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Risk factors for non-union in foot and ankle arthrodesis: a population-based case–control study using registry data

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Abstract

Background Nonunion is a common complication following foot and ankle arthrodesis. This study endeavoured to determine the risk factors for nonunion in foot and ankle arthrodesis.

Methods This was a retrospective case–control study using the National Health Insurance Research Database. Patients who underwent foot and ankle arthrodesis with a minimum follow-up duration of 6 months were included. *International Classification of Diseases* codes were used to identify diagnoses and treatment. Patients with nonunion were matched by age and sex with patients with union at a ratio of 1:4. Logistic regression was performed to compare between patients with nonunion and controls with union to ascertain the effects of various risk factors.

Results A total of 107 joints were identified as nonunion, and 428 age- and sex-matched controls were selected. Patients with diabetes mellitus had a 1.710 times (95% CI = 1.060 – 2.756, $p = 0.0278$) higher risk of nonunion than those without. No significant differences were observed in the risk of nonunion in relation to which joint was treated; the presence of osteoarthritis, traumatic osteoarthritis, rheumatoid arthritis, osteoporosis, or open/arthroscopic arthrodesis; internal or external fixation; or the usage of a bone graft. For patients without diabetes mellitus, those who underwent arthrodesis in the tarsometatarsal joint had a 6.507 times (95% CI: 1.045 – 40.522, $p = 0.0256$) higher risk of nonunion compared to those who underwent arthrodesis in the ankle joint.

Conclusion Diabetes mellitus increases the risk of nonunion among patients with and without diabetes mellitus. For those without diabetes mellitus, arthrodesis in the tarsometatarsal joint is associated with the highest risk of nonunion.

Keywords Ankle arthrodesis, Foot arthrodesis, Risk factor, Nonunion

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Background

Foot and ankle arthrodesis is a surgical treatment for end-stage arthritis, particularly in patients with severe pain and deformity that do not respond to conservative managements. Despite its effectiveness in pain reduction and function recovery, nonunion remains a common complication that necessitates revision surgery due to persistent pain and impaired function, which poses additional challenges for both surgeons and patients.

Several factors have been identified as potential contributors to nonunion. A meta-analysis indicated that being male and having a history of smoking, open injury, infection at the operative site prior to arthrodesis, or avascular necrosis were risk factors for non-union [1]. However, the authors urged caution when interpreting these results because of the limited number of cases for some variables of interest, heterogeneity among the included studies, and bias due to confounders. Recently, two studies have used a large claims database to determine the risk factors for nonunion in ankle arthrodesis, and the results revealed that patients with obesity [2] and diabetes mellitus [3] exhibited an increased risk of nonunion. However, these two studies did not account for surgery-related variables in their analyses, such as fixation methods, bone graft utilization, and surgical approach, which may influence the union rate.

Given these limitations, there remains a need for a comprehensive evaluation of both patient-related and surgery-related risk factors for nonunion following foot and ankle arthrodesis. However, the number of nonunion cases is limited in single-center studies, making it challenging to compare risk factors with adequate statistical power. Therefore, we conducted a population-based case–control study to compare the distributions of patient-related and surgery-related factors between patients with union and nonunion, which allows for a larger sample size and a more generalizable analysis.

Table 1 ICD-10-PCS codes for identifying foot and ankle arthrodesis

	ICD-10-PCS codes
Treated joint	
Ankle joint	0SGFxxx (right), 0SGGxxx (left)
Tarsometatarsal	0SGKxxx (right), 0SGLxxx (left)
Metatarsal-phalangeal joint	0SGMxxx (right), 0SGNxxx (left)
Toe phalangeal joint	0SGP xxx (right), 0SGQxxx (left)
Tarsal Joint	0SGHxxx (right), 0SGJxxx (left)
Open arthrodesis	0SGF0xx, 0SGG0xx, 0SGK0xx, 0SGL0xx, 0SGM0xx, 0SGN0xx, 0SGP0xx, 0SGQ0xx, 0SGH0xx, 0SGJ0xx
Arthroscopic arthrodesis	0SGF3xx, 0SGG3xx, 0SGK3xx, 0SGL3xx, 0SGM3xx, 0SGN3xx, 0SGP3xx, 0SGQ3xx, 0SGH3xx, 0SGJ3xx, 0SGF4xx, 0SGG4xx, 0SGK4xx, 0SGL4xx, 0SGM4xx, 0SGN4xx, 0SGP4xx, 0SGQ4xx, 0SGH4xx, 0SGJ4xx
Usage of bone graft	0SGF07Z, 0SGF37Z, 0SGF47Z, 0SGG07Z, 0SGG37Z, 0SGG47Z, 0SGH07Z, 0SGH37Z, 0SGH47Z, 0SGJ07Z, 0SGJ37Z, 0SGJ47Z, 0SGK07Z, 0SGK37Z, 0SGK47Z, 0SGL07Z, 0SGL37Z, 0SGL47Z, 0SGM07Z, 0SGM37Z, 0SGM47Z, 0SGN07Z, 0SGN37Z, 0SGN47Z, 0SGP07Z, 0SGP37Z, 0SGP47Z, 0SGQ07Z, 0SGQ37Z, 0SGQ47Z, 0SGF0KZ, 0SGF3KZ, 0SGF4KZ, 0SGG0KZ, 0SGG3KZ, 0SGG4KZ, 0SGH0KZ, 0SGH3KZ, 0SGH4KZ, 0SGJ0KZ, 0SGJ3KZ, 0SGJ4KZ, 0SGK0KZ, 0SGK3KZ, 0SGK4KZ, 0SGL0KZ, 0SGL3KZ, 0SGL4KZ, 0SGM0KZ, 0SGM3KZ, 0SGM4KZ, 0SGN0KZ, 0SGN3KZ, 0SGN4KZ, 0SGP0KZ, 0SGP3KZ, 0SGP4KZ, 0SGQ0KZ, 0SGQ3KZ, 0SGQ4KZ

Methods

This study was performed in accordance with the guidelines of the Declaration of Helsinki. The study design was approved by Ditmanson Medical Foundation Chia-Yi Christian Hospital institutional review board (approval no.: 2020057), and the institutional review board waived the requirement to obtain the informed consent.

Data source

This study adopted a case–control design, and data were collected retrospectively from the National Health Insurance Research Database (NHIRD). This population-based database covers > 99% of the approximately 23 million people in Taiwan. *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) and *ICD-10-CM/Procedure Coding System* (*ICD-10-CM/PCS*) codes were used for identifying diagnoses and medical classification of outpatient and hospitalisation treatments.

Study participants

Patients who underwent foot and ankle arthrodesis between January 2016 and December 2017 with a minimum 6-month follow-up period were identified from the database by using *ICD-10-PCS* codes (Table 1), and patients who had undergone foot and ankle arthrodesis before January 2016 were excluded. Patients were categorised into two groups on the basis of whether they experienced nonunion, which was indicated by the record of any of the following events in their medical history: (1) revision arthrodesis in the joint for which arthrodesis was performed, (2) conversion to total ankle arthroplasty (*ICD-10-PCS* codes 0SRF0J9, 0SRF0JA, 0SRF0JZ, 0SRG0J9, 0SRG0JA, or 0SRG0JZ) in the ankle joint for which arthrodesis was performed, or (3) the diagnosis of nonunion (*ICD-10-CM* code M96.0). Patients with nonunion were matched by age and sex with patients with union at a ratio of 1:4. We stratified individuals into five-year intervals and performed single-variable matching

based on age stratification and sex. The age stratification by five-year intervals includes the following groups: 1–5 years old, 6–10 years old, 11–15 years old, and continues in similar intervals up to 91–95 years old, finally concluding with 96–100 years old.

The baseline characteristics of patients were extracted from the database, and diagnostic codes were examined within 1 year before the index foot and ankle arthrodesis. The relevant variables were as follows: (1) age, sex, and length of hospital stay; (2) the joint that underwent arthrodesis, which was identified using *ICD-10-PCS* codes (Table 1); (3) whether open/arthroscopic arthrodesis was performed, which was identified using*ICD-10-PCS* codes (Table 1); (4) the use of a bone graft (yes/no), which was identified using *ICD-10-PCS* codes (Table 1); (5) whether the patient had osteoarthritis (*ICD-10-CM* codes M19.07 and M19.27) or traumatic osteoarthritis (*ICD-10-CM* code M19.17); (6) whether the patient had rheumatoid arthritis (*ICD-9-CM* code 714.0; *ICD-10-CM* codes M05, M06.0, and M06.9); (7) whether the patient had diabetes mellitus (*ICD-9-CM* code 250, *ICD-10-CM* codes E10, E11, and E13)—patients with the diagnosis of gestational diabetes mellitus were excluded (*ICD-9-CM* codes 648.0 and 648.8, *ICD-10-CM* code O24.41); (8) whether the patient had Charcot joint (*ICD-9-CM* codes 713.5, *ICD-10-CM* codes M14.60 and M14.67); and (9) whether the patient had osteoporosis (*ICD-9-CM* code 733.0, *ICD-10-CM* codes M80 and M81). Anatomical Therapeutic Chemical codes were also used to identify osteoporosis (zoledronic acid: M05BA08; ibandronic acid: M05BA06; teriparatide: H05AA02; denosumab: M05BX04; alendronate: M05BA04; and raloxifene: G03XC01).

Table 2 Patient characteristics

	Union	Nonunion	*p*-value
Number of joints	432	108	
Age (years)	54.33 ± 14.23	54.25 ± 14.52	0.956
Male	208(48.1%)	52(48.1%)	1.000
Treated joint			
Ankle	168(38.9%)	53(49.1%)	0.138
Tarsometatarsal	33(7.6%)	12(11.1%)	
Metatarsal-phalangeal	48(11.1%)	9(8.3%)	
Toe phalangeal	53(12.3%)	8(7.4%)	
Tarsal	130(30.1%)	26(24.1%)	
Approach			
Open arthrodesis	413(95.6%)	103(95.4%)	0.917
Arthroscopic arthrodesis	19(4.4%)	5(4.6%)	
Usage of bone graft	77(17.8%)	22(20.4%)	0.541
Diagnosis			
Osteoarthritis	47(10.9%)	13(12.0%)	0.939[a]
Traumatic osteoarthritis	120(27.8%)	30(27.8%)	
Rheumatoid arthritis	32(7.4%)	8(7.4%)	
Charcot's joint	5(1.2%)	2(1.9%)	
None of above	228(52.8%)	55(50.9%)	
Diabetes mellitus	94(21.8%)	37(34.3%)	0.007
Osteoporosis	31(7.2%)	8(7.4%)	0.934
Hospital length of stay (days)	6.20 ± 6.33	7.69 ± 7.13	0.034

[a] Fisher's exact test

Statistical analysis

Differences in continuous and discrete variables between the union and nonunion groups were determined using t and χ^2 tests. Multiple logistic regression was used to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) to evaluate the risk factors in the two groups. The models were adjusted for the treated joint, type of approach, use of bone graft, preoperative diagnosis, diabetes mellitus, osteoporosis, and hospital length of stay. A p-value < 0.05 was considered significant. All analyses were performed using SAS Version 9.4 (SAS Institute, Cary, NC, USA).

Results

A total of 107 joints were identified as nonunion cases. Consequently, to achieve age- and sex-matching at a ratio of 1:4, 428 joints were selected for the control group. Table 2 presents the baseline statistical analysis. Similar distributions observed between the two groups in terms of age, sex, treated joint, open/arthroscopic arthrodesis, use of bone graft, osteoarthritis, traumatic osteoarthritis, rheumatoid arthritis, and Charcot joint. Significantly higher proportions of patients in the nonunion group had diabetes mellitus ($p = 0.007$) and longer hospital stays ($p = 0.034$).

Associations between patient characteristics and the incidence of nonunion after foot and ankle arthrodesis were determined using the logistic regression model and are presented as crude ORs and adjusted ORs in Table 3. The risk of nonunion did not differ among the ankle joint, tarsometatarsal joint, metatarsal-phalangeal joint, toe phalangeal joint, and tarsal joint. No significant differences in the risk of nonunion were observed in relation to open/arthroscopic arthrodesis, use of bone graft, presurgical foot diagnosis, or osteoporosis. Patients with diabetes mellitus had a significantly higher risk of nonunion than those without diabetes mellitus (adjusted OR: 1.710, 95% CI: 1.060 – 2.756, $p = 0.0278$).

Further analysis was conducted on 409 patients without diabetes mellitus (Tables 4 and 5), revealing that performing arthrodesis on the tarsometatarsal joint was associated with the highest risk of nonunion, with a 6.507 times (95% CI: 1.045–40.522, $p = 0.0256$) higher risk compared with that for the ankle joint.

Table 3 Comparing factors associated with union and nonunion

	Crude OR (95% CI)	*p*-value	Adjusted OR[a] (95% CI)	*p*-value
Treated joint[b]				
Ankle	ref		ref	
Tarsometatarsal	1.143 (0.553–2.362)	0.1250	1.473 (0.682–3.181)	0.0700
Metatarsal-phalangeal	0.629 (0.299–1.321)	0.6219	0.770 (0.345–1.718)	0.7427
Toe phalangeal	0.466 (0.209–1.037)	0.1648	0.565 (0.243–1.314)	0.2101
Tarsal	0.614 (0.366–1.030)	0.4234	0.708 (0.415–1.209)	0.3961
Approach				
Open arthrodesis	ref		ref	
Arthroscopic arthrodesis	1.051 (0.384–2.878)	0.9231	1.100 (0.387–3.130)	0.8581
Usage of bone graft	1.136 (0.671–1.921)	0.6355	1.008 (0.578–1.757)	0.9778
Diagnosis[c]				
Osteoarthritis	ref		ref	
Traumatic osteoarthritis	1.106 (0.532–2.303)	0.9791	1.085 (0.509–2.312)	0.8674
Rheumatoid arthritis	1.000 (0.418–2.392)	0.7655	1.147 (0.459–2.866)	0.7752
Charcot's joint	1.601 (0.296–8.658)	0.5943	0.979 (0.167–5.724)	0.9467
None of above	0.975 (0.597–1.593)	0.5603	0.936 (0.553–1.583)	0.6988
Diabetes mellitus	1.799 (1.142–2.832)	0.0113	1.710 (1.060–2.756)	0.0278
Osteoporosis	1.026 (0.478–2.202)	0.9470	1.067 (0.477–2.386)	0.8743
Hospital length of stay (days)	1.029 (1.000–1.058)	0.0477	1.026 (0.996–1.057)	0.0910

[a] This model was adjusted by treated joint, type of approach, usage of bone graft, pre-operative diagnosis, diabetes mellitus, osteoporosis, and hospital length of stay. [b] Ankle joint was selected as reference group to assess the risk of nonunion associated with other joints. [c] Osteoarthritis was selected as reference group to assess the risk of nonunion associated with other diagnoses

Table 4 Baseline characteristics of patients without diabetes mellitus

	Union	Nonunion	*p*-value
Number of joints	338	71	
Age (years)	52.84 ± 14.97	53.38 ± 16.40	0.786
Male	159(47.0%)	36(50.7%)	0.574
Treated joint			
Ankle	113(33.4%)	33(46.5%)	0.263
Tarsometatarsal	31(9.2%)	7(9.9%)	
Metatarsal-phalangeal	41(12.1%)	8(11.3%)	
Toe phalangeal	45(13.3%)	5(7.0%)	
Tarsal	108(32.0%)	18(25.4%)	
Approach			
Open arthrodesis	322(95.3%)	67(94.4%)	0.762[a]
Arthroscopic arthrodesis	16(4.7%)	4(5.6%)	
Usage of bone graft	53(15.7%)	14(19.7%)	0.403
Diagnosis			
Osteoarthritis	92(27.2%)	26(36.6%)	0.199[a]
Traumatic osteoarthritis	38(11.2%)	10(14.1%)	
Rheumatoid arthritis	28(8.3%)	7(9.9%)	
Charcot's joint	3(0.9%)	1(1.4%)	
None of above	177(52.4%)	27(38.0%)	
Osteoporosis	20(5.9%)	6(8.5%)	0.426
Hospital length of stay (days)	6.04 ± 6.35	6.65 ± 6.08	0.464

[a] Fisher's exact test

Table 5 Comparing factors associated with union and nonunion in patients without diabetes mellitus

	Adjusted OR[a] (95% CI)	*p*-value
Treated joint[b]		
Ankle	ref	
Tarsometatarsal	6.507 (1.045–40.522)	0.0256
Metatarsal-phalangeal	0.446 (0.047–4.234)	0.2707
Toe phalangeal	0.902 (0.197–4.121)	0.6315
Tarsal	1.048 (0.378–2.907)	0.7404
Approach		
Open arthrodesis	ref	
Arthroscopic arthrodesis	0.956 (0.086–10.652)	0.9705
Usage of bone graft	0.636 (0.220–1.837)	0.4025
Diagnosis[c]		
Osteoarthritis	ref	
Traumatic osteoarthritis	2.185 (0.369–12.928)	0.9830
Rheumatoid arthritis	2.302 (0.182–29.101)	0.9465
Charcot's joint	3.119 (0.214–45.474)	0.7216
None of above	2.953 (0.890–9.802)	0.4791
Osteoporosis	0.419 (0.077–2.271)	0.3131
Hospital length of stay (days)	1.056 (0.997–1.119)	0.0628

[a] This model was adjusted by treated joint, type of approach, usage of bone graft, pre-operative diagnosis, diabetes mellitus, osteoporosis, and hospital length of stay. [b] Ankle joint was selected as reference group to assess the risk of nonunion associated with other joints. [c] Osteoarthritis was selected as reference group to assess the risk of nonunion associated with other diagnoses

Discussion

In the present study, we used a large nationwide database to determine the risk factors for nonunion following foot and ankle arthrodesis. Diabetes mellitus was identified as a risk factor. Moreover, our analysis revealed that among patients without diabetes mellitus, arthrodesis in the tarsometatarsal joint was a risk factor for nonunion. Surgery-related factors, such as using an open/arthroscopic

approach and bone grafting, were not associated with nonunion.

Three systematic reviews reported a wide range of nonunion rates in ankle arthrodesis, from 0 to 41% [1, 4, 5]. The data were pooled from the included studies, and the overall nonunion rate was calculated to be 12.4% (318/2574). Among the cases, open arthrodesis was associated with a nonunion rate of 12.4% (190/1537), and arthroscopic arthrodesis was associated with a lower nonunion rate of 6.7% (54/809) [1, 4, 5]. In this study, the risk of nonunion did not differ between open and arthroscopic arthrodesis. We identified that among the ankle joints, the tarsometatarsal joint had the highest risk of nonunion. The tarsometatarsal joint is particularly susceptible to nonunion due to its intrinsic instability, which is further exacerbated by substantial shear and torsional forces during ambulation and weight-bearing. To mitigate this risk and enhance surgical outcomes, the use of stable fixation implants, advanced instrumentation for precise articular cartilage resection, and improved techniques for deformity correction should be prioritized. These strategies are essential in optimizing joint stabilization, promoting bony fusion, and minimizing postoperative complications [6]. However, further investigation is needed to verify our perspective, and clarify the other factors contributing to the increased risk of nonunion in this joint and to develop potential strategies for mitigating this risk in patients undergoing arthrodesis for the tarsometatarsal joint.

Another study reported that patients with diabetes mellitus had a 1.51 times higher risk of nonunion than those without diabetes mellitus 12 months after ankle arthrodesis, and the risk of nonunion was not higher in diabetic patients with Charcot joint relative to diabetic patients without Charcot joint [3]. A meta-analysis of tibiotalocalcaneal arthrodesis [7] determined that patients with diabetes mellitus did not have an increased risk of nonunion than those without. However, diabetic neuropathy was identified as a significant risk factor. In this study, diabetes mellitus was identified as a risk factor for nonunion after foot and ankle arthrodesis, and the number of patients with Charcot joint was similar in the union and nonunion groups. In diabetic patients, hyperglycemia, oxidative stress, chronic inflammation, and the accumulation of advanced glycation end products negatively affect bone metabolism. These factors reduce the activity of osteoblasts and increase the activity of osteoclasts, leading to impaired bone healing. As a result, diabetic patients face higher risks of nonunion and amputation [8]. Additionally, when diabetic patients also have obesity and a high BMI, the risk of nonunion further increases. This may be due to excessive mechanical loads compromising the stability of internal fixation, ultimately hindering bone healing [9, 10].

We did not observe an association between bone grafting and an increased risk of nonunion following foot and ankle arthrodesis. Although bone grafting is considering to be a protective factor against nonunion, limited evidence has been collected from patients who underwent foot and ankle arthrodesis. DiGiovanni et al. [11] concluded that if ≥ 50% of the fusion space was filled with bone graft material, regardless of the type of graft and graft harvest site, the fusion rate was significantly higher at 24 weeks after hindfoot and ankle arthrodesis. However, Chalayon et al. [12] determined that bone grafting was not a risk factor for nonunion following open ankle arthrodesis. Multiple factors may influence the effect of bone grafting on fusion outcomes, including the biological potential of the graft material, the mechanical environment of the fusion site, and patient comorbidities. While autografts provide osteogenic, osteoinductive, and osteoconductive properties, allografts primarily serve as scaffolds, which may affect their ability to promote fusion. Additionally, comorbidities can impair bone healing and potentially diminish the effectiveness of bone grafting [13, 14]. Another possible explanation for the lack of association between bone grafting and nonunion is selection bias. Surgeons often use bone grafting in patients with poor bone stock, large fusion gaps, or high risk of nonunion. Therefore, the benefit of bone grafting might be offset by the inherent difficulty of achieving fusion in these patients. Furthermore, variations in surgical technique, fixation methods, and post-operative protocols across studies may contribute to inconsistencies in findings.

Bone health optimisation is being increasingly emphasised in medical practice. To date, the effect of osteoporosis on fracture healing is uncertain; two clinical studies have demonstrated a higher risk of nonunion in patients with osteoporosis [15, 16], but two studies have reported that patients with osteoporosis did not have an increased risk of non-union [17, 18]. Our results indicated that osteoporosis did not contribute to nonunion in foot and ankle arthrodesis. However, bone quality is a multifactorial condition, influenced by factors such as age, sex, lifestyle, and comorbidities, which complicates the interpretation of its impact on surgical outcomes. In this study, despite our efforts to control for confounding factors through matching and regression analysis, there are still numerous variables that we could not control, which may affect our conclusions regarding the association between osteoporosis and nonunion. Additionally, the proportion of patients diagnosed with osteoporosis in both groups was relatively low in this study, which may limit our ability to thoroughly assess its impact on nonunion risk. This limitation should be considered when interpreting our findings. Vitamin D deficiency might play a role in contributing to nonunion. In a previous

study by Moore et al., it was reported that patients with vitamin D deficiency or insufficiency were 8.1 times more likely to experience nonunion after elective foot and ankle reconstruction [19]. However, this factor was not included in our study because the database does not contain specific variables for vitamin D levels.

A notable strength of this study is the use of a large nationwide database. Additionally, the utilisation of *ICD-10-PCS* codes is a significant advantage, because by using *ICD-10-PCS* codes, the measure of nonunion was more accurate because we could identify the laterality of feet. Identifying laterality ensures accurate case classification, as revision arthrodesis is defined as being performed on the same joint. Without this information, procedures on different feet might be misclassified, leading to an incorrect case count. However, the present study also has limitations. Several patient- and surgery-related factors were inaccurate or unavailable in the NHIRD, such as body mass index, vitamin D levels, smoking, alcohol consumption, type of implant, and postoperative protocol. As a result, the association between nonunion and these factors could not be assessed. In this study, three criteria were employed to identify cases of nonunion following foot and ankle arthrodesis. However, cases may have been missed if patients did not undergo revision surgery after nonunion or if the nonunion diagnosis was not recorded during an outpatient visit. Therefore, the number of nonunion might have been underestimated. Additionally, there are no specific *ICD-10-PCS* codes available to identify cases that underwent navicular cuneiform fusion, and there are no codes to further categorize tarsal-metatarsal fusion. Consequently, further investigations regarding navicular cuneiform fusion and tarsal-metatarsal fusion were not conducted. Because the case numbers for arthroscopic arthrodesis, Charcot joint, and osteoporosis were small, caution is warranted when interpreting these results. Diabetes mellitus was identified using both ICD-9 and ICD-10 codes, as our cohort included patients from 2016, during which some cases might still have been coded using ICD-9. Although ICD-9 codes can differentiate between type 1 and type 2 diabetes mellitus, their classification method differs from ICD-10 and may not be as precise. This discrepancy, combined with the transition between coding systems, limited our ability to perform a consistent subgroup analysis based on diabetes mellitus type. Additionally, the database does not provide HbA1c levels, restricting our ability to assess glycemic control status.

Conclusions

Patients with diabetes mellitus exhibited a 1.710 times higher risk of nonunion than patients without diabetes mellitus following foot and ankle arthrodesis. Further analysis of patients without diabetes mellitus revealed that arthrodesis in the tarsometatarsal joint was associated with the highest risk of nonunion.

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Author contributions
C.-H. C.: Writing– original draft, Funding acquisition. C.-H. L.: Methodology, Writing– review & editing H.- Y. Y.: Methodology, Formal Analysis, Writing– review & editing. S.-Y. S.: Data curation, Formal Analysis Y.-H. H.: Resources, Writing– review & editing. C.-M. H.: Writing– review & editing. S.-P. L.: Conceptualization, Methodology, Supervision, Writing– review & editing.

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Data availability
The data that support the findings of this study are available from Taiwan's Health and Welfare Data Science Center but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Taiwan's Health and Welfare Data Science Center.

Declarations

Ethics approval and consent to participate
This study was performed in accordance with the guidelines of the Declaration of Helsinki. The study design was approved by Ditmanson Medical Foundation Chia-Yi Christian Hospital institutional review board (approval no.: 2020057), and the institutional review board waived the requirement to obtain the informed consent.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests.

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