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A retrospective cohort study**

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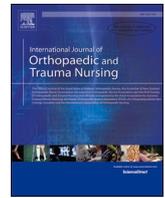
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Impact of compression stockings on wound healing and complications in ankle fractures: A retrospective cohort study

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ABSTRACT

Introduction: Ankle fractures treated with open reduction and internal fixation (ORIF) have a high incidence of wound complications. By reducing oedema, wound complications can, in theory, be minimized. This study investigates the impact of compression stocking (CS) on such complications after treatment with ORIF.

Methods: Compression stockings were introduced as a standard postoperative treatment for all ankle fracture patients treated operatively with ORIF on February 1, 2013. Data were retrieved from medical records two years prior to and following the introduction date. The primary outcome was wound healing status after six weeks and secondary outcomes were wound-healing and major complications up to one year after surgery.

Results: In total, 187 patients were studied, 74 in the CS group and 113 in the control (non-CS) group. Six weeks after the operation, wound-healing problems occurred in 23% and 13% of the patients in the CS group and the non-CS group ($p < 0.0001$) respectively. In total, 34% and 19% of the patients in the CS group and non-CS group experienced wound-healing complications one year after the operation ($p < 0.02$) respectively. Furthermore, major complications within one year occurred in 3% and 4% of patients respectively ($p < 0.77$).

Conclusion: An increase in wound-healing complications after six weeks and one year when using CS was found. However, owing to baseline differences in the two groups, it is only possible to caution against the use of CS.

1. Introduction

Ankle fractures are one of the most common types of fracture with an incidence of 107 per 100,000 people per year in Denmark (Jensen et al., 1998). Almost half of such patients undergo surgery, and the most common method of surgery is open reduction and internal fixation (ORIF) (Donken et al., 2012).

A frequent post-operative complication is wound healing problems that can ultimately lead to deep infection potentially resulting in amputation. Incidence should, therefore, be reduced (Leyes et al., 2003; SooHoo et al., 2009).

Oedema may be one of the reasons for wound-healing disturbances as swelling can lead to bullae and infection (Tull and Borrelli, 2003b). When a bone is fractured, patients immediately experience pain and, because of soft tissue injury, oedema develops (Tull and Borrelli, 2003a). The soft tissue injury leads to an inflammatory response that instigates

healing by moving fluid and white blood cells into the injured area and creating the oedema. This response begins at the moment the fracture occurs but the tissue oedema peaks between 24 and 72 h post-injury (Tull and Borrelli, 2003b).

Oedema can be reduced using compression therapy. Compression therapy is widely used in prevention of deep venous thrombosis (Stranks et al., 1992), oedema management (Lasinski et al., 2012) and in wound care (Lasinski et al., 2012) as a way of decongesting the lower extremity. Compression treatment is gradually finding its way into perioperative care following ankle fracture surgery.

Hypothesizing that, by reducing oedema, the risk of wound-healing problems and infections can be reduced, a randomised controlled trial (RCT) tested the effect of compression stocking treatment (CS) to reduce the oedema after ankle fracture compared to Tubigrip (Sultan et al., 2014). This study found that CS reduced swelling within hours of application, and by four weeks, the mean ratio of the circumferences of

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the ankles with CS had returned to normal (size of the contralateral leg). Furthermore, it was found that wound healing appeared better when using CS, yet the wound inspection score was only analysed in 28 patients and was, therefore, underpowered (Sultan et al., 2014). In a larger population of ankle fracture patients, another RCT tested the effect of a regime of intermittent pneumatic compression, a compression bandage and a compression stocking on wound infection after two and six weeks. No significant difference was found, which the authors proposed could be due to under-powering of the study (Winge et al., 2018).

Compression therapy has a beneficial effect on reducing oedema, but the effect on wound healing is unclear (Winge et al., 2017). Compression therapy using compression stockings has shown positive results, but so far only in a small and highly selected group of ankle fracture patients.

The purpose of this study was to compare the influence of CS on complications in a large unselected group of primary ankle fractures treated with ORIF.

2. Methods

This study was designed as a retrospective cohort study that compared groups with different oedema treatment strategies.

Treatment with a compression stocking on the injured ankle for six weeks was introduced as a standard postoperative protocol for ankle fractures treated with ORIF at a Danish department of orthopaedic surgery on February 1st, 2013.

2.1. Patients

All patients aged 18 years or older primarily treated with ORIF owing to an acute malleolar fracture were included for a period 2 years prior to and following the commencement date. Ankle fractures were identified as codes DS825, DS826, DS827 and DS828, according to the International Classification of Diseases, version 10 (ICD10). NOMESCO procedure codes KNHJ40-3, KNHJ60-3, KNHJ70-3 and KNHJ80-3 were also used (van Netten et al., 2016). Patients were excluded if they experienced multiple trauma or multiple fractures, had temporary or definitive external fixation, were treated non-operatively, experienced secondary displacement of the fracture after the initial conservative treatment or were admitted from or discharged to other hospitals during treatment.

2.2. Treatment

Before February 1st, 2013, the standard protocol for pre- and postoperative oedema treatment was the use of a splint cast, elevation and immobilization. The postoperative protocol included the use of a static walker for six weeks; four weeks without any weight-bearing, followed by two weeks with incremental weight bearing on the fractured limb.

On February 1st, 2013, a new standard protocol for postoperative oedema treatment was implemented. From then on, postoperative treatment involved a long compression bandage for 1–2 days, re-applied daily by an orthopaedic nurse. At discharge, a nurse re-applied a toe-to-knee compression bandage (COBAN-2 Lite) for patients to wear for one week until their first check-up at the outpatient clinic. At the first check-up, a nurse fitted a standard-treatment toe-to-knee compression stocking (double lined) yielding 18–40 mmHg. The patient was informed to wear it for the following 5 weeks. One week later, at the second check-up a nurse inspected the wound and removed the sutures. The postoperative protocol involving the static walker remained unchanged. At 6 weeks postoperatively the patients were assessed in the outpatient clinic by an orthopaedic nurse and surgeon.

Concomitant with the introduction of CS, intermittent pneumatic compression (IPC) was applied to the fractured ankle for 30 min, three times a day, until surgery (Arndt et al., 2017).

2.3. Data collection and outcome variables

Patient data was collected from the medical records. The primary outcome of interest in this study was wound healing status after six weeks. This status was categorized as either good (no signs of infection), inflammatory (signs of infection and intact wound), healing problems (open wound) or not mentioned. Secondary outcomes of interest were wound healing complications and major complications up to one year after surgery. Wound healing complications up to one year after surgery, included superficial infection and minor decubitus. Major complications up to one year after surgery included deep infections treated with intravenous antibiotics and any secondary surgeries (simple metalwork removal not included).

Comorbidities including diabetes, peripheral vascular disease, and smoking can complicate wound and fracture healing because of compromised blood flow (Miller et al., 2012). Surgical procedures including choice of suture and tourniquet (pressure to an extremity in order to limit – but not stop – the blood flow during surgery) and open or complex fractures can also lead to wound infection and reoperation (SooHoo et al., 2009).

Patient and admission-related characteristics were collected including: age, gender, diabetes (yes/no), smoking status (yes/no), American Society of Anaesthesiologist (ASA) score (Daabiss, 2011), suture type (absorbable, non-absorbable, or staples), open fracture (yes/no), tourniquet use (yes/no) and length of surgery. Additionally, all x-ray images were classified according to AO-classification system (Meinberg et al., 2018).

2.4. Analysis

The categorical measurements of wound healing status and complications were expressed as proportions, and the chi-square test was performed to compare the results of different groups. The primary outcome (wound healing problems after 6 weeks) were examined using a binary logistic regression model (categorized as wound healing problem or not) adjusting for age, sex, ASA score, diabetes, AO-classification, suture type and tourniquet. Results are given for odds ratio (OR) with 95% confidence interval.

Numeric patient and admission related characteristics - including age and length of the surgery - were expressed as a median and interquartile range as they were not normally distributed; therefore, the Wilcoxon rank-sum test was applied when comparing groups. When assessing categorical variables, proportions and the chi-square test were used.

All statistical analyses were performed using STATA 16 (Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC).

3. Results

Two hundred and seventy three patients eligible for inclusion in the study were identified and 86 patients excluded, resulting in the inclusion of 187 patients. In total, 113 were allocated to the control group (non-CS group) and 74 were allocated to the CS group (Fig. 1). This cohort was identical to a previous study of preoperative intermittent pneumatic compression (Arndt et al., 2017).

There were no significant differences in demographics between the two groups concerning age, gender, smoking status and ASA-score, but there was a statistically significant difference with regard to diabetes (4% vs 6%, $p < 0.008$) (Table 1).

No significant differences were found regarding the proportion of open fractures or the length of surgery (Table 2). However, the two groups significantly differed with respect to the complexity of the fracture, as a larger proportion of the CS group, in comparison to the non-CS group (15% vs 4%), were diagnosed with a 44 C1–C3 fracture ($p < 0.006$). The groups were also significantly different in terms of the use of absorbable sutures (41% vs. 12%; $p < 0.0004$) and tourniquets (73% vs.

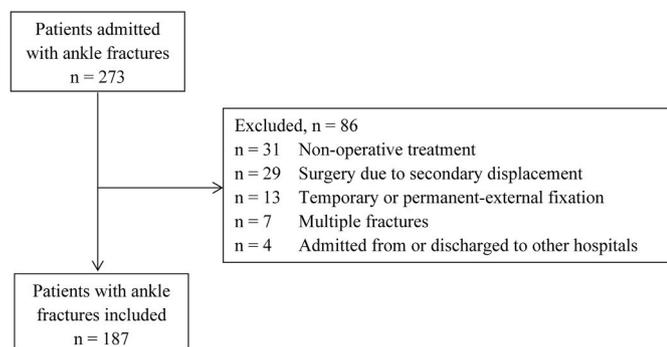


Fig. 1. Flowchart of patient inclusion.

Table 1
Patient demographics.

	CS group	Non-CS group	P
N	74	113	
Age (years), median (IQR)	50 (35–62)	53 (40–64)	0.37
Male, (%)	35 (47)	50 (44)	0.68
Diabetes, (%)	3 (4)	7 (6)	0.008
Smoking, (%)	19 (26)	37 (33)	0.34
ASA-score, (%)			0.13
Score 1	34 (46)	39 (34)	
Score 2	30 (41)	63 (56)	
Score 3	10 (13)	11 (10)	
Score 4–5	0	0	

*CS, Compression Stocking; ASA-score, American Society of Anaesthesiologists score.

Table 2
Admission-related characteristics.

	CS group	Non-CS group	P
N	74	113	
AO classification, (%)	3 (4)	16 (14)	0.006
44 A1–A3	59 (81)	92 (81)	
44 B1–B3	11 (15)	5 (4)	
44 C1–C3			
Suture, (%)	30 (41)	13 (12)	0.0004
Absorbable	38 (51)	92 (81)	
Non-absorbable	6 (8)	8 (7)	
Staples			
Open fracture, (%)	5 (7)	9 (8)	0.78
Tourniquet, (%)	54 (73)	34 (30)	0.0001
Length of surgery (min), median (IQR)	60 (47–75)	60 (46–85)	0.34

CS: compression stocking.

30%; $p < 0.0001$) (Table 2).

A significantly larger proportion of wound healing problems within six weeks were found in the CS group in comparison to the non-CS group (23% vs 13%; $p < 0.0001$) (Table 3). The crude logistic regression demonstrated an OR of 1.95 (0.90–4.19) for the CS group compared to the non-CS group whereas the adjusted OR was 2.92 (0.97–8.80).

A total of 34% of the patients in the CS group experienced wound healing complications within one year, compared to 19% in the non-CS group ($p < 0.02$). However, no significant differences were found regarding major complications within one year (3% vs 4%; $p < 0.77$).

4. Discussion

This study investigated the effect of CS on complications after primary ankle fracture treated with ORIF.

We found that 23% of the patients in the CS group, compared to 13% in the non-CS group, experienced wound healing problems after six weeks, which is a significant clinical difference. However, the groups

Table 3
Wound-healing status, wound-healing and major complications.

	CS group	No CS group	P
N	74	113	
Wound healing status after 6 weeks, (%)	25 (34)	78 (69)	0.0001
Good	3 (4)	4 (4)	
Inflammatory	17 (23)	15 (13)	
Healing problems	29 (39)	16 (14)	
Not mentioned			
1-year, wound healing complications, (%)	49 (66)	91 (81)	0.02
None	4 (5)	3 (3)	
Superficial infection	18 (24)	17 (15)	
Delayed healing	4 (5)	1 (1)	
Minor decubitus			
1-year, major complications [#] , (%)	72 (97)	109 (96)	0.77
None	0 (0)	1 (1)	
IV AB	2 (3)	3 (3)	
Re-operations			

CS: compression stocking.

differed considerably, as patients in the CS group had more complex fractures, an increased use of absorbable sutures, tourniquets and diabetes in comparison to the non-CS group. In fact, almost four times as many complex fractures appeared in the CS group. As the complexity of fractures is associated with higher risks of deep infection, this could have contributed to the increase in incidence of wound healing complications in the CS group (Ovaska et al., 2016). The significant difference in the use of absorbable sutures could have had the opposite effect on these results, as several studies have demonstrated that the use of absorbable sutures leads to fewer complications than other types of sutures or staples. This could have led to fewer wound complications in the CS group (Buresch et al., 2017; Chawla et al., 2016; Mudd et al., 2014; Tuuli et al., 2016). Furthermore, it was found that there were 2.5 times as many tourniquet applications in the CS group in comparison to the control group. Two studies found no correlation between tourniquet use and wound complications or infection (Benedick et al., 2020; Odinson and Finsen, 2006). However, another study found that tourniquet usage for 90 min or more increases the risk of wound infection (Wieviorski et al., 2015). The significant differences in the complexity of fractures and use of tourniquets are likely to be due to coincidence, whereas the significant difference in the use of absorbable sutures is part of the new treatment protocol. These factors could have affected the results. The significant differences in participants with diabetes are based on a small number of patients; yet diabetes has been proven to be associated with wound complications and re-operations (Miller et al., 2012; SooHoo et al., 2009). Our study demonstrated, after adjusting for age, gender, diabetes, ASA score, suture type, AO-classification and tourniquet use, borderline statistical differences in wound healing problems ($p = 0.057$). This may be due to lack of power and we therefore assessed the difference in wound complications after 6 weeks to be clinically relevant.

To the best of our knowledge, only one large randomised controlled study had previously tested CS treatment in relation to wound complications; and found that 1.4% of patients using CS experienced wound infection two weeks after ORIF in comparison to 4.6% of patients not using CS ($p = 0.35$). In contrast, 2.4% of patients using CS experienced wound infection after six weeks compared to 1.4% of patients not using CS ($p = 1.0$) (Winge et al., 2018). However, no significant difference was found.

Compression therapy has shown a beneficial effect on oedema (Sultan et al., 2014), but a solid conclusion on the effect of wound healing is still lacking (Winge et al., 2017, 2018). This may be explained by a new hypothesis that compression therapy may be forcing the fluid out through the wound and thus reducing wound healing.

4.1. Limitations

When performing a retrospective cohort study, information has been collected in the past and data on potential confounding variables can be lacking. Furthermore, distribution of individuals and possible confounders are not random in the two cohorts. A randomised controlled trial would have accommodated for such a lack. Another weakness in the design of our study is the lack of a *priori* sample-size calculation. Furthermore, CS treatment is a relatively new standard treatment, which may have resulted in an increasing awareness of complications at check-up at the outpatient clinic.

5. Conclusion

An increase in wound-healing complications was found when using CS after six weeks and one year compared to no compression therapy. However, owing to study design and baseline differences in the two groups, it is only possible to question the use of CS and identify the need for further study.

Declaration of competing interest

The authors declare that they have no competing interests.

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List of Abbreviations

ASA	American Society of Anaesthesiologist score
CS	Compression stocking
ICD10	The International Classification of Diseases, version 10
IPC	Intermittent pneumatic compression
NOMESCO	Procedure codes
ORIF	Open reduction internal fixation

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Ethical approval statement

The study was approved by the Danish Data Protection Agency (case number 18/27154) and the Danish Patient Safety Authority (case number 3-3013-1157/1). No consent was required from the patients and all data were stored on a secure server at the hospital.

Author contributions

CA contributed with design, interpreting results and writing the article. JSH contributed with design, data acquisition, interpreting results and writing the article. AJ contributed with idea, design and critically revising the manuscript. RJ and KBA contributed with design, data acquisition and critically revising the manuscript. BV contributed with idea, design, data analyses, interpreting results, supervision, and

critically revising the manuscript.

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