



# Geographical Differences in Wound Complication Rates Following the Sinus Tarsi Approach in Displaced Intra-articular Calcaneal Fractures: A Systematic Review of the Literature

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**Background:** The sinus tarsi approach (STA) has gained popularity for the treatment of displaced intra-articular calcaneal fractures. No large studies comparing wound complications worldwide after STA surgery are available. The aim of this systematic review was to compare postoperative wound complication (POWC) and postoperative wound infection (POWI) rates following STA surgery between continents and countries and their differences in climate.

**Methods:** A literature search was performed using the databases of PubMed, Embase, and the Cochrane Library. Studies published before January 1, 2000, including < 10 patients and written in a language other than English were excluded.

**Results:** In total, 86 studies containing 4,392 surgeries via STA from 20 different countries were included. The mean POWC was 5.9% and the mean POWI was 4.4%. The highest median POWC rate was in North America (8.5%) and the lowest in South America (2.0%). No significant differences were found in the POWC and POWI rates between countries ( $p = 0.178$  and  $p = 0.570$ , respectively), but significant differences were found between the POWC and POWI rates between continents ( $p = 0.011$  and  $p = 0.036$ , respectively). The number of surgeries per year and climate differences, as represented by mean local temperature, were not correlated with both the POWC/POWI rates and functional outcome scores.

**Conclusions:** Significant differences between the POWC and POWI rates were found between continents but not between individual countries. With a mean POWC of 5.9% and a mean POWI rate of 4.4%, STA has an intrinsic low risk for complications given the minimally invasive nature of the approach and is inevitably becoming the gold standard for calcaneal surgery.

**Keywords:** Calcaneus, Fracture fixation, Minimally invasive surgery, Postoperative complications, Surgical site infections

Calcaneal fractures represent less than 1% of all fractures.<sup>1)</sup> The majority consists of displaced intra-articular calcaneal fractures (DIACF), which often require surgical intervention.<sup>2)</sup> For a long time, the extended lateral approach (ELA) was considered the standard approach for the surgical

treatment of DIACF.<sup>3)</sup> Although ELA is associated with high postoperative wound complication (POWC) rates, it provides a good perioperative overview of the calcaneus and is needed for anatomical reconstruction.<sup>4)</sup> Nevertheless, the morbidity of POWCs should not be underestimated, as they can lead to prolonged hospitalization, increased healthcare costs, and patient discomfort.<sup>5,6)</sup>

In 2017, Backes et al.<sup>4)</sup> conducted a systematic review about the POWC rate following ELA and evaluated geographical differences. In that study, a mean POWC rate of 14.3%, superficial postoperative wound infection (POWI) rate of 3.8%, and deep POWI rate of 2.2% were

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found, with large differences between countries and continents.<sup>4)</sup> More recently, the sinus tarsi approach (STA) has gained popularity for the treatment of DIACFs.<sup>7)</sup> The lower POWC rate combined with similar reduction and outcome scores are the main reasons why STA is replacing ELA as the gold standard for the treatment of DIACFs.<sup>7-12)</sup>

While studies investigating STA combined with data regarding wound complications are available, they are often limited by small cohort sizes.<sup>10)</sup> As a result, they may not provide an accurate overview of the current POWC rates after surgery performed via STA. Therefore, we conducted a review similar to the review of Backes et al.,<sup>4)</sup> where we collected data regarding POWCs and infections for surgery via STA whilst combining it with geographical differences including differences in climate.<sup>13,14)</sup> Additionally, the correlations between the mean temperature of a country, frequency of performed surgeries, and functional outcome scores were analyzed in order to explain possible differences found between individual countries.<sup>13,14)</sup>

## METHODS

A literature search was performed on January 21, 2023, using the databases of PubMed, Embase, and the Cochrane Library. The search terms included calcaneal, calcaneus, fracture, and STA. Language restriction was set on English and only papers published after January 1, 2000, were included. Screening of titles and abstracts was done by two independent researchers (RE and AMA) utilizing review software (Covidence systematic review software, Veritas Health Innovation). Full-text assessment was performed following the screening process. Inclusion criteria were as follows: inclusion of > 10 patients who received surgery via STA, availability of data regarding wound complications, and full-text availability. Biomechanical studies and reviews were excluded. Disagreements after screening and full-text assessment were discussed, after which consensus was reached.

The total number of included calcaneal fractures, surgeries performed via STA, and the total POWCs were extracted from all included studies and used for the quantitative synthesis. POWCs were classified as POWIs, wound dehiscence or wound edge necrosis with or without the need for surgical intervention or intravenous (IV) antibiotics, and osteomyelitis. POWI included superficial wound infections and deep wound infections. Minor complications were defined as superficial POWI and wound dehiscence or wound edge necrosis without the need for surgical intervention or IV antibiotics. Major complications were defined as deep POWI, osteomyelitis, and

wound dehiscence or wound edge necrosis with the need for surgical intervention or IV antibiotics. Studies that did not differentiate between deep and superficial infections were only included in the total POWI rate. Studies that did not differentiate between the need for surgical intervention or IV antibiotics for wound dehiscence or wound edge necrosis were only included in the total POWC rate. If multiple studies used the same cohort, the largest study was included. Duration of the inclusion period, mean follow-up period in months, mean local temperature of the city in which the affiliated university of the study is established, and outcome scores were also extracted.

The primary outcomes were the difference in POWC and POWI rates between different continents. Secondary outcomes were the relation between both the mean local temperature in degrees Celsius and frequency of performed surgeries via STA with POWC/POWI rates and functional outcome (American Orthopaedic Foot and Ankle Society Ankle-Hindfoot [AOFAS] score). The methodological quality and risk of bias of the included articles were assessed with the Joanna Briggs Institute (JBI) checklist for case series,<sup>15)</sup> the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) checklist for cohort studies,<sup>16)</sup> and the ROB 2.0 checklist for randomized trials<sup>17)</sup> by two authors (RE and AMA) independently.

SPSS ver. 28.0 (IBM Corp.) was used for the data analysis. Data are reported as median and interquartile range (IQR) or mean and standard deviation depending on the normality of the data. For the difference in complications between countries and continents, the Kruskal-Wallis test was used. The Mann-Whitney *U*-test was used for the difference between retrospective and prospective studies and for the difference in follow-up period and POWI/POWC rates. For the effect of the mean temperature on both the POWC/POWI rates and the AOFAS score, as well as the effect of STA surgeries per year, on the POWI/POWC rates, the Spearman's rank correlation coefficient was used. Statistical significance was defined as a *p*-value < 0.05.

## RESULTS

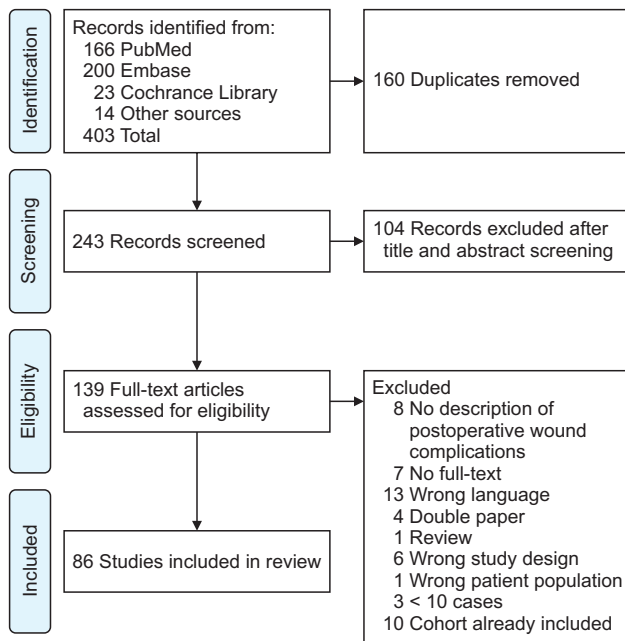
The search yielded 389 studies and 14 studies were retrieved from other sources, which resulted in a total of 403 studies. After removing duplicates, a total of 243 studies were screened based on the title and abstract. After screening and full-text assessment, a total of 157 studies were excluded, leaving 86 studies (Supplementary Material 1) for analysis. The reasons for exclusion are specified in Fig. 1.

A total of 5,898 calcaneal fractures were included, of

which 4,392 were treated via STA in 20 different countries spread out over 5 continents (Tables 1 and 2). China was the most prolific country in publishing papers regarding the subject ( $n = 34$ ), while 9 countries had only 1 paper published regarding the subject. The continent of North America had the highest deep POWI rate with a median

of 2.5%, while all the other continents reported a median rate of 0%. There were 59 prospective studies and 28 retrospective studies. The total number of papers published by continent and country is presented in Tables 1 and 2.

The average percentage of POWC and POWI were 5.9% and 4.4%, respectively. Further specification of the percentage of postoperative infections and complications per continent/country is presented in Tables 1 and 2 and visualized in Figs. 2 and 3. The median follow-up period was 18.5 months (IQR, 12.0–27.9 months) and the median STA surgeries per month was 1.0 (IQR, 0.6–1.6). A significant difference was found between the rates of POWC and POWI between continents ( $p = 0.011$  and  $p = 0.036$ , respectively) and no significant difference was found in the incidence of POWC and POWI between countries ( $p = 0.178$  and  $p = 0.570$ , respectively). No correlation was found between the mean temperature and both the POWC/POWI rates ( $p = 0.682$  and  $p = 0.271$ , respectively) and the AOFAS score ( $p = 0.304$ ), nor was there a difference between the STA surgeries performed per year and both the POWC/POWI rates ( $p = 0.650$  and  $p = 0.886$ , respectively) and the AOFAS score ( $p = 0.283$ ). At last, no difference was found between retrospective and prospective studies with regard to POWC or POWI incidence ( $p = 0.628$  and  $p = 0.779$ , respectively), nor was there a difference between case series, cohort studies, and randomized trials ( $p = 0.660$  and  $p = 0.924$ , respectively).



**Fig. 1.** Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart diagram.

**Table 1.** Postoperative Complication and Infection Rate Per Continent

Variable	Asia	Europe	North America	South America	Africa	<i>p</i> -value*
Number of studies	48	16	15	1	6	-
Number of calcaneal fractures	3,472	1,138	1,032	94	162	-
Number of surgeries with STA	2,253	1,048	880	49	162	-
Patients (STA) per study	40 (26.50–55.75)	55.0 (24.0–84.0)	36.0 (22.0–79.0)	49	21.50 (16.50–38.75)	-
Total POWC (%)	3.39 (0–6.13)	2.78 (0–8.15)	8.49 (6.25–13.64)	2.04	6.78 (2.27–14.88)	0.011
Total POWI (%)	1.21 (0–5.35)	0.47 (0–8–15)	7.69 (2.56–10.71)	0	6.78 (2.27–9.82)	0.036
Total minor complications (%)	3.13 (0–6.03)	0 (0–3.73)	3.13 (0–6.33)	2.04	5.52 (0–12.20)	0.651
Total major complications (%)	0 (0–0.49)	0 (0–2.30)	3.13 (0–8.33)	0	0 (0–4.07)	0.005
Total superficial POWI (%)	0.42 (0–4.94)	0 (0–2.92)	1.35 (0–6.33)	0	5.51 (0–8.93)	0.433
Total deep POWI (%)	0	0	2.53 (0–7.69)	0	0 (0–4.07)	0.006

Values are presented as median (interquartile range) unless otherwise indicated.

STA: sinus tarsi approach, POWC: postoperative wound complication, POWI: postoperative wound infection.

\*Kruskal-Wallis test.

**Table 2.** Postoperative Complication and Infection Rate Per Country

Country	Number of studies	Number of surgeries with STA	Number of calcaneal fractures	Total POWC (%)	Total POWI (%)	Minor complication (%)	Major complication (%)	Total superficial POWI (%)	Total deep POWI (%)
Chile	1	49	94	2.04	0	2.04	0	0	0
China	34	1,623	2,660	3.45 (0–6.69)*	1.68 (0–5.89)*	2.84 (0–6.56)*	0 (0–1.71)*	0.85 (0–5.34)*	0.60 (0–5.26) <sup>†</sup>
Egypt	5	150	150	5.56 (1.15–11.14)*	5.56 (1.15–11.14)*	3.03 (0–9.36)*	0 (0–4.56)*	3.03 (0–9.34)*	0 (0–4.56)*
Germany	2	159	208	11.98 (2.80–21.15) <sup>†</sup>	5.28 (0.93–9.62) <sup>†</sup>	8.63 (1.87–15.38) <sup>†</sup>	3.35 (0.93–5.77) <sup>†</sup>	4.81 (0–9.62) <sup>†</sup>	0.47 (0–0.93) <sup>†</sup>
Greece	1	22	22	0	0	0	0	0	0
India	2	67	67	2.38 (0–4.76) <sup>†</sup>	2.38 (0–4.76) <sup>†</sup>	2.38 (0–4.76) <sup>†</sup>	0	2.38 (0–4.76) <sup>†</sup>	0
Ireland	2	88	88	4.31 (0–8.62) <sup>†</sup>	4.31 (0–8.62) <sup>†</sup>	1.72 (0–3.45) <sup>†</sup>	2.57 (0–5.17) <sup>†</sup>	1.72 (0–3.45) <sup>†</sup>	2.59 (0–5.17) <sup>†</sup>
Italy	3	138	158	3.29 (0–9.88) <sup>†</sup>	3.29 (0–9.88) <sup>†</sup>	3.29 (0–9.88) <sup>†</sup>	0	3.29 (0–9.88) <sup>†</sup>	0
Japan	3	217	249	2.45 (0–4.24) <sup>†</sup>	0.28 (0–0.85) <sup>†</sup>	2.45 (0–4.24) <sup>†</sup>	0.28 (0–0.85) <sup>†</sup>	0.28 (0–0.85) <sup>†</sup>	0
Nepal	1	45	45	2.22	2.22	2.22	0	2.22	0
Netherlands	1	237	237	6.75	6.75	3.80	2.95	3.80	2.95
Romania	1	75	75	5.33	1.33	5.33	0	1.33	0
Saudi Arabia	1	39	39	0	0	0	0	0	0
South Africa	1	12	12	16.67	8.33	16.67	0	8.33	0
South Korea	6	228	378	4.06 (0–6.79)*	0.78 (0–5.75)*	4.06 (0–6.78)*	0	0.78 (0–5.75)*	0
Switzerland	3	165	166	5.46 (0–13.64) <sup>†</sup>	4.55 (0–13.64) <sup>†</sup>	0	0.92 (0–2.75) <sup>†</sup>	0	0
Taiwan	1	34	34	14.71	5.88	11.76	2.94	2.94	2.94
Turkey	2	145	145	1.76 (0–3.53) <sup>†</sup>	0.59 (0–1.18) <sup>†</sup>	1.76 (0–3.53) <sup>†</sup>	0	0.59 (0–1.18)*	0
United Kingdom	1	19	39	0	0	0	0	0	0
United States of America	15	880	1,032	8.49 (6.25–13.64)*	7.69 (2.56–10.71)*	3.12 (0–6.33)*	3.12 (0–8.33)*	1.35 (0–6.33)*	2.53 (0–7.69)*
<i>p</i> -value	-	-	-	0.178 <sup>‡</sup>	0.570 <sup>‡</sup>	0.687 <sup>‡</sup>	0.072 <sup>‡</sup>	0.909 <sup>‡</sup>	0.100 <sup>‡</sup>

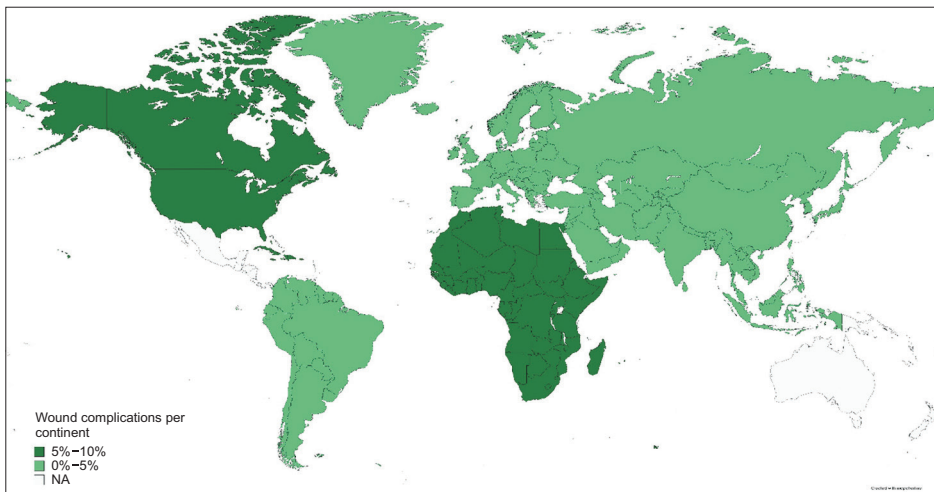
STA: sinus tarsi approach, POWC: postoperative wound complication, POWI: postoperative wound infection.

\*Median (interquartile range). <sup>†</sup>Mean (range). <sup>‡</sup>Kruskal-Wallis test.

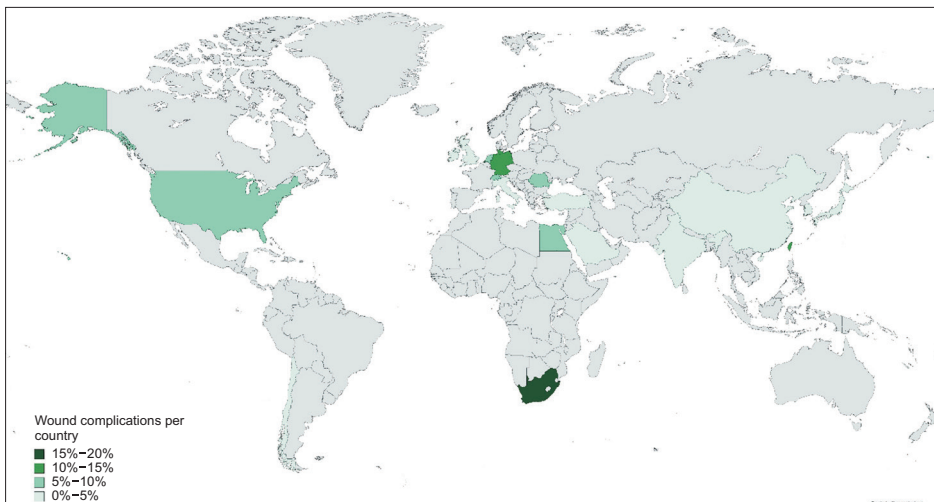
## DISCUSSION

The results showed a significant difference in POWC and POWI rates between continents, but not between individual countries. Additionally, no correlation was found between the mean temperature of a country, frequency

of performed surgeries, and functional outcome scores or complications. North America reported substantially higher deep POWI and POWC rates as compared to the other continents. An explanation could be that in North America, only the United States of America published available data. In other continents, data of more indi-



**Fig. 2.** Wound complications per continent. NA: not applicable.



**Fig. 3.** Wound complications per country.

vidual countries were published, with countries reporting POWC/POWI rates as low as 0%. Additionally, as the healthcare system of the United States of America can be considered as well-organized with respect to documentation, it is expected that complications after surgery are properly documented and therefore lead to higher POWC/POWI rates.

The current literature reports that STA is associated with a lower complication rate and shorter operation time compared to the ELA, whilst maintaining a similar outcome.<sup>8,9,11,12</sup> When compared with the study of Backes et al.,<sup>4</sup> an impressive decrease in the POWC and POWI rates was seen (14.3% to 5.9% for POWC and 6.3% to 4.4% for POWI), further strengthening the superiority of STA over ELA. As opposed to our study, Backes et al.<sup>4</sup> reported significant differences for both POWC and POWI between both countries and continents.

The difference in POWC and POWI rates between

this study and the study of Backes et al.<sup>4</sup> illustrates the fact that the STA is a much safer approach than the ELA. This is most likely also the reason no differences between countries were found as compared to the previous study. The priori chance of POWC or POWI is just low. It, however, does not suggest that anyone should perform this procedure, as this study did not look into the adequacy of reduction. Studies have shown similar reductions and outcome scores in experienced hands. In addition, those who perform foot and ankle trauma operations including those for calcaneal fractures are the ones publishing about the topic. This invariably introduces an expert bias and most likely does not represent overall current practice around the world. A plea for centralized care for complex foot and ankle surgery can still be made, even despite the at first glance negative findings of this study.

Poeze et al.<sup>18</sup> found that < 1 case per month lead to a surgical site infection (SSI) rate of 8.9% while a volume

of > 1 cases per month lead to an SSI of 1.8%. A similar result was found by Court-Brown et al.<sup>19)</sup> and Yin et al.,<sup>20)</sup> showing that as the volume and therefore experience increase, the complication rate decreases, which is in line with the inverse association found between the amount of surgeries performed and infection rate by Qin et al.<sup>21)</sup> and Schepers et al.<sup>22)</sup> Ahn et al.<sup>23)</sup> found that technical competence is achieved after 20 cases of open reduction and internal fixation of calcaneus fractures. The median amount of STA surgeries was 39 with a median STA surgeries per year of 12.28. However, these results of our analysis are not a reliable estimation of the number of surgeries performed via STA per surgeon, as multiple surgeons could have performed the surgeries included in a single study.

As mentioned, correlations between the mean temperature of a country and the POWC/POWI rates and AOFAS score were not found. The results of these analyses are up for debate, as for example one of the biggest countries included in this study, China, is a country with a width of approximately 3,500 km and big differences in the local temperature. For instance, the results of multicenter studies are, therefore, unreliable. We did, however, aimed to raise awareness that the local climate can be of influence on the outcome, especially when diseases such as osteoarthritis are in play.<sup>24-26)</sup>

Although we believe our analysis can be considered reliable given the volume of included surgeries, there are some limitations that need to be mentioned. Assessment of the methodological quality and risk of bias (Supplementary Materials 2-4) show that the included studies were of acceptable quality, but bias could not be ruled out. The main limitations were the heterogeneity of the data and risk of selection bias. Both retrospective and prospective case series, cohort studies, and randomized trials were included and the inclusion criteria varied significantly between the included studies. The included study populations ranged

from studies only including patients with no comorbidities to studies only including patients with open fractures. Additionally, due to adding a minimal follow-up time as an inclusion criterion, there is a significant risk of selection bias as patients who do not have any complaints after the surgery are more likely to waive follow-up appointments. At last, the risk of publication bias has to be addressed.

In conclusion, with the inclusion of 4,392 surgeries performed via STA, this review is the largest review regarding this subject. The data show that, with a mean POWC of 5.9% and a mean POWI of 4.4%, STA has an intrinsically low risk for complications given the minimally invasive nature of the approach and is inevitably becoming the gold standard for calcaneal surgery. Significant differences were seen in the POWC and POWI rates between continents. Nevertheless, differences between the individual countries were all insignificant. A further decrease in complication rates might be expected when surgery for DIACFs via the STA is centralized in high-volume centers given the low incidence of this injury.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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## SUPPLEMENTARY MATERIAL

Supplementary material is available in the electronic version of this paper at the CiOS website, [www.ecios.org](http://www.ecios.org)

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