lower pooled free flap salvage rate of 45% (95% CI: 0.08, 0.84) was in agreement with previous studies that have identified perioperative care and monitoring as the major challenges of microsurgery in Africa.[1,13,70] Early detection of microvascular flap compromise and timely return to theater for surgical intervention are critical to improve flap salvage rates.[69,71,72] This requires constant flap monitoring, especially in the first few days after free tissue transfer. However, shortages of trained support staff including nurses and anesthetists in LMIC impede early detection of flap compromise, and even after compromise is detected, further delays in the assembly of the operating team adversely impact the overall results of salvage procedures.[13,51,73]

Unfortunately, inadequate reporting of factors relating to flap failure and complications prevented detailed analysis in this study. Nevertheless, the binary logistic regression result showing no association between the different free flaps, each with their own technical perils and free flap success suggests more systematic causes for flap failure that warrant further study. However, the equivalent outcomes in North and sub-Saharan Africa regions in the subgroup analyses suggest the challenges faced may be similar and support the robustness of this study result applied across the continent and LMIC in general.

Limitations and Future Implications

This study has several limitations. First, the study largely included observational studies of single-surgeon or single-center experiences with small sample sizes and high likelihood of inherent bias associated with such study designs. To mitigate this, we performed sensitivity analysis and excluded high risk of bias studies from the quantitative analyses of outcomes. Secondly, we did not place a time limit on the reporting of postoperative outcomes. While this may be clinically useful in informing the overall intermediate to long term outcomes, it resulted in significant heterogeneity in reported complications. Furthermore, differences in the definition and reporting of partial flap loss across studies may have also contributed to the increased study heterogeneity and precluded detailed analysis. In practice, free flap outcomes are not restricted only to the extremes of success or failure but span a continuous range of possible outcomes between. Lastly, patient co-morbidity was not assessed in this study. Several patient factors such as cancer staging, concomitant HIV infection and malnutrition that could potentially impact the outcomes of microsurgery in Africa were not considered. These limitations highlight the pressing need for well-designed multicenter prospective longitudinal studies addressing reconstructive microsurgery outcomes in LMIC. Future studies should focus on evaluating the specific factors associated with outcomes such as patient co-morbidity, the causes and timing of flap failure, patient-reported outcomes, and cost-benefit analysis. Creation of local, national and regional prospective free flap registries is recommended.

Conclusion

Microsurgery is increasingly being used in Africa. The free flap success rates in Africa are high and comparable to high income countries. However, the comparatively higher complication rate and lower free flap salvage rate suggests a need for improved perioperative care.

ACKNOWLEDGEMENTS

We would like to sincerely thank Mrs. Kiku Shinano for the general administrative support offered, Dr. Gowsika Yogeswaran for assisting with the database search, Mrs. Anne Zeidan for assistance contacting study authors and Dr. Andrea Venn for guidance with data analysis.

REGISTRATION AND PROTOCOL

The study protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO), ID: CRD42020192344. The date of submission was 15th June 2020 and the date of registration in PROSPERO was 25th September 2020. The study protocol including all changes made and departure from the protocol are available from: https://www.crd.york.ac.uk/prospero

FINANCIAL DISCLOSURE STATEMENT

The authors have no financial interest to declare in relation to the content of this article. No funding was received for this work.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare

ETHICAL APPROVAL STATEMENT

Ethical approval: Not required

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FIGURE LEGENDS

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram showing the search results and selection of studies.

Figure 1

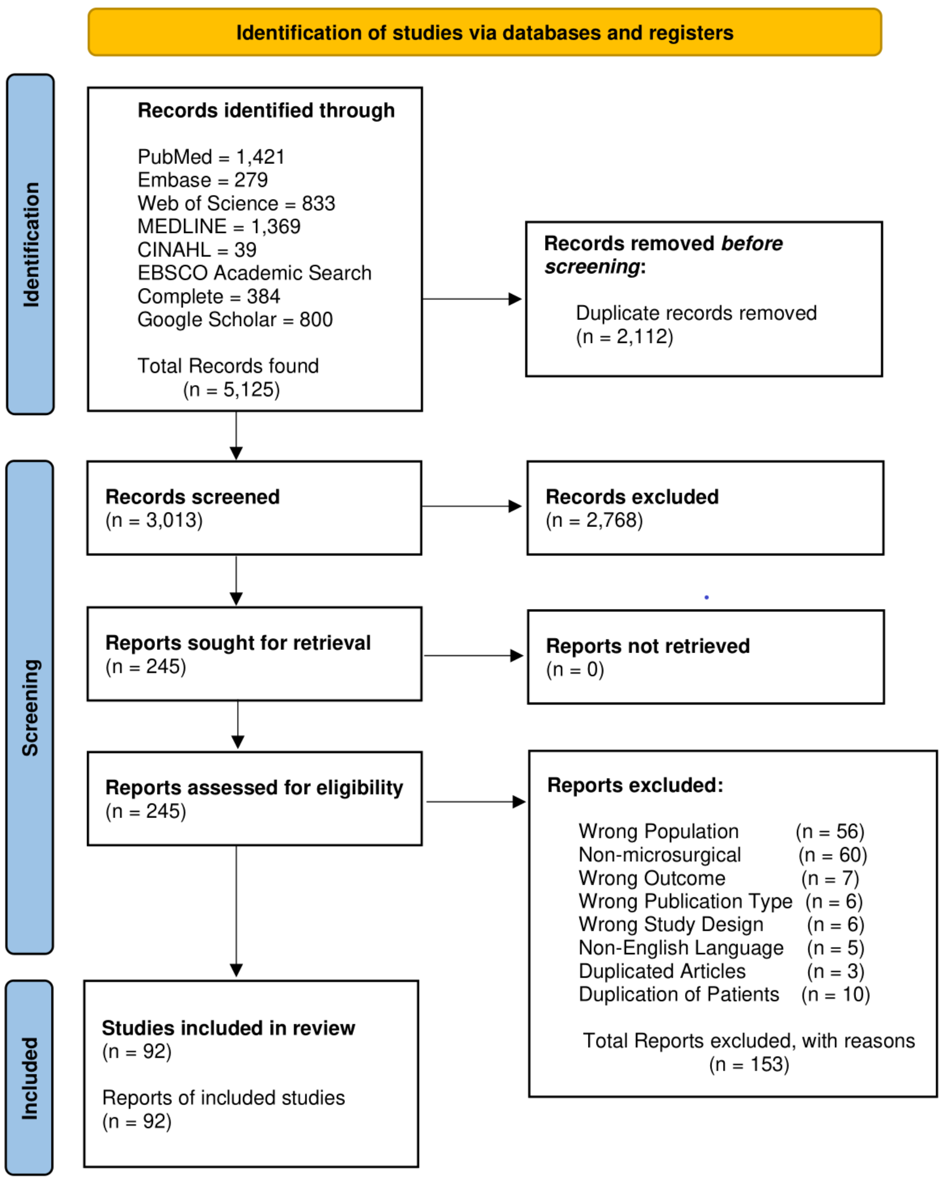

Figure 2: Patient Characteristics.

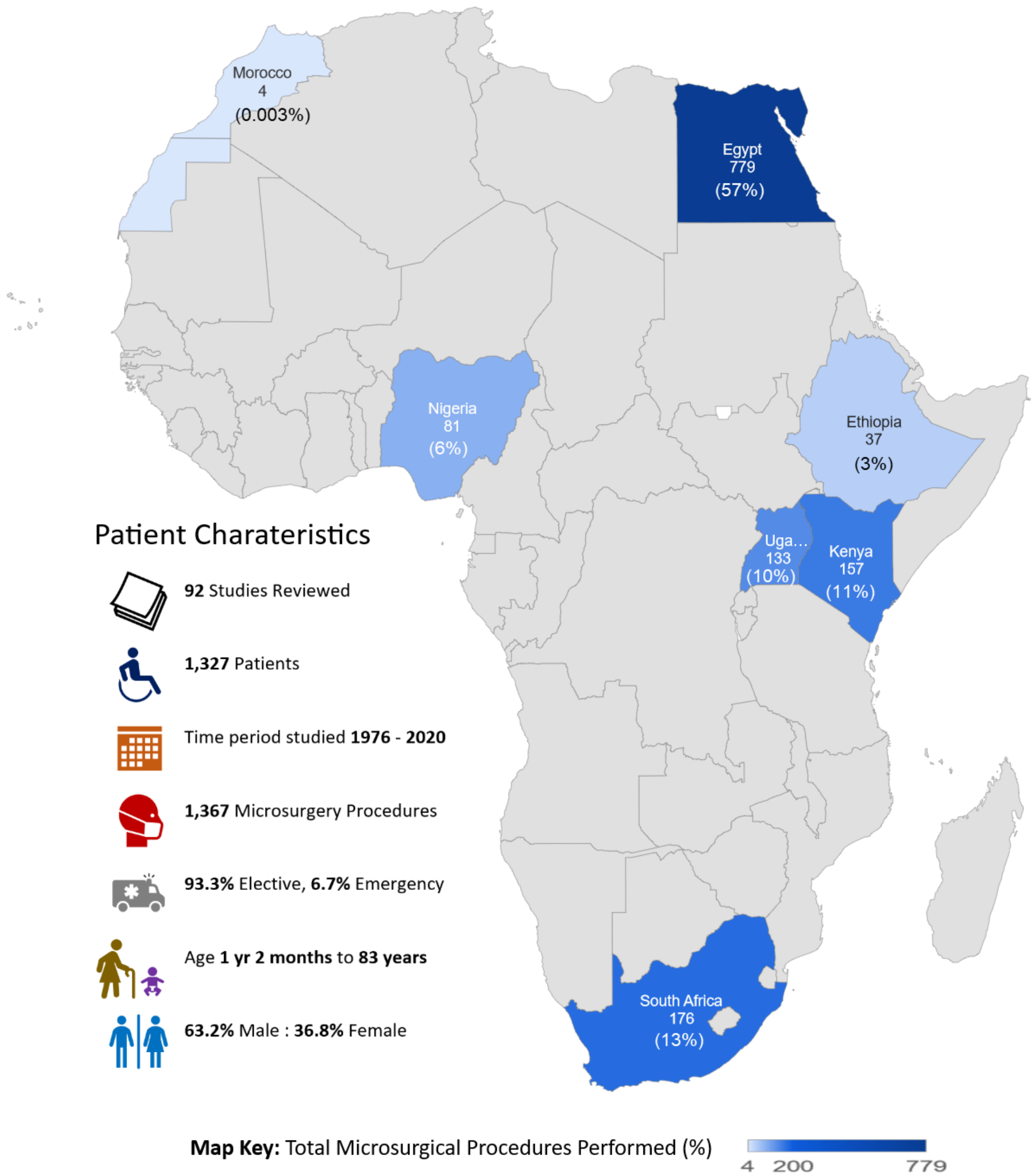

Figure 3: A. Pooled Free Flap Survival Rate, **B.** Subgroup Analysis of the Pooled Free Flap Success Rate by Region, Time Period, Method of magnification, **C.** Pooled Free Flap Salvage Rate.

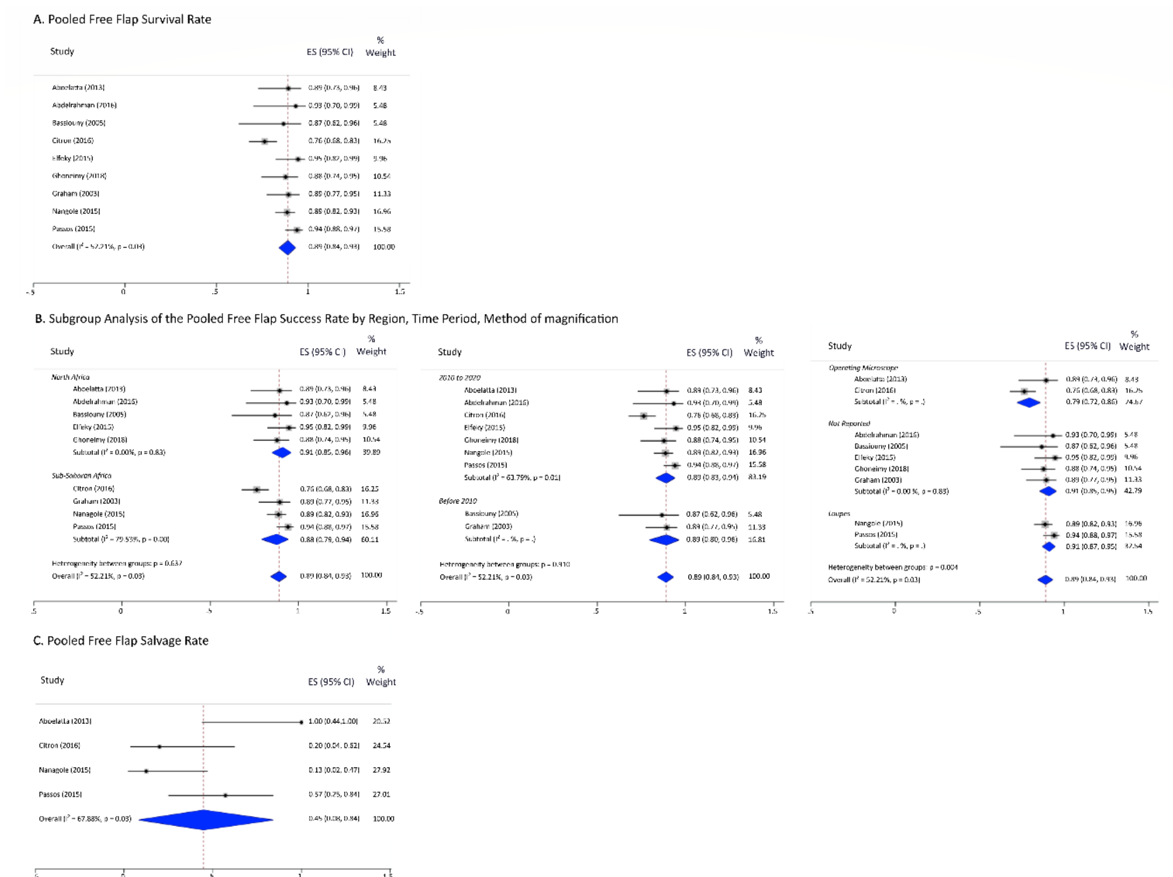

Figure 4: A. Pooled Total Complication Rate, **B.** Pooled Complication Rate excluding free flap complete and partial loss, **C.** Subgroup Analysis of the Complication Rate excluding free flap complete and partial loss by Region, Time Period and Method of magnification.

Table 1: Indications for reconstructive microsurgery in Africa (1976 to 2020) **A.** Indications for Microsurgery **B.** Subgroup Analysis of Indications for Microsurgery

Table 1: Indications for Reconstructive Microsurgery in Africa (1976 to 2020)

A. Indications for Microsurgery

Indications	**Number of Studies**	**Total Number of Procedures (%)**
Head and Neck Tumor	32	405 (29.6%)
Lower Limb Trauma	16	206 (15.1%)
Upper Limb Trauma	16	127 (9.3%)
Lower Limb Tumors	8	103 (7.5%)
Noma	6	70 (5.1%)
Post Burn Reconstruction	10	39 (2.9%)
Chronic Osteomyelitis	5	30 (2.2%)
Breast Reconstruction	3	26 (1.9%)
Head and Neck Trauma	8	20 (1.5%)
Others	47	341 (24.9%)

B. Subgroup Analysis of Indications for Microsurgery

	Post burn	**Noma**	**Head & neck tumor**	**Breast**	**Upper limb trauma**	**Lower limb trauma**	**Head & neck trauma**	**Lower Limb tumors**	**Chronic Osteomyelitis**	**Others**
Region										
Sub-Sahara	27 (4.6%)	70 (12.0%)	266 (45.5%)	0 (0%)	13 (2.2%)	6 (1.0%)	6 (1.0%)	1 (0.2%)	20 (3.4%)	175 (30.0%)
North Africa	12 (1.5%)	0 (0%)	139 (17.8%)	26 (3.3%)	114 (14.6%)	200 (25.5%)	14 (1.8%)	102 (13.0%)	10 (1.3%)	166 (21.2%)
Lead Surgeon										
Local Surgeons	22 (1.9%)	4 (0.3%)	354 (30.3%)	26 (2.2%)	127 (10.9%)	206 (17.6%)	20 (1.7%)	103 (8.8%)	12 (1.0%)	295 (25.2%)

Visiting Surgeons	3 (4.1%)	66 (90.4%)	1 (1.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (4.1%)
Time Period										
2010 to 2020	36 (3.6%)	36 (3.6%)	294 (29.4%)	0 (0%)	65 (6.5%)	171 (17.1%)	15 (1.5%)	54 (5.4%)	28 (2.8%)	301 (30.1%)
Before 2010	3 (0.8%)	34 (9.3%)	111 (30.2%)	26	62 (16.9%)	35 (9.5%)	5 (1.4%)	49 (13.4%)	2 (0.5%)	40 (10.9%)
Magnification										
Loupes	15 (4.6%)	34 (10.4%)	137 (42.0%)	0 (0%)	6 (1.8%)	18 (5.5%)	0 (0%)	4 (1.2%)	0 (0%)	112 (34.4%)
Operating Microscope	19 (6.1%)	33 (10.6%)	70 (22.5%)	1 (0.3%)	53 (17.0%)	46 (14.8%)	3 (1.0%)	1 (0.3%)	27 (8.7%)	58 (18.6%)

Table 2: Reconstructive Microsurgery Procedures Performed in Africa (1976 to 2020) **A.** Free Flaps Performed **B.** Subgroup Analysis of Free flaps Performed.

NB: ALT = Anterolateral Thigh Flap, RFFF = Radial Forearm Free Flap, Rectus Abd Muscle = Rectus Abdominis Muscle Free Flap, LD = Latissimus Dorsi Free Flap

Table 2: Reconstructive Microsurgery Procedures Performed in Africa (1976 to 2020)

A. Free flaps Performed

Procedure	Number of Studies	Total number of Procedures (%)
Free Fibula	24	361 (26.4%)
ALT	22	219 (16.0%)
RFFF	26	199 (14.6%)
LD	22	138 (10.1%)
Free Jejunum	4	91 (6.7%)
Free Gracilis	8	91 (6.7%)
Parascapular flap	8	41 (3.0%)
Rectus Abdominis Muscle flap	7	40 (2.9%)
Finger Replantation	2	6 (0.4%)
Others	42	181 (13.2%)

B. Subgroup Analysis of Free flaps Performed

	ALT	Free Gracilis	RFFF	Free Fibula	Free Jejunum	Parascapular	Rectus Abd Muscle
Region							
Sub-Sahara	108 (18.5%)	9 (1.5%)	135 (23.1%)	165 (28.3%)	1 (0.2%)	35 (6.0%)	12 (2.1%)
North Africa	111 (14.2%)	82 (10.5%)	64 (8.2%)	196 (25.0%)	90 (11.5%)	6 (0.8%)	28 (3.6%)
Lead Surgeon							
Local Surgeons	176 (15.1%)	83 (7.1%)	165 (14.1%)	309 (26.4%)	91 (7.8%)	9 (0.8%)	33 (2.8%)
Visiting Surgeons	13 (17.8%)	0 (0%)	26 (35.6%)	1 (1.4%)	0 (0%)	30 (41.1%)	0 (0%)
Time Period							
2010 to 2020	205 (20.5%)	84 (8.4%)	154 (15.4%)	210 (21.0%)	91 (9.1%)	10 (1.0%)	32 (3.2%)
Before 2010	14 (3.8%)	7 (1.9%)	45 (12.3%)	151 (41.1%)	0 (0%)	31 (8.4%)	8 (2.2%)
Magnification							
Loupes	71 (21.8%)	17 (5.2%)	87 (26.7%)	61 (18.7%)	1 (0.3%)	27 (8.3%)	0 (0%)
Operating Microscope	49 (15.8%)	34 (10.9%)	38 (12.2%)	100 (32.2%)	0 (0%)	7 (2.3%)	24 (7.7%)

NB: ALT = Anterolateral Thigh Flap, RFFF = Radial Forearm Free Flap, Rectus Abd Muscle = Rectus Abdominis Muscle Free Flap, LD = Latissimus Dorsi Free Flap

Table 3: Studies Included in the Quantitative Pooled Meta-analysis of Microsurgery Outcomes.

NB: NR= Not reported, Med =Median, IQR = Interquartile Range

Reference	Country	Study Design	Patients	Procedures	Elective /	Mean Age (Range) years	Lead Surgeon	Magnification	Mean follow-up Duration (Range) months	Failed free flaps	Partial flap loss	Flap Salvage	Successful flaps	Complications	Major	Minor
Abdelrahman, 2016[32]	Egypt	Randomized Controlled Trial	15	15	15/0	27.9 (NR)	Local surgeons	NR	NR	1	1	NR	-	8	NR	NR
Aboelatta, 2013[33]	Egypt	Case Series	28	28	21/7	8.78 (2-15)	Local surgeons	Operating Microscope	27 (3-60)	3	0	3	3	9	1	8
Bassiouny, 2005[31]	Egypt	Randomized Controlled Trial	15	15	15/0	40.1 (23-50)	Local surgeons	NR	NR	2	0	NR	-	3	1	2
Citron, 2016[30]	Uganda	Case Series	100	114	NR	NR (3-61) *Med 22*	Mixed (Local = 80 Visiting = 33 NR = 1)	Operating Microscope	*Med 5 (IQR 1-17)*	27	2	5	1	40	NR	NR
Elfeky, 2015[34]	Egypt	Retrospective Cohort Study	37	37	37/0	60.8 (NR)	Local surgeons	NR	36.7 (NR)	2	NR	NR	-	11	NR	NR
Ghoneimy, 2018[35]	Egypt	Case Series	41	41	41/0	10.3 (5-17)	Local surgeons	NR	48.7 (12-104)	5	NR	NR	-	34	15	19
Graham, 2003[36]	South Africa	Case Series	43	47	47/0	47.7 (13-82)	Local surgeons	NR	15 (NR)	5	0	NR	-	15	11	4
Nangole, 2015[1]	Kenya	Case Series	120	132	NR	47.2 (8-72)	Local surgeons	Loupes	NR (6-NR)	15	NR	8	1	29	3	21
Passos, 2015[37]	South Africa	Case Series	100	100	100/0	55 (19-83)	Local surgeons	Loupes	NR	6	5	7	4	28	13	15

NB: NR= Not reported, Med =Median, IQR = Interquartile Range