DOI: https://doi.org/10.30795/jfootankle.2025.v19.1870

Original Article

Adequate and safe operative fixation of ankle fractures by residents and orthopedic trauma surgeons

Robyn van Vehmendahl[1], Lysanne van Silfhout[1], Dieuwertje L. Tiel Groenestege[2], Albert F. Pull ter Gunne[3], Michael Bemelman[4], Michael J. R. Edwards[1], Stijn D. Nelen[1], Diederik P.J. Smeeing[2]

1. Radboudumc, Nijmegen, The Netherlands.
2. Slingeland Hospital, Doetinchem, The Netherlands.
3. Rijnstate Hospital, Arnhem, The Netherlands.
4. Elisabeth-TweeSteden Hospital, Tilburg, The Netherlands.

Abstract

Objective: Investigate surgical outcomes of patients with ankle fractures operated on by residents and orthopedic trauma surgeons.

Methods: Retrospective cohort study including all adult patients surgically treated for ankle fracture from 2016 to 2020 in regional hospitals in the Netherlands. Data regarding patient demographics, fracture characteristics, and treatment characteristics were collected from patient medical records.

Results: Patient demographics and fracture characteristics were similar for patients who underwent surgery by residents compared to those operated on by orthopedic trauma surgeons. There was no significant difference in postoperative complications, revision surgeries (2.8% vs. 4.7%), surgery duration (60.0 minutes vs. 54.0 minutes), or quality of life for residents compared to orthopedic trauma surgeons. Differences were seen in surgical treatment, with external fixation (2.2% vs. 5.2%), medial screw fixation (21.4% vs. 28.5%), and dorsal plate fixation (21.4% vs. 28.5%) being significantly more often used in patients operated on by surgeons. Logistic regression showed that primary surgeon being a resident or orthopedic trauma surgeon was not a predictor for complications.

Conclusion: Outcomes after surgical fixation of ankle fractures are comparable for residents and orthopedic trauma surgeons. Careful selection of patients combined with an appropriate level of supervision is necessary for residents to develop their skills without putting patients at risk.

Level of evidence: Level II, Prognostic study, Retrospective study.

Keywords: Surgical education; Professional competence; Ankle fractures; Treatment outcome; Postoperative complications.

Introduction

The ultimate goal of any surgical residency program is to prepare the resident to function as a qualified surgeon[1]. Adequate surgical experience in the operating room is a critical factor in the development of technical skills and surgical judgment[1,2]. Residents still predominantly train under the apprenticeship model, where they perform progressively complex surgeries under the supervision of an attending surgeon[3]. As residents advance in their training, more responsibility for independent action is granted in direct patient care, surgeries, and in supervising junior residents[1,4]. However, it is important that this is done in a safe environment, without increasing the risk of complications for patients.

There have been several studies comparing surgical outcomes between surgeons and residents[3]. A study by Abson et al.[5] showed that there was no difference in surgical outcomes found in closed reduction of pediatric distal radius fractures in a comparison of procedures performed by residents and attending surgeons. Additionally, another study found that resident involvement did not independently increase the risk of complications in the surgical treatment of lower extremity injuries[6].

Study performed at the Radboudumc, Nijmegen, The Netherlands.

Correspondence: Robyn Van Vehmendahl. Geert Grooteplein Zuid 10, 6525 GA Nijmegen, The Netherlands. **Email:** robyn.vanvehmendahl@radboudumc.nl.
Conflicts of interest: None. **Source of funding:** None. **Date received:** January 15, 2025. **Date accepted:** May 13, 2025.

How to cite this article: van Vehmendahl RV, van Silfhout L, Groenestege DLT, Pull ter Gunne AF, Bemelman M, et al. Adequate and safe operative fixation of ankle fractures by residents and orthopaedic trauma surgeons. J Foot Ankle. 2025;19(2):e1870.

To date, only a limited number of studies have investigated the impact of surgical resident involvement on outcomes following open reduction and internal fixation (ORIF) of ankle fractures. Studies specifically on this topic originate from Israel and the United States. These studies show that resident involvement does not immediately affect complication rates. So far, no studies have been done on this topic in the European continent, despite well-known differences in residency training programs, as well as in surgical practice[7,8]. In conclusion, the aim of this study is to investigate surgical outcomes of patients with ankle fractures comparing those operated on by residents and those attended by orthopedic trauma surgeons.

Methods

Study design

A retrospective cohort study was conducted to assess surgical outcomes in ORIF of ankle fractures comparing the performance of residents and orthopedic trauma surgeons. Participating teaching hospitals were two level 1 trauma centers and two level 2 trauma centers in the Netherlands. Ethical approval was obtained from local medical ethics committees.

All patients aged 18 years old or older with an ankle fracture surgically treated at one of the four participating hospitals from August 1st, 2016, to April 31st, 2020, were included in this study. Patients under the age of 18 and patients with pilon fractures were not included. Patients were divided into two groups based on the primary surgeon responsible for their treatment. One group consisted of patients treated by an orthopedic trauma surgeon as primary surgeon; the other, of patients treated by a resident with assistance and direct supervision of an orthopedic trauma surgeon or without assistance and direct supervision of an orthopedic trauma surgeon, meaning the surgeon was available for consultation but not present in the operating room. In the Netherlands, the residency program takes at least six years for conclusion, or until the residency training director states the resident is completely competent as an orthopedic trauma surgeon. Residents can fulfill the orthopedic trauma residency requirements through an orthopedic or general surgery program, the latter being the most frequently chosen program. In the first four years of residency, residents complete the common trunk training, covering areas such as trauma surgery, vascular surgery, oncological surgery, and pediatric surgery. In the final two years, they specialize in the field of (orthopedic) trauma. Residents who performed ankle surgery with indirect supervision were senior residents (5th or 6th year). Follow-up was defined as time from surgery till last hospitalization or outpatient clinic appointment.

Study variables

A database was made by retrospectively extracting data from medical records of patients treated in participating hospitals. Data extracted from the records included patient, fracture and treatment characteristics. All data was managed using the online Castor Electronic Data Capture software.

Patient characteristics assessed were age, sex, body mass index (BMI), and the American Society of Anesthesiologists (ASA) classification. Fracture characteristics obtained were classified using the Weber[9] and Lauge-Hansen classifications[10]. It was further analyzed whether or not it was a compound fracture as per the Gustilo classification[11]. Analyses and classifications of fractures were performed by one of the medical researchers. In case of uncertainties, one of three trauma surgeons selected was consulted. Finally, data on primary surgeon (resident or orthopedic trauma surgeon), surgery time, and the type of fracture fixation performed were extracted from the medical records. After the surgical procedure, surgeons must point out the primary and secondary surgeon in an electronic health record, as well as in a surgical resident portfolio. The primary surgeon identification is based on the individual who took the lead during surgery or performed most operative steps, as discussed among attendings and/or residents. Anesthesiologists document the start time and the time the surgery ended by using the electronic health record.

Quality of life (QoL) was measured using the EQ-5D-3L questionnaire. Patients received this questionnaire by mail or e-mail. Where patients did not complete the questionnaire, either two reminders were sent via e-mail or contact was made via telephone, no more than three times. The EQ-5D-3L is a validated questionnaire used to measure QoL using five dimensions of health: mobility, self-care, daily activities, pain, and mood. Patients can indicate the extent to which they experience problems in each area: level 0 (no problems), level 1 (moderate problems), and level 2 (severe problems)[12].

Outcome variables

Primary outcome was the complication rate comparison between residents and orthopedic trauma surgeons. Secondary outcomes were the duration of surgery and frequency of revision operations.

Complications included infections, peripheral nerve damage, bleeding, malunion, nonunion, failure of osteosynthesis material, and revision surgery. The attending surgeon who performed or supervised the surgical treatment decided if revision surgery was necessary. Superficial wound infections were defined as those treated with oral antibiotics only. Wound infections treated with intravenous antibiotics and/or surgical debridement were defined as deep infections. Peripheral nerve damage was defined as the loss of sensibility in the ankle or foot persisting for three months after surgery. When a hematoma led to blood transfusion and/or surgery, it was defined as postoperative bleeding. Cases of malunion, nonunion, and failure of the osteosynthesis material were extracted from the medical records, being diagnosed by the attending surgeon who performed or directly or indirectly supervised the surgical treatment.

Statistical analysis

Data was analyzed using SPSS version 29.0.0.0, statistical significance was set as $p < 0.05$. Patient characteristics were analyzed using absolute and relative frequencies for categorial variables, and median with interquartile range (IQR) for continuous variables. Independent sample t-tests, chi-square tests, and Mann-Whitney U tests were used to determine significance of differences between the groups of patients operated on by surgeons and residents, respectively. Lastly, a logistic regression analysis was performed for complications, and a multivariate linear regression was performed for QoL.

Results

A total of 838 patients were included for analysis; 33.5% (n = 281) were operated on by a resident while under direct or indirect supervision of an experienced orthopedic trauma surgeon. Median follow-up duration was 20.0 weeks (IQR 12.0 to 42.0) and median time to fill the questionnaire in was 2.3 years (IQR 559.00 days to 1150.50 days). Table 1 describes the characteristics of patients; the majority of patients in both groups were females with a closed Weber B ankle fracture. No significant differences in patient and fracture characteristics were found between groups.

Table 2 compares surgical outcomes of procedures performed by surgeons and residents. Postoperative complication rates were similar for residents and orthopedic trauma surgeons (17.8% vs. 17.6%). Besides, no significant differences were found in the rate of revision surgery (2.8% vs. 4.7%) or the median duration of surgery (60.0 (40.0 to 74.0) minutes vs. 54.0 (40.0 to 76.0) minutes) when comparing residents with orthopedic trauma surgeons. Surgical technique was in some aspects significantly different in patients operated on by surgeons compared to

Table 1. Patient demographics and fracture characteristics compared by surgeons vs surgical residents

		Surgical residents (n = 281)	Surgeons (n = 557)	p-value
Sex	Male	124 (44.1%)	239 (42.9%)	0.737
	Female	157 (55.9%)	318 (57.1%)	
Median age in years (IQR)		50.00 (32.00 to 50.00)	56.00 (44.00 to 69.50)	0.511
ASA	1	102 (36.3%)	197 (35.4%)	0.922
	2	138 (49.1%)	269 (48.3%)	
	3	32 (11.4%)	66 (11.8%)	
	4	3 (1.1%)	9 (1.6%)	
	Missing	6 (2.1%)	16 (2.9%)	
Median BMI in kg/m² (SD)		26.60 (24.00 to 30.36)	26.56 (23.15 to 30.43)	0.977
Weber Classification	A	18 (6.4%)	38 (6.8%)	0.466
	B	205 (73.0%)	382 (68.6%)	
	C	56 (19.9%)	130 (23.3%)	
	Missing	2 (0.7%)	7 (1.3%)	
Lauge Hansen Classification	Supination exorotation			0.713
	Type 1	-	-	
	Type 2	39 (13.9%)	64 (11.5%)	
	Type 3	8 (2.8%)	20 (3.6%)	
	Type 4	144 (51.2%)	275 (49.4%)	
	Supination adduction	-	5 (0.9%)	
	Type 1	10 (3.6%)	26 (4.7%)	
	Type 2	9 (3.2%)	11 (2.0%)	
	Pronation exorotation Type 1	-	4 (0.7%)	
	Type 2	18 (6.4%)	36 (6.5%)	
	Type 3	40 (14.2%)	88 (15.8%)	
	Type 4	5 (1.8%)	11 (2.0%)	
	Pronation adduction Type 1	-	1 (0.2%)	
	Type 2	5 (1.8%)	10 (1.8%)	
	Type 3	3 (1.1%)	6 (1.1%)	
	Missing			
Gustilo Classification	Closed fracture	270 (96.1%)	528 (94.8%)	0.369
	1	3 (1.1%)	7 (1.3%)	
	2	5 (1.8%)	7 (1.3%)	
	3	-	12 (2.2%)	
	Unknown/missing	3 (1.1%)	3 (0.5%)	

ASA: American Society of Anesthesiologists; IQR: Interquartile range; SD: Standard deviation; BMI: Body mass index.

those operated on by residents as primary surgeon: external fixation was used more often (2.2% vs. 5.2%, p = 0.019), medial fixation was more often done with screws (21.4% vs. 28.5%, p = 0.018), and dorsal plate fixation was performed more often (2.1% vs. 4.5%, p = 0.041). There were no significant differences in any domain of the EQ-5D-3L between patients operated on by surgeons and those operated on by residents.

A logistic regression analysis was performed correcting for the patient's sex, age, ASA classification, and fracture classification (i.e. Weber and Gustilo, Table 3). It showed that resident or orthopedic trauma surgeon as primary surgeon was not a predictor for complications (p = 0.803). In this model, sex (OR = 0.666, CI 0.457 to 0.971) and open fractures (OR = 2.571, CI 1.251 to 5.286) were significant predictors for complications. Lastly, a multivariate linear regression analysis was performed to assess QoL, which showed that resident or orthopedic trauma surgeon as primary surgeon was not a predictive factor for QoL (Table 4).

Only a relatively small number of patients (n = 54) underwent ORIF by a resident with indirect supervision of a surgeon. This subcategory was analyzed separately, and results can be found in Tables 5, 6, 7 and 8. In short, there were no statistically significant differences in revision surgery rates or in the median duration of surgery. Multivariate analysis also showed no statistically significant difference for residents under direct or indirect supervision compared to orthopedic trauma surgeons.

Table 2. Surgical outcomes compared by surgeons vs surgical residents

		Surgical residents (n = 281)	Surgeons (n = 557)	p-value
Median duration of surgery in minutes (IQR)		60.0 (40.0 to 74.0)	54.0 (40.0 to 76.0)	0.062
External fixation	Temporary	3 (1.1%)	26 (4.7%)	**0.019**
	Final fixation	3 (1.1%)	3 (0.5%)	
Lateral fixation	One-third tubular plate	195 (69.4%)	392 (70.4%)	0.511
	Fixed angle screw fixation	30 (10.7%)	52 (9.3%)	0.580
	Intramedullary fixation	-	4 (0.7%)	0.151
	Lag screw	144 (51.2%)	303 (54.4%)	0.261
Medial fixation	One-third tubular plate	8 (2.8%)	24 (4.3%)	0.283
	Fixed angle screw fixation	2 (0.7%)	3 (0.5%)	0.768
	Intramedullary fixation	2 (0.7%)	9 (1.6%)	0.271
	Screw fixation	60 (21.4%)	159 (28.5%)	**0.018**
	Screws and K-wire	59 (21.0%)	120 (21.5%)	0.791
	Metal cerclage compression wiring	6 (2.1%)	12 (2.2%)	0.968
	Vicryl cerclage compression wiring	9 (3.2%)	19 (3.4%)	0.852
Dorsal fixation	Screw fixation AP	12 (4.3%)	16 (2.9%)	0.471
	Screw fixation PA	7 (2.5%)	15 (2.7%)	0.641
	One-third tubular plate	6 (2.1%)	25 (4.5%)	**0.041**
	Intramedullary fixation	-	1 (0.2%)	0.448
	Other	1 (0.4%)	2 (0.4%)	0.909
Complications	None	229 (81.5%)	457 (82.0%)	0.845
	Nerve damage	2 (0.7%)	3 (0.5%)	0.757
	Hemorrhage	-	1 (0.2%)	0.478
	Malunion	1 (0.4%)	2 (0.4%)	0.995
	Non-union	4 (1.4%)	9 (1.6%)	0.834
	Superficial infection	32 (11.4%)	53 (9.5%)	0.392
	Deep infection	11 (3.9%)	25 (4.5%)	0.703
	Failure of osteosynthesis	-	5 (0.9%)	0.111
Revision surgery		8 (2.8%)	26 (4.7%)	0.219
EQ-5D (N patients reporting problems)	Mobility	83 (42.3%)	195 (49.2%)	0.234
	Selfcare	12 (6.1%)	27 (6.8%)	0.781
	Daily activities	56 (28.6%)	133 (33.7%)	0.452
	Pain	105 (53.6%)	230 (58.4%)	0.159
	Mood	47 (24.1%)	97 (24.7%)	0.915
	VAS (median, IQR)	80.00 (70.00 to 90.00)	80.00 (70.00 to 88.00)	0.915

IQR: Interquartile range; AP: Anteriorposterior; PA: Posterioranterior; VAS: Visual analog scale.

Discussion

In our study, we found that surgical residents can perform an adequate and safe operative fixation of ankle fractures. Neither the complication rate nor the median duration of surgery differed between residents and orthopedic trauma surgeons. This applied to both direct and indirect supervision of the surgical resident. Critical judgment of orthopedic trauma surgeons regarding the degree of supervision required by surgical residents performing operative treatment of ankle fractures is of paramount importance. Findings from this study suggest that more challenging fractures requiring an external fixator or a dorsal approach were more often operated by orthopedic trauma surgeons. These are complicated procedures which require careful consideration regarding the ability of surgical residents.

Our findings are consistent with those of a study by Tenenbaum et al.[13] that showed comparable complication rates for both resident involvement and no resident

Table 3. Logistic regression analysis

		Odds ratio (Exp B)	p-value	95% Confidence interval
Sex	Male	RC		
	Female	0.666	**0.034**	0.457 to 0.971
Age	< 40 years	RC		
	> 40 years	1.489	0.072	0.965 to 2.297
Experience	Trauma surgeon	RC		
	Surgical resident	1.050	0.803	0.717 to 1.537
ASA Classification	ASA 1	RC		
	ASA 2	0.903	0.634	0.592 to 1.376
	ASA 3	1.540	0.141	0.866 to 2.737
	ASA 4	1.936	0.315	0.533 to 7.037
Weber Classification	Weber A	RC		
	Weber B	1.845	0.177	0.759 to 4.482
	Weber C	2.151	0.106	0.849 to 5.445
Gustilo Classification	Closed	RC		
	Open	2.571	**0.010**	1.251 to 5.286

ASA: American Society of Anesthesiologists; RC: Reference category.

Table 4. Multivariable linear regression analysis of quality of life

		Standardized Beta	p-value	95% Confidence interval for B
Sex	Male	RC		
	Female	-0.087	0.036	-0.070 to -0.002
Age	< 40	RC		
	> 40	0.004	0.931	-0.035 to 0.038
Experience	Trauma surgeon	RC		
	Surgical resident	0.004	0.923	-0.032 to 0.035
ASA Classification	ASA 1	RC		
	ASA 2	-0.092	0.038	-0.072 to -0.002
	ASA 3	-0.231	< 0.001	-0.211 to -0.097
	ASA 4	-0.197	< 0.001	-0.595 to -0.254
Weber Classification	Weber A	RC		
	Weber B	0.188	0.009	0.021 to 0.146
	Weber C	0.171	0.015	0.016 to 0.152
Gustilo Classification	Closed	RC		
	Open	-0.098	0.027	-0.171 to -0.010
Complications	No	RC		
	Yes	-0.157	< 0.001	-0.120 to -0.039

ASA: American Society of Anesthesiologists; RC: Reference category.

involvement. Louie et al.[14] also showed comparable complication rates, stating that resident involvement was not an independent risk factor for overall complications. Our study found sex and compound fractures to be an independent risk factors for postoperative complications, Louie et al.[15] additionally identified higher age as a risk factor for overall complications. Gross et al., in a study from the US on resident involvement in foot and ankle surgery, stated that resident involvement was not independently associated with 30-day mortality or 30-day overall morbidity. However, Gross et al. reported more postoperative complications in the resident group, noting they treated sicker and more complex patients.

Table 5. Patient demographics and fracture characteristics compared by surgeons, surgical residents with direct and indirect supervision

		Surgical residents, direct supervision (n = 227)	Surgical residents, indirect supervision (n = 54)	Surgeons (n = 557)	p-value
Sex	Male	101 (44.5%)	23 (42.6%)	239 (42.9%)	0.915
	Female	126 (55.5%)	31 (57.4%)	318 (57.1%)	
Median age in years (IQR)		50.00 (30.00 to 63.00)	49.00 (39.50 to 66.00)	51.00 (33.00 to 63.00)	0.773
ASA	1	83 (36.6%)	19 (35.2%)	197 (35.4%)	0.834
	2	107 (47.1%)	31 (57.4%)	269 (48.3%)	
	3	28 (12.3%)	4 (7.4%)	66 (11.8%)	
	4	3 (1.3%)	0 (0.0%)	9 (1.6%)	
	Missing	6 (2.6%)	0 (0.0%)	16 (2.9%)	
Median BMI in kg/m^2 (IQR)		26.52 (24.00 to 30.41)	27.00 (24.12 to 30.41)	26.46 (23.10 to 30.43)	0.950
Weber Classification	A	14 (6.2%)	4 (7.4%)	38 (6.8%)	0.792
	B	165 (72.7%)	40 (74.1%)	382 (68.6%)	
	C	46 (20.3%)	10 (18.5%)	130 (23.3%)	
	Missing	2 (0.9%)	-	7 (1.3%)	
Lauge Hansen Classification	**Supination exorotation**				0.901
	Type 1	0 (0.0%)	0 (0.0%)	0 (0.0%)	
	Type 2	33 (14.5%)	6 (11.1%)	64 (11.5%)	
	type 3	7 (3.1%)	1 (1.9%)	20 (3.6%)	
	type 4	113 (49.8%)	31 (57.4%)	275 (49.4%)	
	Supination adduction	0 (0.0%)	0 (0.0%)	5 (0.9%)	
	Type 1	8 (3.5%)	2 (3.7%)	26 (4.7%)	
	Type 2	7 (3.1%)	2 (3.7%)	11 (2.0%)	
	Pronation exorotation	0 (0.0%)	0 (0.0%)	4 (0.7%)	
	Type 1	17 (7.5%)	1 (1.9%)	36 (6.5%)	
	Type 2	31 (13.7%)	9 (16.7%)	88 (15.8%)	
	Type 3	3 (1.3%)	2 (3.7%)	11 (2.0%)	
	Type 4	0 (0.0%)	0 (0.0%)	1 (0.2%)	
	Pronation adduction	5 (2.2%)	0 (0.0%)	10 (1.8%)	
	Type 1	3 (1.3%)	0 (0.0%)	6 (1.1%)	
	Type 2				
	Type 3				
	Missing				
Gustilo Classification	Closed	219 (96.5%)	51 (94.4%)	528 (94.8%)	0.866
	1	2 (0.9%)	1 (1.9%)	7 (1.3%)	
	2	4 (1.8%)	1 (1.9%)	7 (1.3%)	
	3	0 (0.0%)	0 (0.0%)	12 (2.2%)	
	Missing	2 (0.9%)	1 (1.9%)	3 (0.5%)	
EQ-5D (n patients reporting problems)	Mobility	66 (42.0%)	17 (43.6%)	195 (49.2%)	0.568
	Selfcare	11 (7.0%)	1 (2.6%)	27 (6.9%)	0.825
	Daily activities	42 (26.8%)	14 (35.9%)	133 (33.7%)	0.581
	Pain	83 (52.9%)	22 (56.4%)	230 (58.4%)	0.038
	Mood	35 (22.4%)	12 (30.8%)	97 (24.7%)	0.639
	VAS (median, IQR)	80.00 (70.00 to 90.00)	79.00 (64.75 to 86.00)	80.00 (70.00 to 88.00)	0.541

IQR: Interquartile range; VAS: Visual analog scale; BMI: Body mass index.

Table 6. Surgical outcomes compared by surgeons, surgical residents with direct and indirect supervision

	Surgical residents, direct supervision (n = 227)	Surgical residents, indirect supervision (n = 54)	Surgeons (n = 557)	p-value
Median duration of surgery in minutes (IQR)	60.0 (40.0 to 64.0)	57.0 (37.4 to 73.0)	54.0 (40.0 to 76.0)	0.165
Complications				
None	189 (83.3%)	40 (74.1%)	457 (82.0%)	0.284
Nerve damage	1 (0.4%)	1 (1.9%)	3 (0.5%)	0.450
Hemorrhage	-	-	1 (0.2%)	0.777
Malunion	-	1 (1.9%)	2 (0.4%)	0.119
Non-union	3 (1.3%)	1 (1.9%)	9 (1.6%)	0.936
Superficial infection	24 (10.6%)	8 (14.8%)	53 (9.5%)	0.434
Deep infection	9 (4.0%)	2 (3.7%)	25 (4.5%)	0.928
Failure of osteosynthesis	-	-	5 (0.9%)	0.282
Revision surgery	4 (1.8%)	4 (7.4%)	26 (4.7%)	0.083

IQR: Interquartile range.

Table 7. Logistic regression analysis

		Odds ratio (Exp B)	p-value	95% Confidence interval for B
Sex	Male	RC		
	Female	0.667	***0.035***	0.457 to 0.972
Age	< 40	RC		
	> 40	1.460	0.88	0.945 to 2.255
Experience	Surgical resident	RC		
	Trauma surgeon	0.619	0.154	-0,320 to 1.197
	Supervision of surgeon on surgical resident	0.573	0.129	0.280 to 1.175
Weber Classification	Weber A	RC		
	Weber B	1.857	0.172	0.764 to 4.517
	Weber C	2.168	0.103	0.855 to 5.494
ASA-classification	ASA 1	RC		
	ASA 2	0.900	0.624	0.590 to 1.373
	ASA 3	1.576	0.122	0.885 to 2.806
	ASA 4	2.016	0.288	0.553 to 7.347
Gustilo Classification	Closed			
	Open	2.550	**0.011**	1.238 to 5.249

ASA: American Society of Anesthesiologists; RC: Reference category.

Table 8. Complications divided by Lauge-Hansen classification

		Lauge-Hansen classification						p-value
		SE2	SE4	SA2	PE3	PE4	PA3	
Complications	Nerve damage	1 (1.0%)	3 (0.7%)	0 (0.0%)	0 (0.0%)	1 (0.8%)	0 (0.0%)	1.000
	Hemorrhage	1 (1.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.853
	Malunion	0 (0.0%)	1 (0.2%)	0 (0.0%)	0 (0.0%)	1 (0.8%)	0 (0.0%)	0.319
	Non-union	1 (1.0%)	5 (1.2%)	1 (2.8%)	0 (0.0%)	2 (1.6%)	3 (20.0%)	**< 0.001**
	Superficial infection	6 (5.8%)	50 (12.0%)	4 (11.1%)	5 (9.6%)	13 (10.2%)	1 (6.7%)	0.798
	Deep infection	3 (2.9%)	17 (4.1%)	2 (5.6%)	5 (9.6%)	8 (6.3%)	1 (6.7%)	0.812
	Failure of osteosynthesis	0 (0.0%)	3 (0.7%)	0 (0.0%)	0 (0.0%)	3 (2.3%)	0 (0.0%)	0.872

Both Louie et al. and Gross et al. did not detail whether the resident was involved as the primary or secondary surgeon.

These findings comply with those of other studies regarding trauma surgery, as Abson et al.[5], who showed no significant difference in achieving fracture reduction or in the re-displacement of pediatric distal radius fractures when comparing residents and attending surgeons.

The present study found sex and open fractures as significant predictive factors for complications. This also aligns with another study investigating the influence of open ankle fractures on complications, which suggests that these fractures lead to more complications[16]. Further, Lorente et al.[17] stated that sex impacted functional outcomes and QoL in patients with ankle fracture.

Based on results from the present study, it is not possible to determine the patient profile or type of operative approach of ankle fractures that are optimal and safe to be performed by surgical residents. This was also the conclusion of the systematic review by D'Souza et al.[3], which described a large heterogeneity among different surgical specialties and, therefore, in results, which prevents generalizing the findings to specific clinical contexts. Careful case selection by the orthopedic trauma surgeon can challenge surgical residents appropriately and develop their skills without putting patients at risk. This is also supported by the overall complication rate found in the present study, which was not significantly different for surgical residents and orthopedic trauma surgeons and similar to complication rates found in the literature[18-20].

A strength of this study is that it is a multicenter study involving both academic and non-academic hospitals. Another strength is that this is the first European study to assess the resident involvement in treating ankle fractures, demonstrating that this system of residency involvement is safe and, therefore, effective.

Some limitations of this study should be considered. Due to its retrospective design, data are based on what was documented in medical records of patients. For example, the primary surgeon is identified through chart review, but interpretations of resident involvement can vary among surgeons. Another point is that long-term complications, such as osteoarthritis, were not considered; however, by including QoL, the follow-up period is extended to 2.3 years. Assuming that osteoarthritis leads to a lower QoL, a significant difference would be expected if one of the groups had a higher prevalence of osteoarthritis. Additionally, this study was conducted in the Netherlands, on a Dutch residency program, so findings may not be directly comparable to those of countries using different residency programs. Also, this database did not provide specific information on the year residents were in when performing the surgery. As aforementioned, residents who performed surgeries without direct supervision concern 5th- or 6th-year residents. The content and level of challenge of the individual cases are difficult to define. Nonetheless, the "proof of concept" remains valid, namely, that it is safe to gradually give residents more independence and that the surgeon should assess the resident competency level.

Conclusion

According to the findings of our study, surgical fixation of ankle fractures by surgical residents as the primary surgeon appears to be safe when compared to those performed by orthopedic trauma surgeons. Duration of the surgery, number of revision surgeries, and postoperative complications were similar for surgical residents and orthopedic trauma surgeons. We advise careful case selection and appropriate level of supervision in order to allow surgical residents to develop their skills without putting patients at risk. Future research should be done on differences in patient-reported outcome measures.

Author's contributions: Each author contributed individually and significantly to the development of this article: RVV *(https://orcid.org/0000-0002-9546-9279) Data collection, wrote the manuscript; LVS *(https://orcid.org/0000-0002-7397-977X) Data collection, wrote the manuscript; DLTG *(https://orcid.org/0009-0005-7827-249X); Data collection; AFPG *(https://orcid.org/0000-0001-5743-4000) Data collection, Data analysis; MB *(https://orcid.org/0009-0000-8778-2196) Data collection; MJRE *(https://orcid.org/0000-0001-8035-8157) Data collection; SDN *(https://orcid.org/0000-0003-0180-0731) Data collection, Data analysis, interpretation of data; DPJS *(https://orcid.org/0000-0002-4895-9806) Data collection, Data analysis, interpretation of data, wrote the manuscript. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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