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Fibula graft under compression for the optimization of the transtibial amputation stump

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A R T I C L E I N F O

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A B S T R A C T

This study evaluates the effects of a modified bone bridge technique using a fibular graft with interfragmentary compression in transtibial amputation stumps, with the goal of reducing tibia-fibula mobility and enhancing terminal weight-bearing capacity and rehabilitation. Eleven patients, eight males and three females, underwent transtibial amputation using this technique. All grafts weresuccessfully integrated, with fragment union achieved within three months. No major stump complications were observed, although three patients required screw removal due to washer-related pain. Functionally, all patients underwent axial loading assessed by an examiner, with stump load tolerance being evaluated using a conventional scale. All patients tolerated axial loading without pain or discomfort, with an average maximum load-bearing capacity of approximately 50 % of body weight. This technique effectively creates a rigid bone bridge suitable for shorter residual limbs, facilitating prosthetic fitting and rehabilitation.

Introduction

With the increasing rate of lower limb amputations in Brazil [1], effective procedures are needed to ensure rapid and safe rehabilitation. An optimal transtibial residual limb should balance length, soft tissue coverage, and bone management to maximize prosthetic function and patient comfort [2]. In the conventional approach, the fibula is sectioned proximally to the tibia, but the union of the two bones has not been emphasized. This can pose challenges for patients who are unable to periodically change their prosthesis, which ends up becoming less adapted over time, impairing their ability to walk. In response to this issue, various alternative amputation techniques have been developed, aimed at improving functional results and patients' quality of life [3–6].

In this context, the bone bridge technique, initially described by Ertl, is recognized [7] for its goalof creating a connection between the tibia and fibula, providing a more stable stump and allowingdistal weight bearing. This pioneering technique has certain limitations that may restrict its applicability. As well as being a technique that requires a certain level of experience, its execution requires at least eight cm of preserved tibia, which may not be viable in cases of infection and post-trauma.

The study in question proposes a technical adaptation for the construction of a bone bridge that overcomes these limitations, improving clinical results and, consequently, the prosthetic adaptation of patients. The modification involves the use of a fibula graft under interfragmentary compression, with the aim of increasing the stability and functionality of the stump. It is hoped that this technique will be a viable and effective alternative for patients undergoing transtibial especially in contexts with limited resources, where the need for efficient rehabilitation is crucial.

Materials and methods

Eleven patients underwent surgery, eight men and three women. Except for one patient with congenital malformations and one with an infected diabetic foot, the remaining patients suffered traumatic injuries. Ages ranged from 17 to 68 years, with an average follow-up time of approximately 4 years, ranging from 1 to 7 years (Table 1). Patients were assessed clinically and radiographically throughout the postoperative follow-up.

All patients received antibiotic prophylaxis (cephalosporin 2 g, administered intravenously 30 min before the start of the procedure).

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Table 1
Demographic and clinical profile of patients undergoing transtibial amputation with bone bridge technique.

Gender	Age	Cause of amputation	Follow-up time (years)
Woman	17	Proteus syndrome	07
Man	49	Truck accident	06
Man	34	Motorcycle accident	06
Man	24	Motorcycle accident	06
Woman	19	Motorcycle accident	05
Woman	32	Motorcycle accident	05
Man	28	Motorcycle accident	05
Man	31	Bicycle accident	04
Woman	23	Car accident	03
Woman	27	Motorcycle accident	02
Man	68	Diabetic foot infection	01

Table 1. Distribution of patients by sex, age at the time of amputation, cause of amputation, and follow-up time.

The amputation was performed conventionally, according to the precepts proposed by Marian Weiss [8].

The modification involves the use of a fibula graft under interfragmentary compression to increase the stability and functionality of the stump. After the procedure, a fragment of fibula was removed from the segment to be discarded to be used as a graft, and a window was made in the lateral cortex of the tibia, exposing its medullary canal. The bone graft was inserted into the tibia and supported on the fibula to promote adequate stabilization and integration. The graft was fixed under interfragmentary compression with a 4.5 mm screw, which was introduced through distal part of the remaining fibula, into the medullary cavity of the graft towards the medial cortex of the tibia (Fig. 1).

All patients were instructed to bear maximum weight on the residual limb, as documented in their medical records and supported by photos and videos. The patients were subjected to resistance applied by the examiner to the stump while it was supported on the examination table, to assess their ability to bear weight (Fig. 2). Additionally, patients were asked to place the residual limb on a calibrated scale for direct measurement of the weight they could support.

Results

All the grafts have healed, with union of the fragments been observed between 12 and 14 weeks of follow-up, allowing terminal weight bearing on the stump. There was no need to revise the stump in any of the patients. However, in three cases, the screw had to be removed due to the pain experienced by the patients from the washer used next to the screw head (Fig. 3). After these episodes, the screw was used without a washer, without compromising graft healing or the patients' rehabilitation.

Fig. 1. Immediate postoperative radiograph of a patient who underwent transtibial amputation using the bone bridging technique.

Fig. 2. Radiograph of a patient 6 years after the removal of the interfragmentary screw head washer.

All patients developed a functional stump that allowed proper prosthetic adaptation. Although formal gait analysis was not performed, a review of medical records suggested that patients who underwent this technique experienced shorter rehabilitation times. Additionally, direct weight-bearing assessment confirmed that among the evaluated patients, all of them were able to support >50 % of their body weight on the residual limb (Fig. 4), reinforcing the functional capacity provided by this technique.

Discussion

The procedure is easy to perform and has proved to be efficient in building a bone bridge that is resistant to the load demanded during walking, without any significant complications. This method has advantages over the Ertl technique, as it does not require the 8 cm length of the tibia to build the periosteal tube, and, therefore, can be performed on shorter stumps. It allowed patients to be rehabilitated quickly and at a lower cost. The fact that the stump allows the support of terminal weight meant that the prosthesis cartridge could be simpler, without causing discomfort to the patient.

In the conventional amputation, the stump may narrow due to the migration of the fibula, which moves medially due to the absence of the distal syndesmosis, resulting in a conical shape stump [9]. The conical shape reduces the contact area and increase the load and the pression on the stump, causing pain, ulcers and adaptation difficulties to the prosthesis [3,10]. In addition, the conventional technique keeping the bone marrow canal open, reducing the intraosseous pressure and the

Fig. 3. Patients undergoing stump load testing on the examination table by the examiner.

Fig. 4. Patient placing the stump on the scale to measure the supported weight.

intraosseous perfusion of the distal tibia. This scenario, along with the lack of mechanical support, leads to bone demineralization, resulting in additional pain, difficulty in prosthesis adaptation, generating a vicious cycle of disuse. Interrupting this vicious cycle becomes difficult in a stump that does not have the characteristics described in this study. The formation of the bone bridge closes the marrow canal, generates a larger support area, which allows for better pressure distribution, good bone trophism and, therefore better patient's ability to adapt [3].

The modern orthopedic socket is primarily designed to avoid terminal loading and distribute the load around the cartridge, but in this context, it needs adjustment techniques at certain intervals to maintain the correct adaptation to the stump over time usually available in high income countries [9,11]. This is not our reality in Brazil, especially in the context of public health system. In a systematic review carried out by Kahle et al. in 2017, the authors compared the results between traditional transtibial amputation and amputation with a bone bridge and concluded that the latter offers significant mechanical advantages [7]. The proposed technique emerges as a solution to mitigate this problem, allowing the development of a high-performance stump, especially for young patients with high functional demands.

This study has important limitations due to its small sample size, the lack of a control group and the fact that the patients were not assessed by gait analysis. However, some strengths can be highlighted, such as the creation of a reliable bone union between the fibula and tibia, regardless of the size of the stump, the absence of significant complications and the simplicity of the method. The evaluations indicate that there was functional improvement in individuals who underwent amputation using this technique, revealing promising potential.

Conclusion

This case series demonstrates that the presented technique is both feasible and effective for patients undergoing transtibial amputation, especially in resource-limited settings. The technique not only facilitates the ability to bear terminal support on the stump with at least 50 % of body weight but also enhances prosthetic adaptation. Furthermore, it holds the potential to increase the average lifespan of prostheses for transtibial amputees, highlighting its promising impact.

Ethics statement

This study was conducted in accordance with the ethical standards of the institutional research committee and was approved by the Ethics Committee of the University of Campinas (UNICAMP), under registration number 1,201,224.6.0000.5404, on October 16, 2024.

CRediT authorship contribution statement

Erica Blenda da Silva: Writing – original draft, Project administration, Formal analysis, Data curation. **Andre Luis Lugnani de Andrade:** Supervision, Formal analysis. **Felipe Lins Rossi:** Writing – review & editing, Supervision, Project administration, Formal analysis. **William Dias Belangero:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Bruno Livani:** Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors of this study declare that there are no conflicts of interest regarding the research, authorship, and/or publication of this article.

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