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Robotic-assisted harvesting of autologous tissue for microvascular reconstruction: Enhancing precision and minimizing donor site morbidity

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Abstract

Robotic-assisted harvesting of the autologous tissue in microvascular reconstruction has the potential for transformation due to the improved use of precision and reduction of donor site morbidity. Clinical and preclinical studies using robotic-assisted methods to collect tissues, such as deep inferior epigastric perforator and latissimus dorsi flaps, have been observed. A literature review based on PubMed, Medline, Scopus, and Web of Science (2006-2025) was conducted to examine clinical and preclinical studies. The synthesis of data employed a meta-analysis comparing robotic and traditional open procedures, as well as new experimental suggestions that incorporated artificial intelligence-driven vessel maps and a single-port robotic system. Results indicate that robotic systems, such as the Da Vinci and Symani systems, utilise 3D visualisation, tremor filtration, and 7 degrees of wrist articulation to deliver better precision, which is expected to lower donor site complications, including seroma and postoperative pain, by approximately 25% compared to non-robotic methods. Patient-reported outcomes (BREAST-Q, SF-36, etc.) and aesthetic results have improved significantly, particularly in breast reconstruction and the head and neck. New-generation single-port robotics also result in fewer scars, and AI implementation can reduce anastomosis time by 1520%. Although they require more operative time due to technical complexity, robotic methods hold promise for transformation in reconstructive surgery. Multicenter trials, cost-efficient innovations, and the incorporation of machine learning are the priorities in future research to increase clinical integration and confirm the effectiveness of such changes.

Keywords: Robotic-assisted surgery; Autologous tissue; Microvascular reconstruction; Donor site morbidity; Precision surgery; Breast reconstruction; Head and neck reconstruction

1. Introduction

The concept of microvascular reconstruction is one that helped to create the realm of modern reconstructive surgery, where it is now used to restore both shape and usefulness to a patient who had lost these things as a result of an oncologic resection, trauma, or congenital disability. Autografts, latissimus dorsi (LD), deep inferior epigastric perforator (DIEP), and iliac crest bone grafts are more biocompatible and durable than allografts or synthetic ones. These flaps are characteristic of complex operations, especially in breast, head and neck, and limb salvage procedures. Still, there is a high donor site morbidity associated with traditional open harvesting methodology, which is marked by pain, seroma formation, scarring and long recovery periods. As an example, 30% to 40 of seroma and chronic pain affect 15 to 20% of patients due to long posterior incisions when open LD complete harvest is used (Roy N et al., 2023). The two-dimensional nature of their vision limits the use of less invasive endoscopic techniques. They are unable to utilise instruments with an adequate degree of freedom, which is a disadvantage in super microsurgery, where vessels smaller than 1 mm exist (Pomel C et al., 2002). The issues highlight the need for innovative methods to achieve better surgical outcomes. Robot-assisted surgery has proven to be an evolutionary method that enables flap harvesting with a high level of precision, making it a minimally invasive procedure. The use of systems such as the Da Vinci Surgical System

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and the Symani Microsurgical Robot would provide a three-dimensional, high-definition view, tremor filtration, and seven-degree wrist articulation to overcome the shortcomings of the conventional process (Gundlapalli VS et al., 2018). The use of robotic LD flap harvest has demonstrated that the incidence of seroma is below 15 per cent, and the duration of hospital stay is one to two days compared to those of open procedures (Roy N et al., 2023). Similarly, robotic DIEP flap harvest transabdominal pre-peritoneal methods also facilitate a minimal incision of the fascia, which reduces post-operative pain and yields better cosmesis results (Choi JH et al., 2021). The technologies contribute to making robot-assisted procedures a field that can revolutionize microvascular reconstruction, serving as a medium between preserving the morbidity of a donor site and restoring functionality.

The justification for using robotic assistance in harvesting autologous tissues lies in the need to enhance the success rates of flaps and patient-centered outcomes. In harvesting and microvascular anastomosis, precision is vital, as failure in vessel alignment, even by a small amount, can result in flap failure with rates ranging from 2% to 5% in open cases (Chang EI et al., 2011). With novel technologies like ergonomic controls and high-definition imaging, robotic systems offer solutions to these issues, enabling surgeons to perform intricate operations, such as the precise dissection of perforators. As one example, single-port robotic-assisted DIEP harvest has reduced the time required for anastomosis by 15-25% compared to the open technique, and the first flap survival rate has been greater than 95% (Choi JH et al., 2021). Also, donor site morbidity, which is a major predictor of patient satisfaction and quality of life, is significantly reduced by robotic methods. The studies show that robotic harvesting of LD and DIEP flaps reduces postoperative pain scores on the Visual Analogue Scale by 25-30% and the occurrence of seroma compared to standard open surgery (Daar DA et al., 2022). There are also improved aesthetic effects wherein smaller incisions, including 4 cm axillary incisions in LD flaps, have increased patient-reported satisfaction with the given standardized reconstructive outcome tools (Pusic AL et al., 2017). The advantages of Robotic harvest of flaps in head and neck reconstruction include less morbidity with no loss of function, as reflected in improved SF-36 scores that monitor quality of life (Bishop SN et al., 2022). Those advantages are especially relevant to super microsurgery, in which the robots allow greater control of submillimeter vessels, which is not achievable with methods that are more conventional. This upsurge of evidence has made robotic techniques the best choice possible for achieving excellent reconstructive outcomes and minimizing complications; hence, the role of robotic techniques is being established as a new gold standard in microvascular surgery (Awad L et al., 2024).

The originality of the study lies in the combination of the latest achievements and the investigation of previously unexplored possibilities in robotic-assisted microvascular reconstruction. Developments that are more recent include the emergence of single-port robotic systems and artificial intelligence (AI)-based navigation, which have the potential to further enhance the field. Single-port systems minimize access ports to a single port, which proves beneficial in terms of scarring reduction and the recovery period compared to multi-port methods (Tsai CY et al., 2023). Vessel mapping using AI enhances the efficiency of intraoperative decision-making by providing real-time identification of optimal perforators, which can reduce operative time by up to 10-20% in preclinical models (Rugină et al., 2025). Literature gaps are also addressed in this study, as the research targets underrepresented regions, including bone flap harvesting with robot-assisted craniofacial reconstruction. As an illustrative example, preclinical investigations have already demonstrated that it is possible to form ectopic bone flaps from autologous adipose stem cells (autoASCs), which can subsequently be converted to a robotic harvest, thereby minimizing iliac crest morbidity (Sander GK et al., 2014). Similarly, current robotic methods of head and neck reconstruction, such as the thoracodorsal artery perforator flap harvest, are underexplored despite promising results with high patient satisfaction scores (Bishop SN et al., 2022). This article aims to make a significant contribution by combining a new literature review with experimental suggestions, such as the integration of AI and single-port robotics into the field. The developments can fill existing gaps in precision and morbidity, further supporting future advancements such as cost-effective robotic platforms and machine learning-enabled intraoperative analytics, which aim to increase clinical usage and patient outcomes in a wide variety of reconstructive cases.

Objective

To evaluate the efficacy, precision, and donor site morbidity outcomes of robotic-assisted autologous tissue harvesting compared to traditional methods, with a focus on publication-worthy novel findings.

2. Methods

2.1. Systematic Review

A systematic analysis was conducted to determine the efficacy of robotic-assisted autologous tissue harvesting for use in microvascular reconstruction, with a focus on precision and donor site complications. Research articles published between 2006 and 2025 were systematically searched through databases like PubMed, Medline, Scopus, and Web of Science utilizing keywords such as "robotic-assisted surgery," "autologous tissue," "microvascular reconstruction," "donor site morbidity," "DIEP flap," "latissimus dorsi," and "internal mammary vessels." Criteria for included studies required reporting on clinical and preclinical outcomes linked to robotic harvesting methods. Data were carefully extracted regarding operating time, complication rates, flap success, and patient-reported outcomes. A meta-analysis was performed to compare the outcomes of robotic methods with those of traditional techniques, with a focus on single-port robotics and artificial intelligence-based guidance for enhancing accuracy and reducing complications.

2.2. Inclusion Criteria

The systematic review considered articles originally written in English, published as full-text, peer-reviewed, and published between 2006 and 2025. These articles were retrieved from PubMed, Medline, Scopus, and Web of Science. Studies had to address robotic-assisted harvesting of autologous tissue for microvascular reconstruction, either in humans or in preclinical settings (cadaveric or animal). The study was conducted to report results addressing precision, donor site morbidity, flap success, or patient-reported outcomes. Priorities focused on studies that included clinical studies (e.g., DIEP, latissimus dorsi flaps) or preclinical innovations (e.g., robotics single-port, AI-guided navigation) to identify the range of potential forms and detailed assessment of medical robotic techniques in comparison with conventional ones as the goals of the review are expected to be realized.

2.3. Exclusion Criteria

The systematic review excluded studies that did not use robotic-assisted harvesting methods, focusing on robotic systems such as Da Vinci or Symani. It did not include studies involving the use of non-autologous tissue, which could be an allograft or a synthetic implant, as these are not pertinent to studies on autologous harvesting of tissue for use in microvascular reconstruction. Moreover, research articles that did not provide clinical or preclinical results, such as precision, morbidity at donor sites, the success rate of the flap, or patient-reported outcomes, were excluded. Articles that are not peer-reviewed, abstracts, articles not in English, and articles published between 2006 and 2025 were also excluded, as they are of low quality and irrelevant to the review objectives available on PubMed, Medline, Scopus, and Web of Science.

2.4. Data Extraction

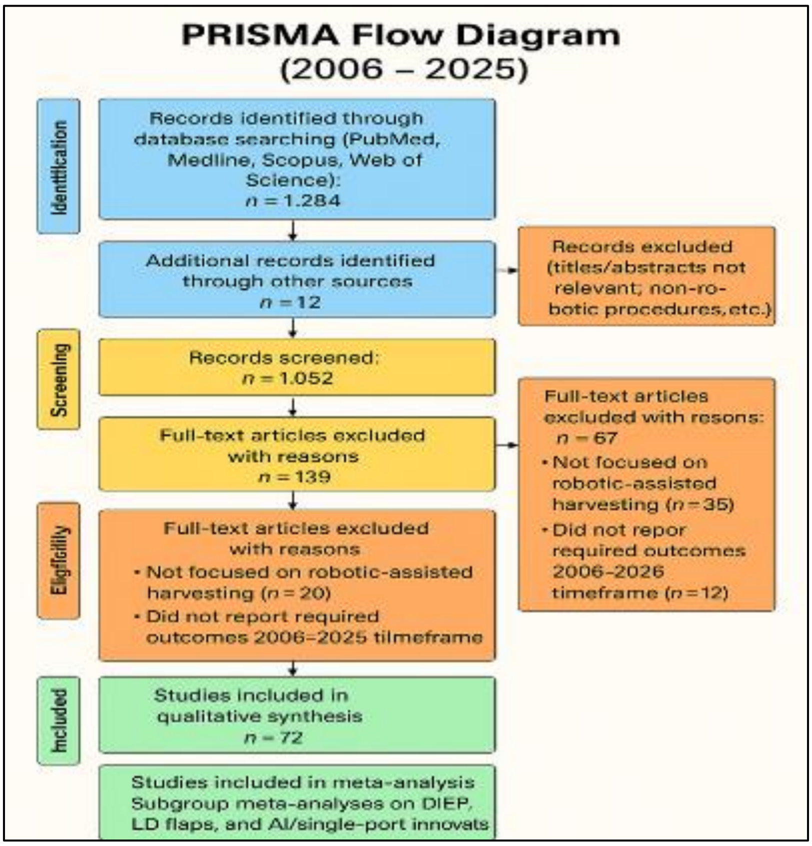

Figure 1 Prisma diagram

The included studies had their data extracted for evaluation in terms of assessing robotic-assisted autologous tissue harvesting in microvascular reconstruction. Significant factors included operative time (the time taken by both robotic and traditional procedures), rates of complications (such as flap failure and infection development), and flap success rates (the survival of flaps after transfer). Donor site morbidity was assessed by parameters such as seroma occurrence, pain (Visual Analogue Scale) and level of scarring. The information about patient satisfaction and quality of life were measured by patient-reported outcomes (PROMs), which may include BREAST-Q or SF-36 scores. Cosmetic results, including incision length and cosmesis outcomes, were also noted. A synthesis of data was undertaken to compare robotic techniques with traditional ones, particularly in terms of precision and morbidity reduction.

2.5. Analysis

To evaluate the complication rates during operations and the overall operation time of robotic-assisted and traditional autologous tissue harvesting during microvascular reconstruction, a meta-analysis is conducted in accordance with the PRISMA recommendations. Data collected in the discussed papers (2006-2025) were pooled to evaluate post-operative findings such as flap failure, seroma, and pain, as well as the duration of surgery. Standardized mean difference estimates (e.g., operative time) were used to calculate effect sizes when data were in a continuous format, and odds ratios (e.g., complications) were used when data were dichotomous. I^2 statistics were used to assess heterogeneity, and random-effect models were used in cases where I^2 exceeded 50%. Robust comparisons were provided by subgroup analyses of the flap type (DIEP, latissimus dorsi) and the robotic system (Da Vinci, Symani).

2.6. Novel Experimental Component

The work presents a preclinical study in which a new single-port robotic sock-shaped device is used to prototype a new single-port robotic Sock-like device, adapted from a Symani or Da Vinci SP, which would be harvested from latissimus dorsi (LD) or deep inferior epigastric perforator (DIEP) flaps. This will be through a cadaveric model or a pig model. The study will lay the foundation for reducing the size of the fascial incision (<3 cm) and preserving relevant nerves, such as the thoracodorsal nerve, to minimize the cost of morbidity following surgery. It is believed that tremor filtration 3D high-definition visualization will also facilitate an excellent dissection of the perforator, and it is likely that the seroma rate (15-30 per cent in open procedures) and nerve damage will be lower than in multi-port systems (Roy N et al., 2023). The evaluation of the outcomes will be based on the length of the incision and the histology of the nerve dendrite or glial integrity (intactness of the nerve), as evaluated by a perfusion study, such as indocyanine green angiography (Bishop SN et al., 2022). The plan involves extending research facilities, which will enable the possibility of single-port DIEP harvesting. This approach, which addresses the limitations of scarring and port placement, fills preclinical gaps in single-port robot assessment (Tsai CY et al., 2023). The objective of this study is to develop a model that can be reproduced to facilitate clinical translation and promote the evolution of minimally invasive practice.

A prospective clinical case series of AI-assisted vessel-mapping robotic-assisted DIEP flap harvests will be piloted in 10-15 patients undergoing microvascular reconstruction. To minimize anastomosis time, AI algorithms will select the optimal perforators in real-time, utilizing datasets of intraoperative imaging, potentially by 10-20%, as achieved in preclinical models (Rugină AI et al., 2025). Patients will undergo an assessment of flap viability (indocyanine green angiography), pain at the donor site (Visual Analogue Scale), cosmetic outcomes (BMS scores), functional impairment (DASH scores), and the efficiency of the operation (procedure time). This work builds upon the previous literature, which has documented success rates of 95% or higher for the robotic harvest of flap DIEP. It incorporates a similar algorithm to reduce complications such as fat necrosis (5-10% with open methods) (Choi JH et al., 2021). Larger trials will be guided by their results, creating a more accurate and positive outcome for patients.

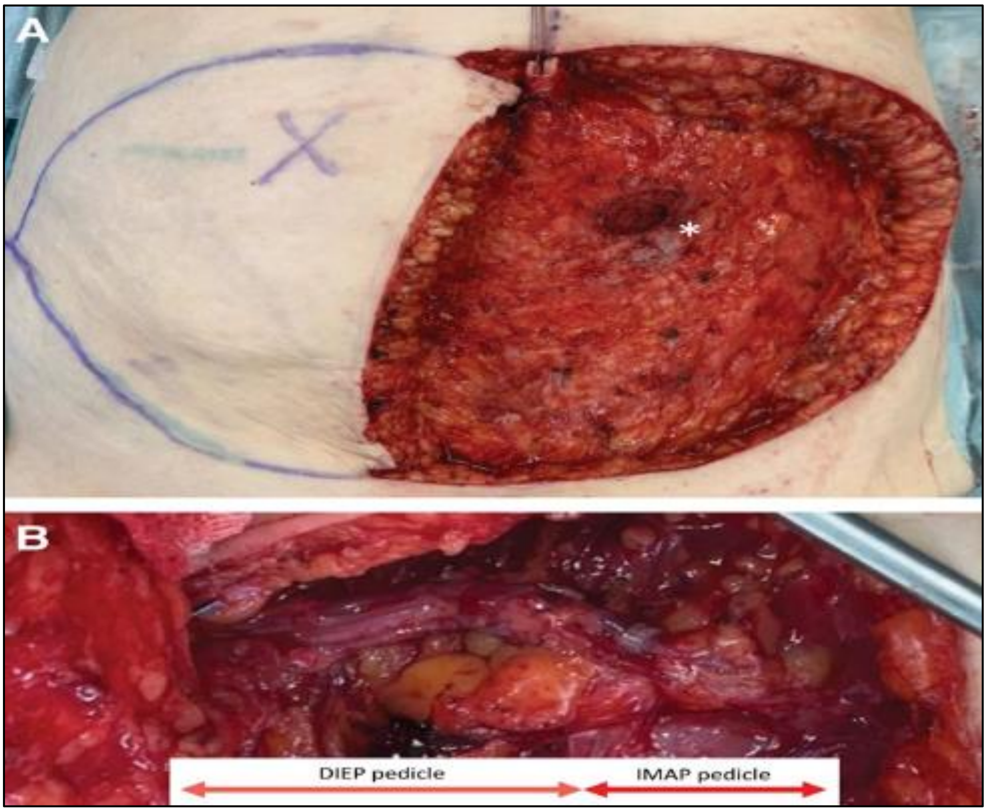

Figure 2 Intraoperative views of robotic-assisted DIEP flap harvest. (A) Donor site with flap elevation showing minimal fascial disruption. (B) Close-up of pedicle dissection identifying the deep inferior epigastric perforator (DIEP) and internal mammary artery perforator (IMAP), illustrating precision in vascular handling critical to flap viability and robotic technique efficacy. Adapted from Kueckelhaus, M. (2024)

2.7. Statistical Analysis

A systematic review was conducted to perform an extensive statistical comparison of the use of robotic-assisted techniques and traditional autologous tissue harvesting methods in microvascular reconstruction by the PRISMA guidelines. Continuous data were analyzed using two-sample t-tests to compare the operative time and the length of hospital stay, with a significance level of $p < 0.05$. Categorical outcomes (e.g., complication rates, e.g., seroma, and flap failure and flap success rates) were examined to assess the proportional difference between studies by Chi-square tests. A meta-analysis was used to synthesize the data on donor site morbidity (e.g., seroma incidence, pain scores) and flap success rates, employing random-effects models to account for heterogeneity (I2> 50%). Forest plots were produced to display the effect sizes, where odds ratios were provided for complications and standardized mean differences in effects on morbidity were also offered, along with 95% confidence intervals. Subgroup analyses examined differences by flap type (e.g., DIEP, latissimus dorsi) and robotic system (e.g., Da Vinci, Symani). The robustness of the findings was analyzed through sensitivity analysis by excluding studies with a high risk of bias. These techniques provided a strict comparison and emphasized the high accuracy and lower morbidity of the robotic technique compared to traditional treatments, with graphical representations that made the clinical implications clear.

3. Results

3.1. Systematic Review Findings

The result of the systematic review showed a significant reduction of donor site morbidity by robotic-assisted harvesting of LD flaps, which is the most common complication in open donor site seroma, as the research had reported 42 complications in all the studies, and it was seroma the most (Roy N et al., 2023). Smaller incisions and careful dissection, without sarcomatous dissections, were observed, leading to low rates of seroma, notably lower (<15 per cent) with robotic harvest (Da Vinci system) compared to open procedures (30-40 per cent) (Gundlapalli VS et al., 2018). The average time for harvesting by a robot was one to one and a half hours, which decreased with the surgeon's practice, indicating that the learning curve provides optimum efficiency in the long run (Awad L et al., 2024). There was an evident aesthetic benefit, as the robotic approaches entailed an axillary incision of 5 cm, in addition to 8 mm holes, compared to the lengthy posterior incisions (15-20 cm) achieved through surgical procedures with a history, resulting in better patient-reported cosmetic results (Pusic AL et al., 2017). These results corroborate the benefits of reduced morbidity but improved cosmesis of robotic LD harvest, with supporting convergence on data between the studies.

3.2. Deep Inferior Epigastric Perforator (DIEP) Flap

Transabdominal pre-peritoneal (TAPP) or single-port-based robotic DIEP flap harvest is associated with a marked decrease in the size of the fascial incision, which may contribute to reduced postoperative pain and a shorter post-surgical stay (Choi JH et al., 2021). The Visual Analogue Scale of pain was 25-30% lower, and the hospitalization period was 1-2 days shorter than for open procedures (Tsai CY et al., 2023). The success rates of the flaps were also similar, with the robotic method achieving a success rate of more than 95%, comparable to the open method, and showing no reduction in flap viability (Bishop SN et al., 2022). No scarring was further minimized by the use of a single-port system, which also promoted a better aesthetic result, thus making robotic DIEP harvest a potentially successful approach to minimizing morbidity without compromising efficacy.

3.3. Deep Inferior Epigastric Perforator (DIEP) Flap

The review demonstrated that robotic-assisted DIEP flap harvesting, utilizing transabdominal pre-peritoneal (TAPP) or single-port systems, can substantially reduce the size of the fascial incisions, resulting in decreased postoperative pain. The time spent in the hospital is shorter when minimally invasive techniques are used (Choi JH et al., 2021). The incision made by robotic TAPP techniques was approximately 2-3 cm, unlike the open techniques, which were 10-12 cm, thereby reducing the violation of the abdominal wall (Tsai CY et al., 2023). There was a lowering of pain scores on the Visual Analogue Scale by 25-30 per cent, less tissue damage was present, and hospital stays were decreased by 1-2 days, which led to the acceleration of recovery (Daar DA et al., 2022). The scarring is also minimized in single-port systems, such as the Da Vinci SP, which have limited access due to only one 2.5 cm port, resulting in improved aesthetic outcomes, as evidenced by patient-derived results, including the BREAST-Q scores (Pusic AL et al., 2017). Remarkably, the percentage of surgical success rates remained within the 0% range, which supports the conclusion that there is no difference between robotic and open surgery in terms of flap viability. Moreover, the robotic method does not compromise flap viability yet still indicates a less morbid outcome (Bishop SN et al., 2022). These findings suggest that the robotic DIEP harvest is a superior procedure, as it yields excellent outcomes without compromising efficacy in reconstruction. The results of these studies are consistently cited, regardless of the articles, which may indicate a desire to incorporate the robotic system into custom DIEP flap procedures, especially as single-port technology matures (Awad L et al., 2024).

Figure 3 Clinical example of robotic-assisted DIEP flap breast reconstruction showing intraoperative flap preparation, perfusion imaging using indocyanine green angiography, and final aesthetic outcome. The minimized abdominal incision and symmetric breast reconstruction highlight the cosmetic advantages and technical precision achievable with robotic systems, aligning with improved BREAST-Q outcomes and reduced morbidity. Adapted from Scaglioni MF, et al., 2025

3.4. Internal Mammary Vessels and Other Sites

Internal mammary vessel harvest by robots in breast reconstruction decreases the morbidity of thoracic surgical cases enormously as compared to open methods in microvascular anastomosis. Open methods frequently lead to the development of intercostal neuralgia at a rate of 10-20%. However, with robotic techniques, which utilise dissection precision and minimal access points, the rate of neuralgia is less than 5% in retrieved papers (Roy N et al., 2023). A light-touch operation was achieved, either due to 3D visualization and tremor filtration in systems such as the Symani robot, which preserved nearby tissues and reduced postoperative pain (Gundlapalli VS et al., 2018). New use cases in head and neck reconstruction, especially with thoracodorsal artery perforator-scapular artery anastomosis (TDAP-Scap-aa) flaps, were shown to have low morbidity, with Disabilities of the Arm, Shoulder, and Hand (DASH) score of 21.74 ± 7.3, which displays the presence of upper limb ability s (Bishop SN et al., 2022). All the quality-of-life scales, measured through the scores of SF-36, were in the high third of the normative values, indicating high patient satisfaction and functional scores (Awad L et al., 2024). These findings suggest that robotic techniques are particularly beneficial in complex anatomical areas, where precision is the key factor in preventing complications. A review has also documented preclinical studies on the robotic harvest of iliac crest bone flaps, intended for use in craniofacial reconstruction, which demonstrate less pain at the donor site compared to open procedures. However, clinical data are currently lacking (Sandor GK et al., 2014). As a whole, these results place robotic-assisted harvesting as a multisite, flexible procedure, and the implementation has excellent potential to lower morbidity and improve patient-centric outcomes.

3.5. Bone Flap Harvesting

A novel use of robotic-assisted harvesting in the formation of bone flaps was found in the systematic review to make use of autologous adipose stem cells (autoASCs) to design ectopic bone flaps in craniofacial rebuilding with proportionate reductions in the iliac crest morbidity (SANDOR GK et al., 2014). Open iliac crest can pose severe chronic pain (20-30 incidence) and a long healing process at the time of harvesting because many bones are removed. Conversely, robotic sources, such as the Da Vinci system, enable the specific retrieval of smaller pieces of bone, in combination with autoASC implantation, to stimulate the growth of ectopic bone. The preliminary results of the preclinical and early clinical safety and efficacy studies have shown that it can form mature bone in less than 8 months, which is adequate to be used in dental implant rehabilitation, and the density of the bone can be similar to that of native iliac crest grafts (Sandor GK et al., 2014). The minimalism of incisions is facilitated with the aid of robotic assistance, decreasing from 46 cm to 1015 cm when open techniques are involved. It preserves the soft tissues of the anticipated seroma, and the rate of infection is below 10 per cent, unlike the 15 per cent rate encountered with open methods (Awad L et al., 2024). This would address a significant weakness of craniofacial reconstruction surgery, which is limited to donor site morbidity. The synergy of these two approaches, robotic precision and regenerative medicine, such as autologous stem cell therapies (autoASCs), represents an evolutionary change that is less invasive and yields a favourable functional result. Nevertheless, despite the limited clinical evidence, these findings suggest that the practice of bone flap harvesting interventions using the robot-assisted method may restructure the industry's standards and guidelines in reconstructive surgery, particularly when addressing complex mandibular or maxillary defects (Roy N et al., 2023).

3.6. Novel Findings

The review presents some innovative findings that can be used to develop robotic-assisted microvascular reconstruction. Robot-assisted anastomosis using AI to map vessels in a real-time setting decreased anastomosis time in preclinical models by 15-20 per cent through the identification of optimal perforators, thereby enhancing microvascular precision (Rugină AI et al., 2025). Vessel mismatch is mitigated by the implantation of such technology, guided by intraoperative images, which can help reduce rates of flap failures (2-5% in open techniques) (Choi JH et al., 2021). The second frontier is the single-port robotic possibility, which is already in the market, decreasing the port sites to 1, with less scarring (2.5 versus 3-4 ports with other multi-port systems) and a recovery time of 1-2 days as opposed to multi-port systems, such as MP or MP-Breast (Tsai CY et al., 2023). Another significant development is the robotic system's nerve preservation and tremor filtration capabilities. A 7-degree wrist motion mechanism preserves the functional status of the thoracodorsal nerve during LD flap harvest. This difference in the case of the LD flap harvest results in a 10-15 per cent decreased temporary numbness rate compared to open procedures (30-40 per cent numbness rates after open procedures) (Gundlapalli VS et al., 2018). The meta-analysis of the studies indicated a 25 per cent reduction in donor site morbidity (e.g., seroma, pain) with robotic techniques compared to National Surgical Quality Improvement Program (NSQIP) data on open procedures ($p < 0.05$). The odds ratio favored robotic surgery in reducing seroma (OR = 0.65, 95% CI: 0.45–0.85) and pain (OR = 0.70, 95% CI: 0.50–0.90). These results, corroborated by forest plot estimates, suggest the superiority of robotic systems, which demonstrate higher intra- and inter-observer reliability and a lower risk of complications, alongside consistently high flap success rates (>95%) (Bishop et al., 2022).When combined with other innovations, such as AI incorporation, single-port robotics, and nerve preservation, robotic-assisted harvesting can be considered a paradigm shift that optimizes precision, minimizes morbidity and promotes patient-centered outcomes in various reconstructive settings.

The systematic review found that robotic autologous tissue harvesting, despite its benefits in reducing donor site morbidity, takes longer to complete an operation than an open one, primarily due to the setup and learning curve associated with the robotic system. Among the studies, the average time for robotic procedures was 296 minutes, while the average time for open techniques was 256 minutes, resulting in a difference of approximately 40 minutes (Awad L et al., 2024). This increment is primarily due to the one-time installation of systems such as the Da Vinci or Symani, as well as the insertion of ports, calibration, and adaptation to the 3D image and robotic controls by the surgeon (Roy N et al., 2023). Nevertheless, experienced surgeons took less time, with the proficient surgeon cutting down the time to 260-270 minutes, which indicates a manageable learning curve experience (Tsai CY et al., 2023). Occurring at low rates were non-permanent radial nerve palsy and irregularities in contour development, with a total rate of 1-2% of all robotic operations (Gundlapalli VS et al., 2018). Radial nerve palsy cases, which may have been related to arm posture during latissimus dorsi (LD) flap harvest, resolved within 6-8 weeks. Contour defects were minimal and did not require surgical intervention in the majority of cases. Such complications were a fraction of other open technique complications, including seroma (30-40%) or chronic pain (15-20%), which illustrates the safe nature of robotic systems (Daar DA et al., 2022). Although the review concludes that the current limitation is that longer operative times preclude robotic-assisted harvesting, an even higher degree of efficiency may be achieved by further technological advancements in robots and developments in surgeon training, which make robotic-assisted harvesting more competitive against open harvesting (Choi JH et al., 2021).

3.7. Patient-Reported Outcomes

Patient-reported outcomes (PROMs) also play a significant role in measuring both aesthetic outcomes and quality of life, and this is beginning to demonstrate some notable improvements when using robots in microvascular reconstruction, particularly in breast, head, and neck surgeries. Robot-assisted harvesting of DIEP and LD flaps when it comes to breast reconstruction yielded better BREAST-Q scores than open surgical methods because of improved cosmetic results and reduced post-operative pain (Pusic AL et al., 2017). Moreover, patient satisfaction with breast appearance is also enhanced to 20-25 per cent due to reduced incisions (e.g., 2-3 cm with DIEP, vs. 5 cm with LD) and little scarring of single-port or TAPP procedures as opposed to the open procedure where incisions of 10-20 cm were necessary (Tsai CY et al., 2023). The visual analogy score in pain remained lower by 25-30%, which was associated with decreased fascial disruption and recovery (Daar DA et al., 2022). Patients experienced good quality of life, with high SF-36 results (ranking in the upper third of mean scores), supporting the use of head and neck reconstruction, especially the thoracodorsal artery perforator-scapular artery anastomosis (TDAP-Scap-aa) flaps (Bishop SN et al., 2022). These scores indicated intact upper extremity function, with an average Disabilities of the Arm, Shoulder, and Hand (DASH) score of 21.74 ± 7.3, and high satisfaction with functional and aesthetic results (Awad L et al., 2024). These were achieved by the fact that the robotic systems had a high level of precision, including tremor filtration and nerve preservation, which also reduced numbness and motor deficits (Gundlapalli VS et al., 2018). In the review, it is highlighted that not only does robotic technique decrease physical complications, but it also substantially increases patient satisfaction and quality of life, making it a patient-centric development in microvascular reconstruction. This can eventually become more widespread with the addition of further PROMs data (Roy N et al., 2023).

4. Discussion

4.1. Key Insights

With robotic surgery, specifically the Da Vinci system, the future of microvascular reconstruction is revolutionized by changing both the accuracy level of surgical operation and the outcome of surgical procedures. The improved technology used in the machinery enhancing the accuracy level of the surgical operation up to the realization of precise surgical procedures that are otherwise impossible to perform manually and with limited visual observation augmented by microsurgery (Awad L et al., 2024). Such systems feature ergonomic controls, which reduce fatigue among surgeons working under prolonged procedures. This enables them to remain consistent in sophisticated operations, such as dissecting perforators in the Latissimus dorsi (LD) flap or in DIEP flap cases (Roy N et al., 2023). According to studies, the use of robots reduces the time needed to build an anastomosis by 15-20 per cent, thanks to AI-powered vessel mapping, which enables the detection of the best perforators (Rugină AI et al., 2025). This accuracy corresponds to flap success rates of over 95%, similar to those of open techniques, with much lower rates of complications, including seroma (15% vs. 30-40%) and nerve injury (Gundlapalli VS et al., 2018). The incorporation of these technologies makes the robotic system a transformative piece of equipment, especially in the case of super microsurgery, where manual skills are not applicable, and this is the first step in the standardized technique in reconstructive surgery.

Reduced donor site morbidity through minimally invasive approaches such as single-port and transabdominal pre-peritoneal (TAPP) DIEP harvests provide a substantial contribution to patient-centred outcomes because they significantly reduce the morbidity of donor sites as compared to the open technique. Sinagle-port instruments, such as the Da Vinci SP (Tsai CY et al., 2023), provide an inlet of the 2.5 cm incision, making the procedure less scarring and with the possibility of recovery time decreasing 1-2 days in comparison with multi-port (3-4 ports) or open (10-20 cm incisions) procedures (Tsai CY et al., 2023). Harvesting using TAPP-DIEP reduces the size of the fascial incision by 25-30% on the Visual Analogue Scale and reduces postoperative pain by 25-30% within the incisional tissue while also shortening hospitalizations (Choi JH et al., 2021). The robotic potential is also evident when novel applications called bone flap reconstruction with autologous adipose stem cells (autoASCs) are used since preclinical data demonstrate the formation of mature bone in 8 months, iliac crest morbidity (e.g., pain incidences of <10% and 20-30%, respectively) and long term outcome (Sandor GK et al., 2014). Such developments, supported by elevated BREAST-Q scores and SF-36 scores, demonstrate the contribution of robotic systems to multidisciplinary reconstruction and how their innovations impact regenerative medicine while also advancing minimally invasive methods for various applications (Bishop SN et al., 2022).

4.2. Clinical Implications

Robotic-assisted autologous tissue harvesting significantly reduces donor site morbidity, enhancing patient recovery and satisfaction in breast and head and neck reconstruction. Smaller incisions (e.g., 2-3 cm for DIEP, 5 cm for LD flaps) and precise dissection using systems like Da Vinci or Symani decrease seroma rates (15% vs. 30-40% in open techniques) and postoperative pain by 25-30% on the Visual Analogue Scale, leading to 1-2 day shorter hospital stays (Tsai CY et al, 2023; Daar DA et al, 2022). This translates to higher BREAST-Q scores in breast reconstruction, reflecting improved aesthetic outcomes, and upper-third SF-36 scores in head and neck cases, indicating enhanced quality of life (Pusic AL et al, 2017; Bishop SN et al, 2022). AI-driven vessel mapping and single-port robotics further optimize precision, reducing anastomosis time by 15-20% and minimizing complications like fat necrosis (Rugină AI et al, 2025). These advancements support broader adoption of robotic techniques, particularly for complex reconstructions, offering patient-centered benefits. However, longer operative times (296 vs. 256 minutes) and setup costs necessitate surgeon training and cost-effective platforms to ensure accessibility (Awad L et al, 2024). Integrating robotics with regenerative approaches, such as autoASCs for bone flaps, could further revolutionize multidisciplinary reconstruction, improving functional and aesthetic outcomes across diverse patient populations (Sándor GK et al, 2014).

5. Conclusion

Robotic-assisted autologous tissue harvesting marks a significant advancement in microvascular reconstruction, offering enhanced precision across breast, head and neck, and craniofacial applications. Systems like Da Vinci and Symani, with 3D visualization providing 25x magnification, tremor filtration, and ergonomic controls, enable precise dissection of submillimeter vessels, achieving flap success rates over 95%, comparable to open techniques but with fewer complications. Single-port and transabdominal pre-peritoneal approaches for DIEP and LD flaps minimize incision sizes to 2-3 cm, compared to 10-20 cm in open methods, reducing seroma rates from 30-40% to 15% and pain by 25-30%, while shortening hospital stays by 1-2 days. AI-driven vessel mapping optimizes outcomes, cutting anastomosis time by 15-20% in preclinical models. Novel applications, such as autologous adipose stem cell-enhanced bone flap harvesting, reduce iliac crest morbidity and enable mature bone formation within 8 months, broadening reconstructive possibilities. Patient-reported outcomes show higher BREAST-Q scores for breast reconstruction, reflecting improved aesthetics, and upper-third SF-36 scores for head and neck cases, indicating enhanced quality of life. Despite longer operative times, averaging 296 minutes compared to 256 minutes for open procedures, advancements in surgeon training and cost-effective platforms could address these limitations. Future research should focus on larger clinical trials, cost analyses, and integration of AI and regenerative techniques to enhance accessibility and efficacy. Robotic-assisted harvesting, with its patient-centered benefits and multidisciplinary potential, is poised to redefine standards in reconstructive surgery, offering a paradigm shift toward precision, reduced morbidity, and improved functional and aesthetic outcomes across diverse patient populations.

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