

Subtalar arthrodesis with bone graft. Is it needed for smokers?

Artrodese subtalar com enxerto ósseo. Uma necessidade para tabagistas?

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ABSTRACT

Objective: To evaluate the union rate of subtalar arthrodesis in smokers and nonsmokers and effect of the use of different types of autologous bone grafts.

Methods: This was a retrospective study with radiological evaluation of patients with subtalar arthrosis who underwent primary arthrodesis at a reference hospital between January 2008 and December 2014. Patients with a minimum follow-up period of 12 months were included and were divided into smokers and nonsmokers with or without autologous bone grafting.

Results: In total, 235 patients with a mean age of 47 years (range: 19-74 years) were evaluated, among whom 90 (40%) were smokers and 141 (60%) were nonsmokers. In 221 (94%) cases, the indication for arthrodesis was due to sequelae of calcaneal fractures. A bone graft was used in 65 (27.7%) patients. The overall union rate was 85.4%, and 14.6% of the patients progressed to pseudoarthrosis. A statistically significant difference was found in the nonunion rate in smokers (p -value=0.015 by chi-square test), especially in those who did not receive a bone graft (p -value=0.014 by chi-square test). However, no significant difference was found between smokers who received a bone graft and those who did not (p -value=0.072 by chi-square test). The union rate was related to the donor site, with pseudoarthrosis in 33.3% of surgeries with an autologous calcaneal bone graft (p -value=0.011).

Conclusion: Smoking increased the likelihood of pseudoarthrosis in subtalar arthrodesis by 2.5-fold, and pseudoarthrosis is related to the autologous bone graft donor site.

Level of Evidence III; Therapeutic studies; Comparative Retrospective Study.

Keywords: Arthrodesis; Subtalar joint; Pseudoarthrosis; Tobacco use disorder.

RESUMO

Objetivo: Avaliar a taxa de consolidação da artrodese subtalar em pacientes tabagistas e não-tabagistas e a influência do uso de diferentes tipos de enxerto ósseo autólogo.

Métodos: Estudo retrospectivo com avaliação radiológica dos pacientes com diagnóstico de artrose subtalar submetidos à artrodese primária em um hospital de referência, entre janeiro de 2008 e dezembro de 2014. Foram incluídos os pacientes com tempo mínimo de seguimento de 12 meses, divididos em tabagistas e não tabagistas e com utilização ou não de enxerto ósseo autólogo.

Resultados: Foram avaliados 235 pacientes com idade média de 47 anos (19-74 anos), sendo 90 (40%) pacientes tabagistas e 141 (60%) pacientes não-tabagistas. Em 221 (94%) casos a indicação se deveu à seqüela de fratura de calcâneo. O enxerto ósseo foi utilizado em 65 (27,7%) pacientes. A taxa de consolidação global foi de 85,4%, e 14,6% dos pacientes evoluíram com pseudoartrose. Houve diferença significativamente estatística da taxa de não-consolidação em fumantes (p -valor=0,015 do teste qui-quadrado), principalmente naqueles que não receberam enxerto ósseo (p -valor=0,014 do teste qui-quadrado). Entretanto, não houve diferença significativa entre os fumantes que receberam ou não enxerto ósseo (p -valor=0,072 do teste qui-quadrado). A taxa de consolidação relacionou-se com o sítio doador, com pseudoartrose em 33,3% das cirurgias com enxerto autólogo do calcâneo (p -valor=0,011).

Work performed at the Instituto Nacional de Traumatologia e Ortopedia, Rio de Janeiro, RJ, Brazil.

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Conclusão: O tabagismo aumentou a probabilidade de pseudoartrose nas artrodeses subtalares em 2,5 vezes e a pseudoartrose está relacionada com o sítio doador do enxerto autólogo.

Nível de Evidência III; Estudos Terapêuticos; Estudo Retrospectivo Comparativo.

Descritores: Artrodese; Articulação talocalcânea; Pseudoartrose; Tabagismo.

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INTRODUCTION

Isolated subtalar arthrodesis has been used to treat several diseases that affect the hindfoot, including tarsal coalitions, posterior tibial tendon dysfunction, inflammatory arthritis and posttraumatic arthrosis due to fracture of the calcaneus or talus, with the latter being one of the most frequent reasons for indicating this procedure^(1,2). This procedure has been shown to be effective in the control of pain and functional limitation of primary or secondary subtalar osteoarthritis, with high rates of patient satisfaction, preserving some of the hindfoot range of motion⁽¹⁻³⁾. However, some authors did not find such satisfactory numbers, with a higher rate of pseudoarthrosis, especially in smokers^(1,4,5).

Smoking, in addition to being recognized as one of the greatest public health problems in the world, has well-known negative effects in several postoperative outcomes, such as surgical wound complications, higher nonunion rates and worse results in arthroplasties⁽⁶⁻⁹⁾.

Bone grafting is an important component of foot and ankle arthrodesis that has been widely used in recent decades of the past century and is not necessary in the absence of complicating factors⁽¹⁰⁾. It is used as an osteoinductive material and to improve the osteogenic potential under conditions of suboptimal systemic biology, in revision surgeries after failed fusion and when a major structural defect is present after joint debridement⁽¹¹⁾.

The primary objective of this study was to evaluate the union rate of subtalar arthrodesis in smokers and nonsmokers and, as a secondary objective, to evaluate the effect of bone grafts on the union rate.

METHODS

This study was approved by the Research Ethics Committee with registration in the Brazil Platform under CAAE number: 64396516.4.0000.5273.

This was a retrospective cases series in which 235 patients underwent primary subtalar arthrodesis between January 2008 and December 2014. Surgeries were performed

by all physicians in the Foot Surgery group and not by a single surgeon.

The sample included all patients who underwent surgery with a minimum follow-up time of 12 months. Patients with a history of previous infection, diabetes mellitus, revision surgeries and arthrodesis of other joints in addition to the subtalar joint in the same surgical procedure, as well as skeletally immature patients, were excluded.

All patients were evaluated radiologically by X-rays on anteroposterior (AP), lateral and oblique (Broden's) views 3 months after surgery, which were stored in the institution's database. At that time, in cases where there was doubt regarding union, computed tomography (CT) was performed to diagnose pseudoarthrosis. The obliteration of the joint space, with the presence of trabeculae crossing the subtalar joint, was used as a radiographic criterion to define fusion/union. The tomographic criterion used was the fusion of at least 50% of the posterior facet.

The patients were divided into two groups: smokers and nonsmokers. Regarding the bone graft, it varied according to the personal choice of the surgeon, using as donor sites the iliac crest, proximal end of the tibia and posterior calcaneal tuberosity. The age and sex of the patients were also evaluated according to the union rate.

The data collected from the medical records were used to construct a database that was analyzed statistically using *Statistical Package for the Social Science* (SPSS) software, version 22.0. The graphs were constructed using Microsoft Excel 2011 software. In the inferential analysis, two complementary proportions were compared using the binomial test, and the association between two qualitative variables was analyzed by chi-square test. All analyses considered a maximum significance level of 5% (0.05).

Surgical technique

Patients were placed in the lateral decubitus position, with a pneumatic tourniquet in the thigh of the operated limb. The sinus tarsi was accessed through a longitudinal approach, approximately 5 cm, starting at the distal end of

the fibula. After exposure of the subtalar joint, the articular surfaces were debrided with the aid of the spreader, and the subchondral bone was drilled with a 1.5-mm K wire. Reduction of the subtalar joint was then carried out, with alignment of the hindfoot and temporary K-wire fixation, in an anterograde manner, from the posterolateral region of the calcaneus to the body of the talus, crossing the posterior facet of the calcaneus. After confirmation of the correct positioning of the K wires in the lateral and AP views with the "C-arm", final fixation was performed using one (171 feet), two (63 feet) or three (one foot) seven-millimeter cannulated screws, parallel to each other, based on the surgeon's preference.

The patients were discharged the next day with a short leg cast, avoiding weight-bearing. After 2 weeks, the stitches were removed, and partial weight-bearing with a short leg cast and the aid of crutches was allowed until the 12th week, when full weight-bearing was allowed and the cast was removed. At that point, X-rays were taken to evaluate the joint fusion (Figure 1). In patients for whom it was not possible to determine via X-rays where union was achieved, CT was performed to confirm the arthrodesis (Figure 2).



Figure 1. Pre- and postoperative X-ray of subtalar arthrodesis. **Source:** Author's personal archive.

RESULTS

A total of 247 subtalar arthrodeses performed between 2008 and 2014, with a minimum follow-up of 12 months, were evaluated. Based on the exclusion criteria, 12 patients were excluded: six patients with diabetes mellitus, one patient with a previous infection in the calcaneus, one patient undergoing tibiotarsal arthrodesis in the same surgery and four due to missing data in the medical record.

The statistical sample consisted of 235 patients: 45 women (19.1%) and 190 men (80.9%). The frequencies indicated that the most typical age groups of patients undergoing subtalar arthrodesis were 40 to 46 years (29.5% of cases) and 47 to 53 years (26.9% of cases). Subtalar arthrodesis is uncommon in patients younger than 26 years (only 2.5% of cases) and older than 67 years (3.0% of cases). This typical pattern was observed in the male group; however, in the female group, the predominant age groups were 47 to 53 years and 54 to 60 years (24.4%), and a higher proportion of patients over 67 years was in the female group (8.9%). At the global level, patients undergoing subtalar arthrodesis were aged between 19 and 74 years, with a mean age of 47 years.

Reasons for indicating arthrodesis included the following: sequelae of calcaneal fractures in 221 (94%) cases; tarsal coalition in eight (3.4%) cases; sequelae of talus fractures in two (0.9%) cases; primary arthrodesis in two (0.9%) cases; osteochondral lesion of the calcaneus in one (0.4%) case; and posterior tibial dysfunction in one (0.4%) patient.

The sample comprised 94 (40%) smokers and 141 (60%) nonsmokers. Bone grafting was performed in 65 arthrodeses (27.7%). Among the patients who received a bone graft,

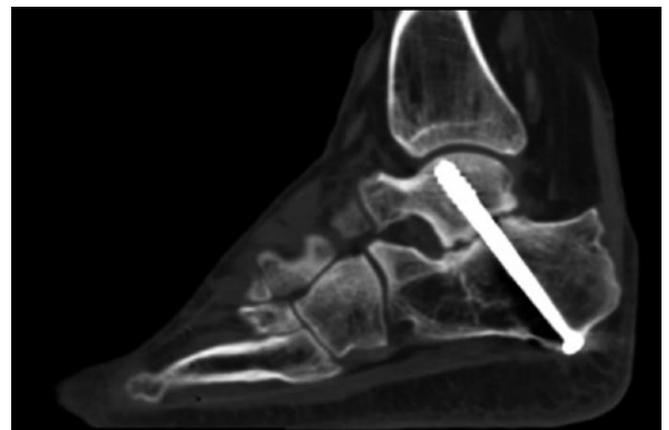


Figure 2. Tomographic image of pseudoarthrosis. **Source:** Author's personal archive.

the donor site was the iliac crest in 38 (58.5%) cases, the tibia in 13 (20.0%) cases and the calcaneus in 14 (21.5%) cases. Grafting was performed in 21.3% of nonsmokers and at a significantly higher proportion ($p=0.007$) in smokers, at 37.2%.

The variance and mean age of the subgroups of smokers and nonsmokers, as well as those who received or did not receive a graft, were compared by parametric tests that showed no significant difference between the groups (p -values greater than 0.05 in the two tests). Regarding the number of screws, no significant difference was found between the patients who achieved fusion and those who did not, smokers and nonsmokers, those who received a graft or not and between donor graft sites (p -values greater than 0.05 in all tests).

The overall union rate was 85.4%, with 14.6% of patients presenting with pseudoarthrosis. The proportion of pseudoarthrosis in the subgroup of smokers (21.3%) was significantly different from the proportion of pseudoarthrosis in the group of nonsmokers (9.9%) (p -value=0.015 by chi-square test). The odds ratio was 2.5, with a significant confidence interval (1.2, 5.1). The odds of a smoker presenting with pseudoarthrosis in subtalar arthrodesis was 2.5-fold greater than that of a nonsmoker presenting with pseudoarthrosis in subtalar arthrodesis. Figure 3 illustrates the difference between the incidence of pseudoarthrosis in the two groups.

Considering the graft cases, a significant association was found between the outcome and graft donor site (p -value=0.011 by chi-square test). Among the cases of pseudoarthrosis, most were calcaneal grafts (62.5% of the cases). The incidence of pseudoarthrosis in the cases of grafts from the calcaneus was 33.3% (5 of 14 cases), that of pseudoarthrosis in the cases of grafts from the iliac crest was 5.3% (2 of 38 cases) and that of pseudoarthrosis in the cases of grafts from the tibia was 7.7% (1 of 13 cases). The difference between these incidences was statistically significant (p -value=0.011 by chi-square test), that is, pseudoarthrosis was significantly more prevalent in cases of bone grafts from the calcaneus. The difference between these incidences is illustrated in Figure 4.

Table 1 shows the incidence of outcomes in the four subgroups defined according to smoking and grafting. The incidence of pseudoarthrosis was higher in the group of smokers who did not receive a graft, and the difference was statistically significant (p -value=0.014 by chi-square test for the four groups). However, comparing the incidence of pseudoarthrosis in the group of smokers who did receive a graft (11.4%) and incidence of pseudoarthrosis in

the group of smokers who did not receive a graft (27.1%), the chi-square test did not detect a significant difference between these groups (p -value=0.072 by chi-square test). Thus, smokers who did not receive a graft were 2.9-fold

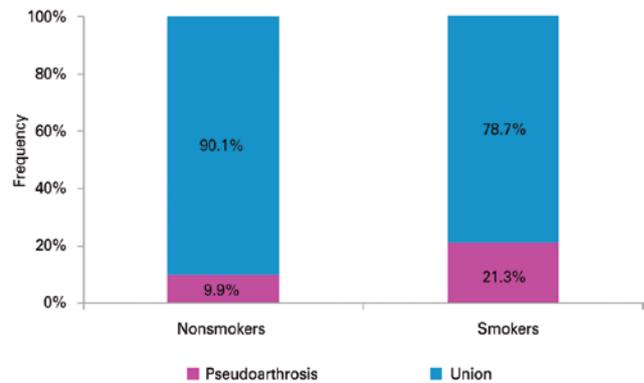


Figure 3. Association between pseudoarthrosis and smoking. **Source:** Prepared by the author based on the results of the research.

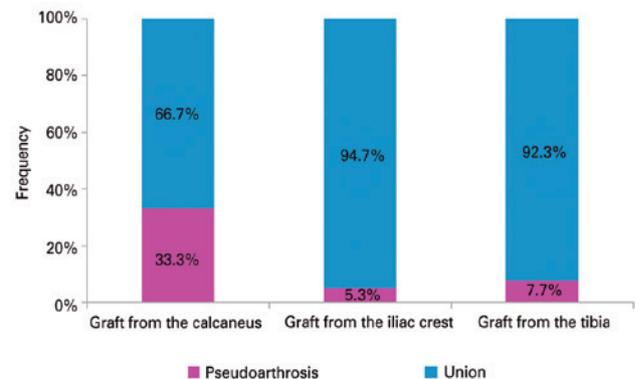


Figure 4. Incidence of pseudoarthrosis in cases that received a graft, by graft donor site. **Source:** Prepared by the author based on the results of the research.

Table 1. Outcomes in the four subgroups defined according to smoking and grafting

Results in X-ray/CT	Nonsmoker		Smoker		Total
	Did not receive graft	Received graft	Did not receive graft	Received graft	
Union	101	26	43	31	201
	91.0%	86.7%	72.9%	88.6%	85.5%
Pseudoarthrosis	10	4	16	4	34
	9.9%	13.3%	27.1%	11.4%	14.5%
Global	111	34	59	35	243
	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Prepared by the author based on the results of the research.

more likely to present with pseudoarthrosis than smokers who did receive grafts; however, because the sample of this study did not show statistically significant differences for this risk, the incidence of pseudoarthrosis in these two groups is not significantly different.

DISCUSSION

In the literature, there is a higher prevalence of subtalar joint arthrodesis in men⁽¹²⁻¹⁴⁾. In this study, there was a large predominance of operated male patients (80.9%). Regarding the age group, there was a predominance of individuals aged between 40 and 53 years, with a mean age of 47 years, a finding that was very similar to that found by Davies⁽¹²⁾ in their study (46 years).

The main indication for arthrodesis was sequelae of calcaneal fractures, corresponding to 94% of the patients in our sample. In the studies by Easley⁽¹⁾ and Davies⁽¹²⁾, this indication was also the main reason but with lower frequencies (62.4% and 67.3%, respectively). In turn, Shah⁽¹⁵⁾ reported posterior tibial tendon dysfunction as the main reason for the indication for arthrodesis.

The mean union rate of isolated subtalar arthrodesis with cannulated screws found in the literature ranged from 84 to 100%^(1,3,4,12-14), similar to that found in our study (85.4%). Easley et al.⁽¹⁾ followed the evolution of 184 feet operated by isolated arthrodesis, with progression of 30 cases (16%) to pseudoarthrosis, which was slightly higher than our nonunion rate (14.6%).

Chahal et al.⁽⁴⁾ evaluated 88 patients and found a union rate of 68.4% in smokers and 89.8% in nonsmokers. Additionally, they achieved 84.8% union using bone grafting, while the rate was only 65% in those who did not use it, regardless of smoking habits. Easley et al.⁽¹⁾ reported a 92% union rate in nonsmokers versus 73% in smokers ($p < 0.01$). In our patients, the union rate in nonsmokers was 90.1%, consistent with that found in the literature, and a union rate of 78.7% was observed in smokers ($p = 0.015$). Thus, in the present study, we observed that the odds of a smoking patient progressing to pseudoarthrosis was 2.5-fold higher than that of nonsmokers, a value similar to that found by Ishikawa⁽¹⁶⁾ (2.7-fold). On the other hand, in a recent study by Shah⁽¹⁵⁾, although smokers had a lower union rate than nonsmokers (78% and 88%, respectively), with an odds ratio of 0.471, this proportion was statistically significant ($p = 0.19$).

Nicotine causes an increase in catecholamines, leading to vasoconstriction and hypoxia, increased platelet aggregation and reduced proliferation of keratinocytes,

erythrocytes, macrophages and fibroblasts⁽¹⁶⁻¹⁸⁾. Nicotine also acts directly on the function of osteoblasts and osteoclasts⁽¹⁹⁾. Carbon monoxide binds to hemoglobin and decreases the oxygen-carrying capacity⁽²⁰⁾. Direct lymphocyte damage and decreased calcium absorption are also possible causes of a higher nonunion rate in smokers⁽²¹⁾.

Easley et al.⁽⁵⁾ reviewed 45 cases of pseudoarthrosis of tibiotarsal arthrodesis and cited as possible factors for nonunion diabetes mellitus (nine cases), osteonecrosis of the bones involved (six cases) and 20 patients (44%) who were smokers. These high rates of pseudoarthrosis demonstrate the importance of smoking as an etiological factor of this complication in foot and ankle surgeries⁽⁵⁾.

When analyzing only smoking patients, we obtained 27.4% of pseudoarthrosis in those who did not receive a bone graft and 11.4% in those who received one. Thus, smoking patients who did not receive a bone graft had a 2.9-fold higher likelihood of not achieving union at the site of the subtalar arthrodesis; however, this difference was not statistically significant ($p = 0.072$). Shah et al.⁽¹⁵⁾ found different results, with a higher likelihood of achieving union in patients who did not receive a graft (87%) than smokers who did receive a graft (73%).

In our study, all cases requiring bone grafting were performed using an autologous graft. According to Bostrom⁽²²⁾, compared with other types of bone grafts, autogenous grafts have a lower risk of infection and are more likely to be incorporated into their new site because they have minimal or no immunogenicity. We observed that the evolution to the fusion of subtalar arthrodesis was related to the graft donor site. In 33.3% of the surgeries with grafts from the calcaneus, no union was detected; the same occurred in 7.7% of grafts from the tibia and 5.3% of grafts from the iliac crest. This difference was statistically significant ($p\text{-value} = 0.011$). Miller and Chiodo⁽²³⁾ stated that only the cancellous bone harvested from the iliac crest has significant osteogenic capacity, but the osteoinductive capacity of bone harvested from other sites would be sufficient to achieve fusion. These authors defend the need for the use of grafts from the iliac crest in patients with a high degree of pseudoarthrosis⁽²³⁾.

In the present study, there were no complications in the donor site in any surgical procedure or any relevant postoperative complaints, despite what was expected. Deorio and Faber⁽²⁴⁾ presented a low rate of complications, with a 6.7% incidence of hematoma at the donor site after harvesting the graft from the iliac crest. O'Keeffe⁽²⁵⁾ presented 1.3% of complications after grafting from the proximal ti-

bia. Raikin and Brislin⁽²⁶⁾ reported five cases of 44 patients with pain when wearing footwear after grafting from the calcaneus.

A limitation of this study is its retrospective design, which does not allow establishment of a cause-effect relationship, achievement of homogeneity in the studied groups or control over the factors that may affect the results⁽²⁷⁾. Another limitation is that the diagnosis of pseudoarthrosis was based on physical examination, X-rays and CT scans, but confirmation of union was not based on CT scans in all patients. Despite being a much more specific examination⁽²⁸⁾, CT scans would incur a high cost and

unnecessary exposure of patients who did not present symptoms or X-rays suggestive of fusion failure.

CONCLUSION

Smoking increases the likelihood of pseudoarthrosis in subtalar arthrodeses by 2.5-fold, and pseudoarthrosis is related to the autologous bone graft donor site. Additionally, bone grafting was not confirmed as a protective factor in smokers, although there were indications that it leads to a 2.9-fold decrease in the likelihood of pseudoarthrosis occurring in these patients.

Authors' contributions: Each author contributed individually and significantly to the development of this article: GGBS *(<https://orcid.org/0000-0003-1012-2020>) conceived and planned the activities that led to the study, wrote the article, participated in the review process, approved the final version; IMCJ *(<https://orcid.org/0000-0002-7815-6086>) wrote the article, participated in the review process; HM *(<https://orcid.org/0000-0001-7527-969X>) wrote the article, interpreted the results of the study; GFM *(<https://orcid.org/0000-0001-9817-3089>) wrote the article, participated in the review process. *ORCID (Open Researcher and Contributor ID).

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