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The Use of Free Vascularized Fibula Graft in Spinal Reconstruction: A Comprehensive Systematic Review

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Background: Reconstructive surgeons frequently face large structural abnormalities after spine resection. Unlike defects in the mandible or long bone, where a free vascularized fibular graft (FVFG) is a popular alternative for segmental osseous reconstruction, data on the use of an FVFG in the spine are still limited. The purpose of this study was to comprehensively describe and analyze the outcome of spinal reconstruction utilizing FVFG.

Methods: The extensive search included the following databases: PubMed, ScienceDirect, Web of Science, Cumulative Index to Nursing and Allied Health Literature, and Cochrane for relevant studies published up to January 20, 2023, according to PRISMA 2020 guidelines. Demographic data, flap success, recipient vessels, and flap-related complications were evaluated.

Results: We identified 25 eligible studies involving 150 patients, consisting of 82 men and 68 women. Spinal reconstruction utilizing FVFG is mostly reported in the case of spinal neoplasm, followed by spinal infection (osteomyelitis and spinal tuberculosis) and spinal deformities. The cervical spine is the most common vertebral defect reported in the studies. All studies summarized in the present study reported successful spinal reconstruction, while wound infection was the most reported postoperative complication after spinal reconstruction utilizing FVFG.

Conclusions: The results of the current study highlight the ability and superiority of using FVFG in spinal reconstruction. Despite being technically challenging, this strategy provides enormous benefits to patients. However, a further additional large-scale study is required to corroborate these findings. *(Plast Reconstr Surg Glob Open 2023; 11:e5079; doi: 10.1097/GOX.0000000000005079; Published online 15 June 2023.)*

INTRODUCTION

Severe spinal deformity, pseudarthrosis, infection, and oncological resections can cause spinal instability, leading to functional and neurological impairment. To avert this, it is essential to establish long-lasting spinal stability. The most prevalent approach for this condition is posterior and/or anterior spinal instrumentation combined with cages or bone transplants. However, all mechanical devices will progressively lose mechanical stability, leading to collapse.[1] The only way long-lasting stability can be achieved is through bony consolidation. For this reason, patients with a reasonable life expectancy are mostly treated with the modality of bone grafts.

There are two types of autologous bone grafts: vascularized and nonvascularized. Previous studies have connected nonvascularized bone transplants to an increased risk of infection, delayed consolidation, and graft strength loss due to bone mass resorption.[2,3] Vascularized bone grafts, on the other hand, are associated with reduced rates of infection, better consolidation, and less graft resorption, resulting in better and longer-lasting results.[4] As a result, in spinal reconstruction, vascularized bone grafts are more preferrable over nonvascularized grafts. Several donor sites are available for harvesting a free vascularized bone graft. Size, shape, strength and availability of the graft are important criteria for graft choice, along with the location of the defect and the mechanical demands. For

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this reason, in cases of spinal repair, free vascularized fibula grafts (FVFGs) are the primary choice in most cases of spinal reconstruction. The fibula is superior in axial compression strength and available length. It has proven to be resistant to adjuvant oncologic (radiation) therapy; is easily accessible in a ventral, dorsal, and lateral approach; and has a low donor site morbidity.[5,6]

To the best of our knowledge, studies pertaining to spinal reconstruction utilizing fibula free flaps are scarce, consisting of a handful case reports and small retrospective case series. However, it is not established whether vascularized bone flaps in spinal reconstruction are superior to the standard of care (nonvascularized bone graft and alloplastic instrumentation). Therefore, the aim of this study was to comprehensively describe and evaluate the outcome of spinal reconstruction utilizing fibula free flaps.

Takeaways

Question: Why are free vascularized fibula grafts not widely used in spinal reconstruction compared to other sites of reconstruction, such as long bone reconstruction and jaw reconstruction?

Findings: Free vascularized fibula grafts offer many advantages in spinal reconstruction, such as improved bone union; structural support for spine stability; ability to accommodate various lengths of vertebral defects, particularly in cases involving multiple segments of the spine; and minimal donor-site morbidity. However, the limitations in free vascularized fibula graft for spinal reconstruction involve a long operative time and technically challenging surgical procedure.

Meaning: The free vascularized fibula graft can be considered an effective modality in spinal reconstruction.

METHODS

Search Strategy

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.[7] We performed an electronic data search in PubMed, Web of Science, ScienceDirect, Cumulative Index to Nursing and Allied Health Literature via EBSCO, and the Cochrane Central Register of Controlled Trials (CENTRAL) for relevant studies published up to January 20, 2023. The following search terms were used: (spinal reconstruction [MeSH Terms] OR (“spine” OR “cervical” OR “thoracal” OR “lumbar”) AND “reconstruction”) AND (“fibula” OR “bone”) AND (“flap” OR “graft” OR “transplant”). The search language was limited to English. No restrictions on the publication date were set for the search.

Selection of Studies and Eligibility Criteria

After removing the duplicates, the remaining articles were filtered by reviewing their titles, and then the abstracts of the potentially relevant articles were screened. Finally, the selected articles with available full texts were retrieved and assessed according to the eligibility criteria. The overall study selection process was independently performed by two investigators. Disagreements were discussed with the other investigators until a consensus was reached.

We included all studies reporting the use of fibula free flaps in spinal reconstruction in populations aged 18 years or older. Exclusion criteria were (1) irrelevant title or abstract; (2) irretrievable full texts; (3) review articles, letters to the editors, or conference abstracts; and (4) non-English studies.

Data Extraction and Quality Assessment

Data extraction was independently conducted by two authors and subsequently checked for certainty. Disagreements were resolved through a discussion. For each included study, the following relevant data were collected: first author, year of publication, study location, study design, demographic data (age, sex, sample size), primary outcome (flap success), and secondary outcome (flap-related complications incidence).

A quality assessment of each study was performed using the original Newcastle-Ottawa Scale tools for case-control and cohort studies and the Joanna Briggs Institute (JBI) critical appraisal checklist for case reports, case series, and cross-sectional studies on all studies that met the aforementioned criteria.[8,9] The assessment was performed by two investigators, and disagreements were resolved by discussion. The tools evaluate the quality of observational studies from the following three domains: (1) sample selection; (2) study comparability; and (3) study outcome. The original Newcastle-Ottawa Scale contains eight items, with scores ranging from 0 to 9. The total score of 0–3, 4–6, and 7–9 indicated low-, moderate-, and good-quality studies, respectively. The JBI checklist consists of eight items, where studies can receive up to 8 points. The quality of studies with a total 0–4 points was rated as high risk, 5–6 points as moderate risk, and 7–8 points was rated as low risk.

Statistical Analysis

Owing to key differences in the comparisons performed in each study and various outcome measures, we could not perform a meta-analysis of the included studies, but instead we narratively synthesized the evidence from each study.

RESULTS

Study Characteristics

The initial database search of this study yielded 2726 records. A total of 46 duplicates were then removed. After reviewing 1384 records, 1328 titles and 14 abstracts were excluded. A total of five reports were irretrievable due to inaccessible full-text and non-English full-text. Afterward, 37 reports were further assessed based on the eligibility criteria. Accordingly, the overall screening process of this systematic review successfully included a total of 25 studies, including nine retrospective studies,[5,10–17] three case series,[18–20] and 13 case reports,[21–33] as mentioned in the PRISMA flow diagram (Fig. 1).

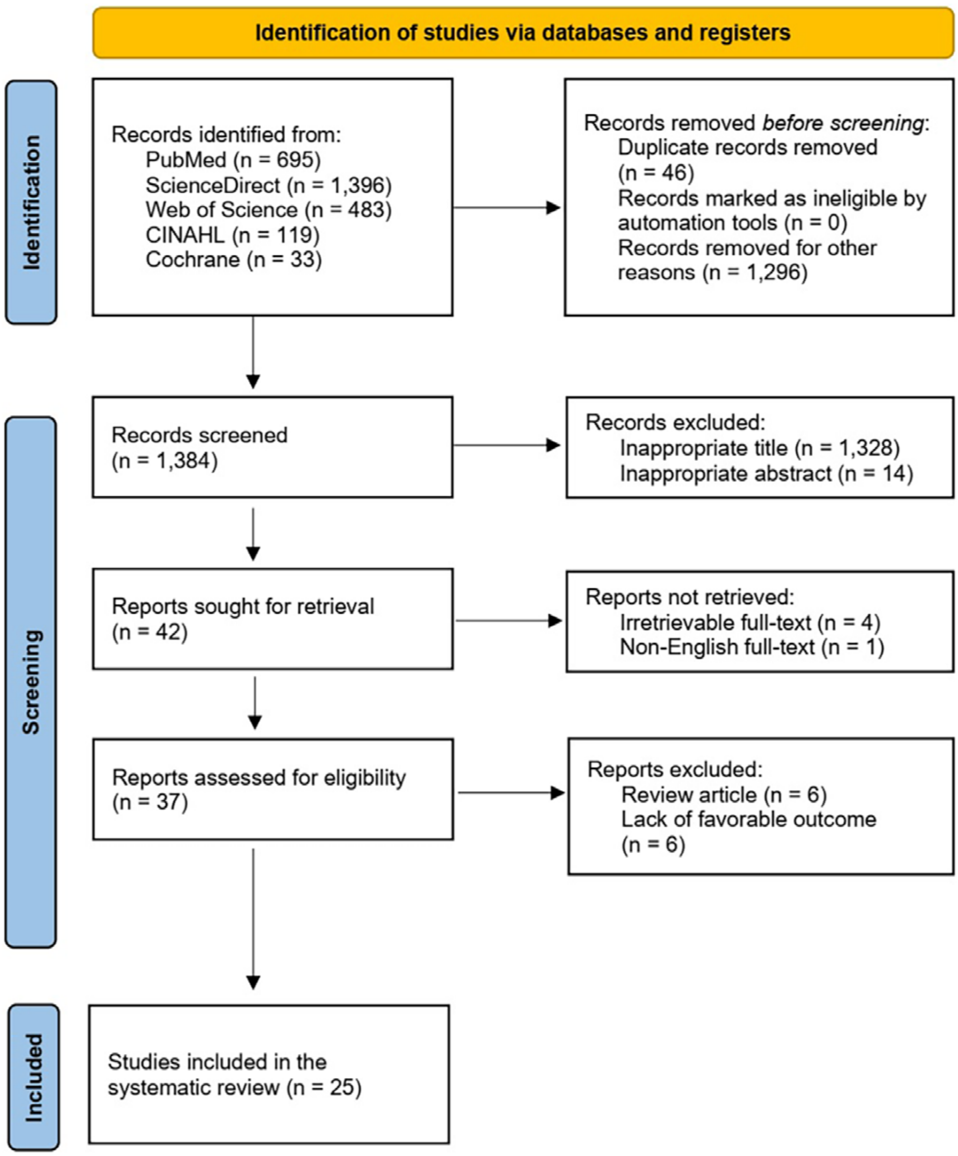

Fig. 1. PRISMA flow chart of the study selection process.[7]

The characteristics of the 25 studies involving 150 patients (82 men and 68 women) are summarized in Supplemental Digital Content 1a. [**See table, Supplemental Digital Content 1**, which displays (a) the characteristics of the included studies and (b) the Quality assessment of included studies based on JBI criteria (Moola et al., 2020), **http://links.lww.com/PRSGO/C619**] All studies were conducted on three large continents: America ($n = 14$), Europe ($n = 8$), and Asia ($n = 3$). Of all reasons for spinal reconstruction, spinal neoplasms (malignancies) and deformities were two common causes of spinal defects that were reported in the studies. The quality assessment of each study using the JBI checklist resulted in 22 studies being deemed to have a low risk of bias, whereas the other three studies were deemed to have a moderate risk of bias (Supplemental Digital Content 1b). (**See table, Supplemental Digital Content 1, http://links.lww.com/PRSGO/C619**) Owing to most of the included studies being case reports and case series with various outcome measures, we could not perform a meta-analysis of the included studies, but instead narratively synthesized the evidence.

Outcomes

Spinal reconstruction using FVFG was performed in various vertebral levels, including the cervical, thoracal, and lumbar spine, in all patients. Reconstruction was done either by a straight free flap or double-barrel flap. The length of follow-up and detailed characteristics were also presented in Supplemental Digital Content 1a. Each of the 25 studies included in the present study reported the primary outcome, in which the flap success is indicated by fusion of the graft. Of the 150 patients reviewed, flap success was achieved in 123 patients (82%), whereas nonfusion fibular graft was most frequently reported by

Bongers et al.[32] Various types of vessels were used in microvascular anastomosis of FVFG to recipients' vessels according to vertebral levels (SDC1a).

In terms of the secondary outcome, complications that occurred related to the FVFG are presented in Supplemental Digital Content 1a. Wound infection was the most common postoperative complication after spinal reconstruction utilizing FVFG. In contrast, no complication was reported in several studies.[12,18–22,24,26,28,30,33] In this study, of the 150 patients undergoing spinal reconstruction with FVFG, 27 patients (18%) had nonunion. Nonunion itself is defined as gaps occurring at the fracture site even after 6 months postintervention.

DISCUSSION

The fibula free flap or free vascularized fibular graft (FVFG) has become the most commonly used vascularized bone graft, as it can be modified to suit many clinical situations. Initially, FVFGs were used to treat posttraumatic bony defects, yet the indication rapidly broadened to include bony defects resulting from congenital anomalies, infections, and tumors. Since its introduction, the use of FVFG has emerged as the first-line option for a variety of reconstructions and was most frequently applied to defects in extremities, mandible, spine, and osteonecrosis of femoral head; however, its use in the spine is constrained because patients requiring vascularized bone grafting to the spine are infrequent and represent only a small percentage of patients who require spinal reconstruction.[13] Given the complexities of such reconstructions, the use of an FVFG poses unique challenges in spine reconstruction. There is currently a scarcity of evidence on the use of FVFGs in the reconstruction of the spine deformities. The purpose of this study was to comprehensively assess the outcomes of FVFG for reconstruction of the spine as well as the morbidity found during follow-up period.

As can be seen in the current study, spinal reconstruction utilizing FVFG is mostly reported in the case of spinal neoplasm, followed by spinal infection (osteomyelitis and spinal tuberculosis) and spinal deformities. The cervical spine was the most reported vertebral defect in the studies, accounting for up to 16 studies, followed by thoracolumbar defect. These cases are extremely complicated with considerable surgical morbidity, yet reconstruction is possible. The FVFG has been used in all areas of the spine with variable success. In the current review, the use of FVFG generally offered successful spine reconstruction and can be considered an excellent alternative for multi-level spinal abnormalities, albeit reported with some complications.

The use of FVFGs have fared well in terms of union, as the majority of studies reported flap success, indicating fusion of spine to FVFG. The number of nonunion of spine reconstruction was widely reported in three studies.[13,14,16] These findings were in line with a prior study that supported the use of vascularized bone graft for reconstruction of the extensive spinal defects.[34] In terms of morbidity, this study found that wound infection was the most commonly reported postoperative complication following spinal reconstruction utilizing FVFG. The complication, however, does not necessarily relate to the FVFG because the patient population is prone to surgical site complications for a variety of reasons, including their myriad comorbidities, frequent use of neoadjuvant chemoradiation, preceding surgery, and the need for lengthy instrumentation constructs and significant dead space creation.[13] Prior study revealed a modest wound complication rate (18%), which is lower than rates reported with other methods of spinal reconstruction.[35] Taken together, a number of practices, including preoperative nutritional optimization, postoperative prophylactic intravenous antibiotics during the hospital stay, intraoperative antibiotic irrigation, the liberal long-term (weeks to months) use of closed-suction drains, dead space obliteration with well-vascularized soft tissue flaps, and strict postoperative activity restrictions designed to offload pressure on the surgical sites, can be performed to lower these wound-related complications.[6]

Long-term stabilization is essential in spinal column reconstruction. The FVFG possesses several unique advantages over nonvascularized bone allograft or autograft and instrumentation alone due to the vascularized graft's biologic superiority and subsequent ability to adapt to the hostile environment in which it is typically transplanted.[6] In animal models, the use of FVFGs compared with nonvascularized grafts was found to be superior in terms of improved union with host bone as well as improved stability and stiffness, which was shown to continue to improve over time.[36] A prior clinical study reported that the fracture rate of nonvascularized bone allograft in spinopelvic fixation was at 50% at 6 months of follow-up.[37] However, the risk of fracture is reduced in vascularized bone because the osteocytes remain viable, limiting creeping substitution and enhancing primary bone healing, resulting in increased mechanical strength. Graft consolidation is accelerated, resulting in an enhanced union rapidity, thereby decreasing morbidity. Additionally, vascularized bone grafts can avoid massive bone remodeling and consequently reduce the risk of stress fractures.[30] Hypertrophy may also occur in response to mechanical stress; this is particularly beneficial to patients with long life expectancies who desire return to full function and can allow patients to no longer be dependent on hardware.[5,26]

Donor graft selection depends on the recipient size and location as well as the mechanical recovery goal.[30] In addition to fibula, other options for vascularized osseous reconstruction of the spine include pedicled rib flaps in the thoracic spine and free iliac crest vascularized bone grafts in the mobile spine, sacrum, and ilium.[37] However, these sources of vascularized bone have several drawbacks compared with the FVFG. The pedicled rib graft is curved and less stable, resulting in a less anatomic construct. Aside from that, it is typically limited to thoracolumbar reconstruction, and the graft is fragile due to a relatively thin cortex and often requires additional fixation. The vascularized iliac crest graft is stronger compared with pedicled rib graft yet yields a comparatively small length of bone, which is intolerant of osteotomies and potentially creates persistent donor site pain.[30,34] In contrast, the fibula is comparatively superior because of its length, and it can be harvested up to 25 cm, has no innate angulation, and can resist fracture because of a thick strong cortex.[11] FVFGs can accommodate to various locations and lengths along the vertebral column. This graft can also be osteotomized multiple times without disrupting the perfusion to the bone, allowing for double-strut designs for single or multi barrel segments for vertebrectomy defects.[6] Prior studies conducted by Winters et al have described using double-, triple-, and quadruple-barrel techniques to increase strength and filling of defects.[2,5] If osteotomies remain more than a few centimeters from each other, there is no risk of osseous weakening or devascularization.[12]

Although the benefits of FVFG in spine reconstruction have been extensively outlined herein, the use of this technique does have acknowledged limitations. First, the use of FVFG has been associated with donor-site morbidity, including sensory changes, pain, gait abnormalities, and wound infection/dehiscence.[38,39] However, previous findings by Momoh et al showed in a prospective study of 157 patients that, despite a complication rate of 31.2%, the majority of patients undergoing FVFG have no long-term functional limitations.[40] Other possible limitations of FVFG include the cost associated with longer operative times and the logistical difficulties inherent in coordinating multiple operative specialties. Harvesting and insetting a vascularized bone graft in the setting of an already challenging spinal reconstructive procedure is not always beneficial for the patient in terms of operative time and donor-site morbidity. It is the ultimate joint decision of all surgeons involved to coordinate a sound, logical, and rational plan for the patient undergoing the surgical procedure.[34]

In regard to the flap monitoring, several included studies in the current article reported that postoperative X-ray and CT scans are the two most reported examinations in flap monitoring.[16,20,31] In broad terms, the flap monitoring can be performed using a flap; however, because there was no skin paddle in this reconstruction case, it is challenging to evaluate it with a handheld doppler. Alternatively, the existing implantable Doppler, which can be placed around the fibula's pedicle, can be another option to detect flow in the absence of a skin pedicle. Although inserting such probes in spinal applications is technically feasible, if a disruption in flow were to be detected, it would warrant a return to the operating room for exploration. Unfortunately, the morbidity of an additional lengthy operation for flap salvage following two lengthy surgical stages is likely too great to justify the complex instrumentation, including pedicle screw placed around the flap. Therefore, most plastic and spine surgeons with experience doing these procedures leave the flap unmonitored, with the understanding that if the pedicle were to thrombose, the bone would still have utility as a standard nonvascularized autograft.[6]

The primary shortcoming of systematic review in this study is related to the constraints of case reports and case series. The complex nature of these cases and their limited indications restrict the ability to perform a prospective study, even making a multicenter study difficult to perform. Because of the small number of patients and limited indications, there was substantial selection bias in the patients presented. It should be noted that some of the studies are from the same institution and are part of a larger series; thus, the likelihood of participant duplication in the current study should be considered, which decreases the overall number of patients even further. Furthermore, this kind of study does not have a control group, so it is not possible to compare what happens to other individuals who do not have the disease or receive treatment. These sources of bias mean that reported results may not be generalizable to a larger patient population and, therefore, could not generate information on incidences or prevalence rates and ratios.[41] To our knowledge, there are few studies that compare nonvascularized bone grafting and FVFG in spinal reconstruction within a large study population; thus, it remains difficult to definitively compare the two techniques. Future directions include examining a larger cohort study of these patients to outline the effectiveness and indications more definitively for FVFG in spine reconstruction.

CONCLUSIONS

In conclusion, free vascularized fibular grafting of the spine offers significant advantages in spinal reconstruction in situations where previous attempts at union with conventional bone grafting have failed, especially when there are unfavorable host factors (radiation necrosis, osteomyelitis, areas previously operated on) as well as in the reconstruction of segmental defects secondary to tumor or infection. Notwithstanding its technical difficulties, the use of FVFG offers an effective and beneficial repair for patients who require spinal reconstruction. Ultimately, a multidisciplinary approach that weighs the risks and benefits of FVFG in an immediate setting needs to be undertaken for patients identified as having a higher risk of failure in the setting of spinal reconstruction. In addition, mutual collaboration of an experienced multidisciplinary team of surgical subspecialists, involving neuro, orthopedic and plastic and reconstructive surgeons, is required to successfully perform this type of complex reconstruction.

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DISCLOSURE

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