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Original Article

Implant failure after ankle arthrodesis versus total ankle arthroplasty: a matched- cohort study

Cláudia Diniz Freitas[1], Natália Helena Tau[1], Deivid Ramos dos Santos[2], Eduardo Cezar Silva dos Santos[1,2]

1. Hospital Alemão Oswaldo Cruz, São Paulo, SP, Brazil.
2. Porto Dias Hospital, Belém, PA, Brazil.

Abstract

Objective: To compare the risk of implant failure between ankle arthrodesis and total ankle arthroplasty using propensity score matching and time-to-event analysis.

Methods: This multicenter retrospective cohort study used data from the TriNetX Global Collaborative Network. Adult patients aged 18-100 years with ankle osteoarthritis who underwent ankle arthrodesis or total ankle arthroplasty between 2012 and 2023 were included. Propensity score matching (1:1) was performed to balance demographic and clinical covariates. Implant failure was the primary outcome. Survival analyses were conducted using Kaplan-Meier methods and Cox proportional hazards regression, with follow-up censored at implant failure, death, loss to follow-up, or three years after the index date.

Results: Among 7,973 eligible patients, 2,745 matched pairs were analyzed. Implant failure was more frequent after ankle arthrodesis than after total ankle arthroplasty (17.4% vs 12.0%; p < 0.001). Arthrodesis was associated with a higher hazard of implant failure (HR 1.94; 95% CI, 1.75-2.15). Elevated hemoglobin A1c independently increased the risk of failure, whereas body mass index and serum albumin did not.

Conclusion: Ankle arthrodesis was associated with a significantly higher risk of implant failure compared with total ankle arthroplasty. Metabolic optimization, particularly glycemic control, should be considered in surgical decision-making.

Level evidence III; Retrospective Comparative Study.

Keywords: Ankle; Arthrodesis; Arthroplasty, replacement, ankle; Risk factors.

Introduction

End-stage ankle arthritis is a debilitating condition associated with chronic pain, functional limitation, and reduced quality of life[1]. When conservative management fails, surgical intervention is often required, with ankle arthrodesis and total ankle arthroplasty representing the two primary surgical treatment options[2]. While ankle arthrodesis has long been considered the gold standard due to its predictable pain relief and durability, total ankle arthroplasty has gained increasing acceptance as a motion-preserving alternative that may offer functional advantages in selected patients[3]. However, the optimal surgical strategy remains controversial, particularly with respect to implant durability and the long-term risk of failure[4].

Implant failure following ankle surgery is a clinically meaningful outcome, frequently necessitating revision procedures that are technically complex and associated with substantial morbidity and healthcare costs[5]. Prior comparative studies evaluating implant failure between ankle arthrodesis and total ankle arthroplasty have reported inconsistent results[6]. These discrepancies are likely attributable to heterogeneity in patient selection, surgical indications, and follow-up duration, as well as inadequate adjustment for baseline differences between treatment groups[4-6]. Importantly, patients undergoing ankle arthrodesis often present with a higher burden of comorbidities, which may confound observed associations between procedure type and postoperative outcomes[5-6].

Study performed at Hospital Alemão Oswaldo Cruz, São Paulo, SP, Brazil.

Correspondence: Eduardo Cezar Silva dos Santos. 1815, Treze de Maio Street, Postal code: 01323-903, São Paulo, Brazil. **Email:** eduardocezar.ortopedia@gmail.com. **Conflicts of interest:** none. **Source of funding:** none. **Date received:** December 19, 2025. **Date accepted:** March 4, 2026.

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Metabolic and nutritional factors are increasingly recognized as critical determinants of surgical outcomes in orthopedic procedures[7]. Poor glycemic control, commonly assessed by hemoglobin A1c (HbA1c), has been consistently associated with impaired wound healing, increased risk of infection, and implant-related complications[8]. Similarly, hypoalbuminemia reflects compromised nutritional and inflammatory status and has been linked to adverse postoperative outcomes, while elevated body mass index (BMI) may contribute to mechanical overload and altered biomechanics around the ankle joint[9]. Despite their biological plausibility and clinical relevance, these factors are infrequently incorporated into comparative analyses of ankle arthrodesis and arthroplasty, particularly within time-to-event frameworks.

Propensity score matching (PSM) offers a robust method for minimizing baseline confounding in observational studies by balancing measured covariates between treatment groups. When combined with survival analysis using Cox proportional hazards modeling, this approach allows for an adjusted comparison of the risk of implant failure over time while accounting for both treatment selection bias and independent risk factors[10]. To date, large-scale studies integrating PSM with multivariable time-to-event analysis to evaluate implant failure following ankle arthrodesis versus total ankle arthroplasty remain limited.

Therefore, the purpose of this study is to compare the risk of implant failure between ankle arthrodesis and total ankle arthroplasty in a large multicenter retrospective cohort, using propensity score matching to balance demographic and clinical covariates, followed by an adjusted Cox proportional hazards model accounting for metabolic and nutritional factors, including hemoglobin A1c, serum albumin, and body mass index.

Methods

Study design and data source

This was a multicenter, retrospective, observational cohort study conducted using data from the TriNetX Global Collaborative Network, a federated health research network providing access to de-identified electronic medical records (EMRs) from large healthcare organizations (HCOs) worldwide. The network used for this analysis comprised 161 HCOs, all of which responded to the query. TriNetX provides access to diagnoses, procedures, medications, and laboratory data recorded during routine clinical care. The analysis was generated using the TriNetX platform on December 14, 2025. Because all data were de-identified, institutional review board approval and informed consent were not required. This ensures that users of the platform do not have access to any protected health information or personal data. The data is centralized in the Innovation, Research, and Education DataLab of the Oswaldo Cruz German Hospital in São Paulo, which serves as a hub institution for TriNetX in Brazil. Data access is available through the TriNetX research network at https://live.trinetx.com.

As with all analyses based on administrative and electronic health record data, the TriNetX platform does not provide detailed information on implant brand, fixation method, surgical approach, deformity severity, or surgeon volume and experience.

Study population

Adult patients aged 18 to 100 years with a diagnosis of ankle osteoarthritis were eligible for inclusion. Osteoarthritis was defined using ICD-10-CM codes for primary osteoarthritis of the ankle and foot (M19.07), post-traumatic osteoarthritis of the ankle and foot (M19.17), or secondary osteoarthritis of the ankle and foot (M19.27).

Patients were included if they underwent either ankle arthrodesis or total ankle arthroplasty between January 1, 2012, and December 31, 2023. The date of the qualifying surgical procedure was defined as the index date.

Cohort definitions

Two mutually exclusive cohorts were defined based on procedural codes:

Cohort 1: Ankle arthrodesis – Patients with qualifying osteoarthritis diagnoses who underwent ankle arthrodesis, identified using CPT and SNOMED procedure codes for ankle arthrodesis. Patients with any record of ankle arthroplasty were excluded from this cohort.

Cohort 2: Total ankle arthroplasty – Patients with qualifying osteoarthritis diagnoses who underwent ankle arthroplasty, identified using CPT codes for total ankle replacement. Patients with any record of ankle arthrodesis were excluded from this cohort.

Patients with neoplastic diagnoses (ICD-10-CM C00–D49) were excluded from both cohorts.

Outcome definition

The primary outcome was implant failure, defined using ICD-10 codes T84.0, T84.1, and T84.2 (complications of internal orthopedic prosthetic devices, implants, or grafts). Importantly, this code represents a composite, coding-based outcome and does not distinguish among specific failure mechanisms. In ankle arthrodesis, implant failure codes may reflect nonunion-related hardware failure, symptomatic or broken fixation devices, or infection. In contrast, in total ankle arthroplasty, the same codes more commonly capture prosthesis-related complications such as loosening, wear, or infection. Therefore, 'implant failure' should be interpreted as a heterogeneous administrative outcome rather than a uniform biological or mechanical failure across procedures.

Covariates

Baseline characteristics assessed at or prior to the index date included demographic variables (age, sex, race, and ethnicity), comorbidities (including diabetes mellitus, chronic

kidney disease, hypertension, obesity, nicotine dependence, chronic obstructive pulmonary disease, Charcot arthropathy, venous insufficiency, and prior infection), prior procedures, medication exposure (including systemic corticosteroids and anabolic steroids), and laboratory parameters.

Variables of interest included anthropometric measurements and laboratory parameters. Anthropometric assessment included BMI. Laboratory variables were analyzed using a complete-case approach. Hemoglobin A1c and serum albumin were available for a subset of patients only (approximately 14% and 23% of the matched cohort, respectively), and no data imputation was performed, as this is not supported by the TriNetX platform.

Propensity score matching

To minimize confounding due to baseline differences between cohorts, PSM was performed using all listed baseline characteristics. Propensity scores were estimated using logistic regression, with cohort assignment (ankle arthrodesis versus total ankle arthroplasty) as the dependent variable.

Propensity score matching was performed using nearest-neighbor matching in a 1:1 ratio, without an explicit caliper width, consistent with the standard implementation of TriNetX platform. Covariate balance before and after matching was assessed using standardized mean differences, with values below 0.10 considered indicative of adequate balance.

Although PSM achieved adequate balance for most baseline covariates, small residual imbalances remained for selected metabolic and nutritional variables, including hemoglobin A1c, BMI, and serum albumin. Given their known clinical relevance and standardized mean differences exceeding 0.10 after matching, these variables were prespecified for inclusion in subsequent multivariable time-to-event analyses.

Statistical analysis

Baseline characteristics were summarized using means and standard deviations for continuous variables and percentages for categorical variables. Comparisons between cohorts were performed using appropriate statistical tests as implemented within the TriNetX platform.

Outcome analyses were conducted on the propensity score-matched cohorts. The risk of implant failure was evaluated using risk differences, risk ratios, and odds ratios along with their corresponding 95% confidence intervals (95% CI).

Time-to-event analyses were performed using Kaplan-Meier survival curves, with differences between cohorts assessed using the log-rank test.

To account for residual imbalance after propensity score matching, a multivariable Cox proportional hazards regression model was constructed, including variables with standardized mean differences greater than 0.10 following matching, specifically hemoglobin A1c, BMI, and serum albumin levels, in addition to the exposure variable (ankle arthrodesis versus total ankle arthroplasty).

Patients were followed for up to three years from the index surgical procedure. This 3-year follow-up window was selected a priori to ensure uniform outcome ascertainment across the study period and to minimize bias related to differential loss to follow-up in a large, multi-institutional administrative database. This time frame captures most early and intermediate implant-related complications while maintaining consistent censoring across cohorts. Follow-up was censored at the time of implant failure, death, loss to follow-up, or at 3 years after the index date, whichever occurred first. Death was treated as a censoring event and was not explicitly modeled as a competing risk. Although patients were included between January 2012 and December 2023, all time-to-event analyses were anchored to the individual index date, allowing uniform assessment of outcomes within the predefined 3-year follow-up window and appropriate handling of right censoring.

The proportional hazards assumption for the Cox regression model was assessed using graphical inspection of log-log survival plots and evaluation of Schoenfeld residuals. No clinically meaningful violations of the proportional hazards assumption were identified.

Additional multivariable analysis

Given the residual imbalance after propensity score matching, an additional Cox proportional hazards regression model was constructed. This model included covariates with standardized mean differences greater than 0.10 after matching, specifically BMI, hemoglobin A1c, and serum albumin levels. The primary exposure variable was cohort membership (ankle arthrodesis versus total ankle arthroplasty).

Hazard ratios (HRs) with 95% CI were reported. Statistical significance was defined as a two-sided p-value < 0.05.

The statistical programs used were R and SPSS Statistics version 19.0, in addition to four programs or language tools intrinsic to the TriNetX platform.

Ethics

The data used in this study were acquired from TriNetX (https://trinetx.com), a global federated health research network that provides real-time anonymized EMRs provided by HCOs around the world. All TriNetX data are de-identified and anonymized in compliance with HIPAA (The US Health Insurance Portability and Accountability Act); thus, informed consent was not necessary, and the study was granted an exemption from specific institutional ethics board approval.

Results

A total of 412,471 patients with a diagnosis of ankle osteoarthritis between 2012 and 2023 were identified. After applying exclusion criteria, 7,973 patients who underwent surgical treatment were included in the final analysis (Figure 1). Of these, 4,825 underwent ankle arthrodesis and 3,148 underwent total ankle arthroplasty.

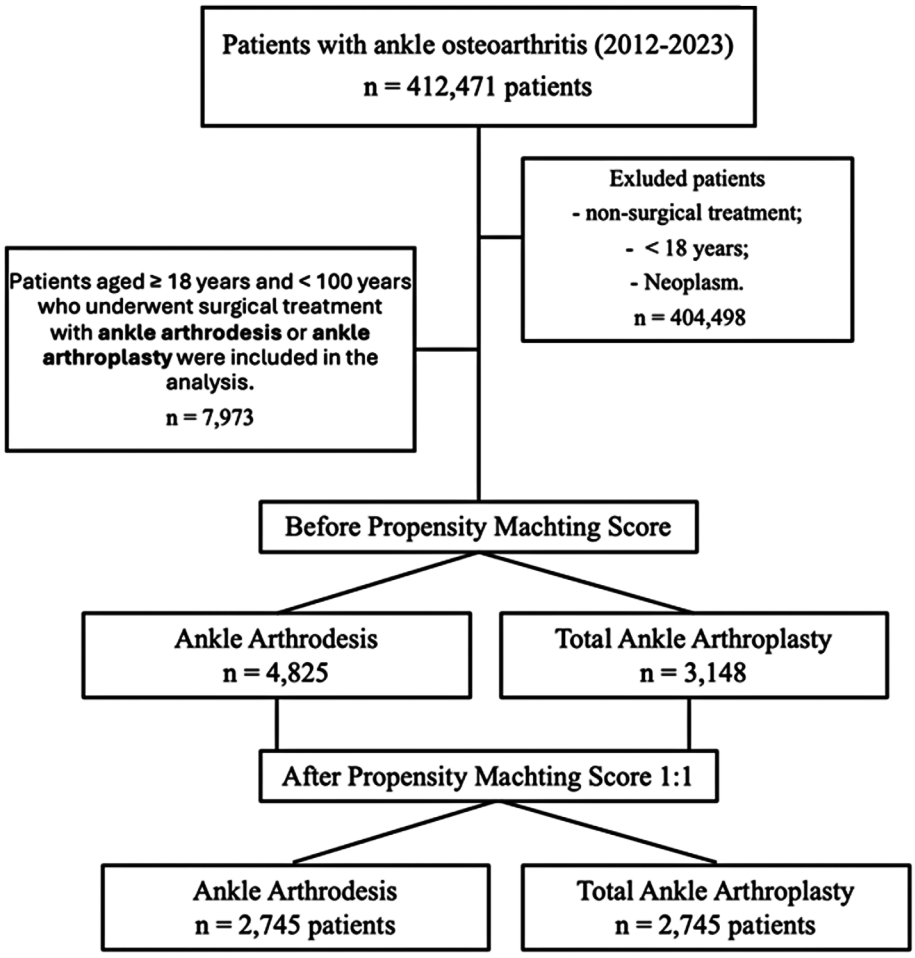

Figure 1. Flow diagram of cohort identification, eligibility, and propensity score matching.

Before propensity score matching, patients in the ankle arthrodesis cohort were younger than those undergoing arthroplasty (mean age, 55.3 ± 14.1 vs 60.9 ± 12.0 years) and had a higher prevalence of several comorbidities, including smoking, diabetes mellitus, obesity, chronic kidney disease, and Charcot arthropathy. Significant baseline differences were also observed in race, ethnicity, prior ankle-related procedures, and laboratory values. Several covariates demonstrated standardized mean differences (SMDs) > 0.10, indicating substantial imbalance between groups.

Preoperative laboratory data were incompletely available. Hemoglobin A1c values were present for 13.7% and 14.7% of patients in the arthrodesis and arthroplasty groups, respectively, while serum albumin levels were available for 23.4% and 23.8%.

Propensity score matching generated 2,745 well-balanced pairs (n = 5,490 total). After matching, age was comparable between cohorts (59.7 ± 12.6 vs 59.7 ± 12.0 years), and most demographic and clinical variables were adequately balanced (SMDs < 0.10) (Table 1, Figure 2). Small residual imbalances persisted for hemoglobin A1c, serum albumin, and BMI; these variables were subsequently adjusted for in multivariable Cox regression analyses.

All comparative outcome analyses were performed using the matched cohorts.

Outcome

Outcomes analyses were performed in the propensity score-matched cohorts. After exclusion of patients who experienced implant failure prior to the defined time window, 2,074 patients remained in the ankle arthrodesis cohort and 2,249 in the total ankle arthroplasty cohort. A total of 361 implant failures occurred in the ankle arthrodesis group and 271 in the total ankle arthroplasty group.

Table 1. Baseline demographic and clinical characteristics before and after propensity score matching in patients undergoing ankle arthrodesis and total ankle arthroplasty

CID-10	Demographics	Before Propensity Score Matching							After Propensity Score Matching						
		Ankle Arthrodesis (n=4,825)			Total Ankle Arthroplasty (n=3,145)			Std diff.	Ankle Arthrodesis (n=2,745)			Total Ankle Arthroplasty (n=2,745)			Std diff.
		Mean ± SD	n	% cohort	Mean ± SD	n	% cohort		Mean ± SD	n	% cohort	Mean ± SD	n	% cohort	
	Age at Index	55.3 ± 14.1	4,825	100%%	60.9 ± 12.0	3,148	100%	0.430	59.7 ± 12.6	2,745	100%	59.7 ± 12.0	2,745	100%	0.001
	Male		2,757	57,1%		1,701	54%%	0.063		1,515	55.2%		1,515	54.7%	0.010
	Female		2,066	42,8%%		1,446	45,90%	0.063		1,229	44.8%		1,244	45.3%	0.011
	Race														
	Whrite		3,840	79,6%		2,702	85.8%	0.166		2,349	85.6%		2,340	85.2%	0.009
	Black or African American		460	9.5%		171	5.4%	0.156		167	6.1%		168	6.1%	0.002
	Unknown Race		298	6.2%		106	3.4%	0.132		102	3.7%		104	3.8%	0.004
	Ethnicity														
	Not Hispanic or Latino		3,727	77.2%		2,502	79.5%	0.054		2,188	79.7%		2,169	79.0%	0.017
	Hispanic or Latino		300	6.2%		90	2.9%	0.162		81	3.0%		88	3.2%	0.015
	Unknown Ethnicity		798	16.5%		556	17.7%	0.030		476	17.3%		488	17.8%	0.011
	Comorbidity														
F17.2	Smoking		600	12.4%		170	5.4%	0.249		167	6.1%		169	6.1%	0.003
F10	Alcohol abuse		92	1.9%		23	0.7%	0.103		22	0.8%		22	0.8%	<0.001
I10	Essential (primary) hypertension		1,560	32.3%		939	29.8%	0.054		795	29.0%		799	29.1%	0.003
E08-E13	Diabetes mellitus		896	18.6%		252	8,00%	0.315		242	8.8%		251	9.1%	0.011
M14.67	Charcôt's joint, ankle and foot		314	6.5%		10	0.3%	0.346		10	0.4%		10	0.4%	<0.001
J44	chronic obstructive pulmonary disease		190	3.9%		59	1.9%	0.123		55	2,0%		56	2.0%	0.003
I87.2	Venous insufficiency (chronic) (peripheral)		65	1.3%		25	0.8%	0.054		23	0.8%		24	0.9%	0.004
Z22.322	Carrier or suspected carrier of Methicillin resistant Staphylococcus aureus		34	0.7%		10	0.3%	0.054		10	0.4%		10	0.4%	<0.001
N18	Chronic kidney disease (CKD)		286	5.9%		80	2.5%	0.169		63	2.3%		73	2.7%	0.023
E66	Overweight and obesity		900	18.7%		415	13.2%	0.150		364	13.3%		372	13.6%	0.009
	Body Mass Index (Kg/m2)	33.2 ± 7.8	3,597	74.5%	31.3 ± 6.0	2,256	71.7%	0.274	32.6 ± 7.4	1,964	71.5%	31.5 ± 6.1	1,994	72.6%	0.161
	> 30 kg/m^2		2,359	48.9%		1,306	41.5%	0.149		1,197	43.6%		1,194	43.5%	0.002
	Procedure														
	Surgical Procedures on the Leg (Tibia and Fibula) and Ankle Joint		873	18.1%		218	6.9%	0.343		210	7.7%		213	7.8%	0.004
	Aspiration and/or intra-articular injection of the ankle		455	9.4%		501	15.9%	0.196		336	12.2%		359	13.1%	0.025
	Medications														
	Anabolic steroids		10	0.2%		10	0.3%	0.022		10	0.4%		10	0.4%	<0.001
	Corticosteroid for systemic use		1,630	33.8%		1,034	32.8%	0.020		816	29.7%		846	30.8%	0.024
	Fracture														
S82.309D	History of closed distal tibial fracture with complete healing.		74	1.5%		10	0.3%	0.127		10	0.4%		10	0.4%	<0.001
S82.309E	History of an open Gustilo–Anderson type I or II distal tibial fracture, healed		74	1.5%		10	0.3%	0.127		10	0.4%		10	0.4%	<0.001
	Laboratory														
	Hb1Ac (mg/dL)	6.5 ± 1.5	1,024	21.2%	5.9 ± 0.9	448	14.2%	0.468	6.2 ± 1.2	375	13.7%	5.9 ± 1.0	403	14.7%	0.228
	Serum albumin level (mg/dL)	3.9 ± 0.6	1,434	29.7%	4.2 ± 0.4	767	24.4%	0.480	4.1 ± 0.5	642	23.4%	4.2 ± 0.4	654	23.8%	0.229
	< 6.0 mg/dL		1,434	29.7%		767	24.4%	0.121		642	23.4%		654	23.8%	0.010
	Total serum protein level (mg/dL)	7.1 ± 0.7	1,374	28.5%	7.1 ± 0.5	727	23.1%	0.006	7.1 ± 0.6	621	22.6%	7.1 ± 0.5	616	22.4%	0.068
	<3.5 mg/dL		10	0.2%		0	0,0%	0.064		10	0.4%		0	0	0.086

The cumulative risk of implant failure was higher among patients undergoing ankle arthrodesis than among those undergoing total ankle arthroplasty (17.4% vs 12.0%). This corresponded to an absolute risk difference of 0.054 (95% CI, [0.032-0.075]; p < 0.001). Ankle arthrodesis was associated with a significantly increased relative risk of implant failure (risk ratio, 1.45; 95% CI, 1.25-1.67) and higher odds of failure (OR, 1.54; 95% CI, 1.29-1.82) compared with total ankle arthroplasty (Table 2).

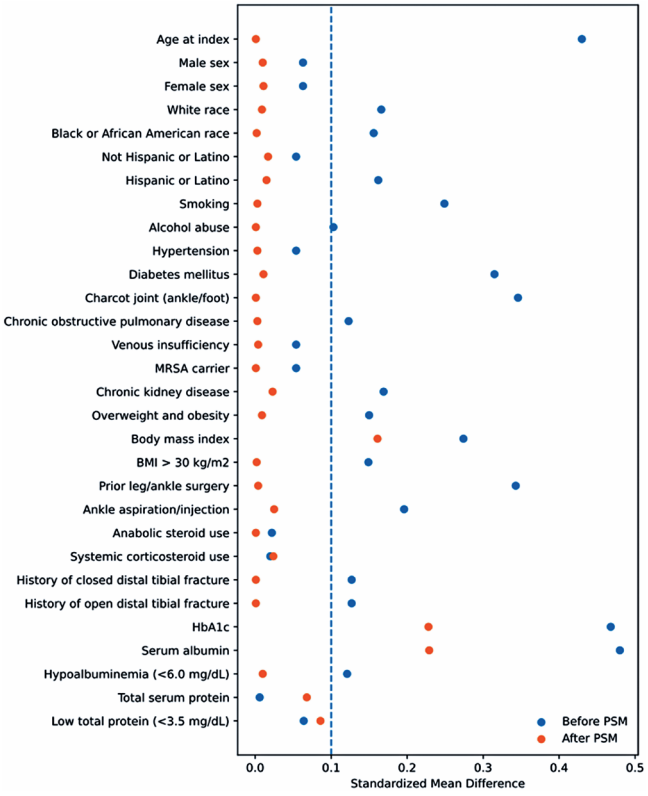

Figure 2. Standardized mean differences demonstrating covariate balance before and after propensity score matching.

Survival analysis

Kaplan-Meier survival analysis demonstrated significantly lower implant survival in the ankle arthrodesis cohort over the follow-up period. Survival probability at the end of the observation window was 77.9% for ankle arthrodesis and 84.5% for total ankle arthroplasty. The difference between groups was statistically significant by log-rank testing (χ^2 = 29.48; p < 0.001). Median survival was not reached in either cohort during the study period (Figure 3).

Cox proportional hazards analysis

This model was specifically designed to adjust for residual metabolic and nutritional imbalances observed after propensity score matching.

In multivariable Cox proportional hazards analysis, adjusting for residual metabolic and nutritional imbalances, ankle arthrodesis remained independently associated with an increased hazard of implant failure compared with total ankle arthroplasty (HR, 1.94; 95% CI, 1.75-2.15; p < 0.001). Elevated hemoglobin A1c was also independently associated with an increased risk of implant failure (HR, 1.36; 95% CI, 1.21-1.54; p < 0.001). Serum albumin level (HR, 1.10; 95% CI, 0.99-1.22; p = 0.074) and BMI (HR, 1.08; 95% CI, 0.97-1.22; p = 0.150) were not independently associated with implant failure after adjustment (Table 3).

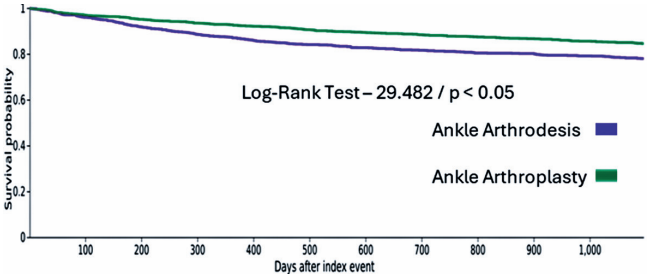

Figure 3. Kaplan-Meier survival curve for implant failure comparing ankle arthrodesis and total ankle arthroplasty.

Table 2. Association for implant failure after propensity score matching

Cohort		Cohort statistic		
		Patients in cohort	Patients with outcome	Risk
1	Ankle Arthrodesis	2,074	361	17,4%
2	Total Ankle Arthroplasty	2,249	271	12%

Risk difference	Risk difference			Risk ratio		Odds ratio	
	95% CI	z	p	Risk ratio	95% CI	Odds ratio	95% CI
5.4%	(0.032-0.075)	4.98	0.0	1.445	(1.249-1.671)	1.538	(1.297-1.824)

* 671 patients in the ankle arthrodesis cohort and 496 patients in the total ankle arthroplasty cohort were excluded from the results because they had the outcome prior to the time window. CI: Confidence interval.

Table 3. Multivariable Cox proportional hazards regression analysis evaluating factors associated with implant failure after ankle arthrodesis and total ankle arthroplasty

Covariate	Hazard ratio	Coefficient	Standard error	z	P > |z|	95% CI
Arthrodesis or Arthroplasty	1.944	0.665	0.053	12.586	0.000	(1.753-2.156)
Hemoglobin A1c/	1.369	0.314	0.060	5.253	0.000	(1.218-1.540)
Albumin (mg/dL)	1.103	0.098	0.055	1.787	0.074	(0.991-1.229)
BMI (kg/m^2)	1.089	0.085	0.059	1.439	0.150	(0.970-1.223)

BMI: Body mass index; CI: Confidence interval.

Discussion

In this retrospective comparative cohort study using the international TriNetX database, ankle arthrodesis was associated with a significantly higher risk of coded implant failure than total ankle arthroplasty. This association remained consistent across multiple analytic approaches, including propensity score matching and adjusted time-to-event analyses.

A key consideration when interpreting these findings is the conceptual non-equivalence of the outcome between procedures. Although both involve implanted materials, administrative implant failure codes capture different underlying mechanisms. In arthrodesis, these codes often reflect nonunion-related hardware complications or symptomatic fixation, whereas in arthroplasty, they more commonly represent prosthesis-specific failures, such as loosening, wear, or infection. Consequently, the outcome reflects heterogeneous implant-related complications rather than directly comparable biological or mechanical failures and may systematically disadvantage the arthrodesis cohort.

Historically, ankle arthrodesis has been regarded as a durable and reliable treatment for end-stage ankle osteoarthritis, particularly among younger patients and those with greater comorbidity burdens[11]. Early comparative studies suggested similar intermediate-term survivorship between arthrodesis and arthroplasty, but were limited by small sample sizes, heterogeneous implant designs, and non-standardized selection criteria[12-14]. Haddad et al.[15] emphasized these methodological challenges in their systematic review. With modern implant designs and improved surgical techniques, more recent prospective and multicenter investigations have demonstrated progressively better outcomes following total ankle arthroplasty[16,17]. Saltzman et al.[18] reported acceptable early survivorship of the STAR prosthesis, and Daniels et al.[19], in the COFAS multicenter study, observed comparable survival with superior functional outcomes for arthroplasty. Similar advantages were described by Glazebrook et al.[20].

The present study extends this literature by leveraging a large, contemporary population and applying propensity score matching to reduce indication bias. These real-world data suggest a higher rate of coded implant-related complications following arthrodesis compared with arthroplasty.

Our findings are consistent with national registry and meta-analytic data demonstrating improved durability of modern ankle arthroplasty. Henricson et al.[21] reported favorable long-term survival in registry analyses, while Zaidi et al.[22] showed progressive improvements in arthroplasty outcomes over time. Functional and gait studies further suggest that biomechanics are more physiological and that quality of life is better after arthroplasty compared with fusion[23,24].

Several limitations warrant consideration. This analysis relies on administrative ICD-10 and CPT coding, which limits clinical detail and introduces potential misclassification. Important operative variables—including implant type, fixation method, surgical technique, deformity severity, bone quality, and surgeon experience—were unavailable and may contribute to residual confounding. In addition, the ICD-based implant failure definition aggregates heterogeneous complications that are not directly comparable between procedures and may overestimate failure after arthrodesis. Laboratory data were incomplete, restricting some analyses to complete cases and potentially introducing selection bias. Although longer-term outcomes at five or ten years are clinically relevant, extended follow-up in administrative databases is often affected by incomplete longitudinal capture and differential attrition. A 3-year horizon was therefore selected to balance clinical relevance with methodological robustness. Finally, death was treated as a censoring event rather than explicitly modeled as a competing risk, which may bias estimates if mortality differs between groups.

Despite these limitations, this study is strengthened by its large sample size, multicenter international data source, contemporary timeframe, and adjustment for key metabolic and nutritional factors. The consistency of results across analytic strategies supports the robustness of the observed association.

Conclusion

In this large propensity score-matched analysis of patients with ankle osteoarthritis, ankle arthrodesis was associated with a significantly higher risk of coded implant failure compared with total ankle arthroplasty. These findings suggest that, when patient-specific factors permit, total ankle arthroplasty may represent a durable alternative to arthrodesis in appropriately selected patients. Future prospective studies incorporating detailed radiographic parameters, implant-specific data, and patient-reported outcomes are needed to further refine surgical decision-making and optimize patient selection.

Author' contributions: Each author contributed individually and significantly to the development of this article: ECSS *(https://orcid.org/0000-0001-5018-3923) Conceived and planned the activities that led to the study, wrote the article, participated in the review process, approved the final version; interpreted study results, participated in the review process; and participated in the review process; CDF *(https://orcid.org/0000-0002-6649-2066), NHT *(https://orcid.org/0009-0002-8116-819X), and DRS* (https://orcid.org/0000-0002-7558-0359) Interpreted study results, participated in the review process. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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