Smartphone-based Gait Metrics Demonstrate Effects Of Treatment Delay Following Ankle Fracture

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INTRODUCTION: Traumatic injuries of the ankle, perhaps in part due to their dramatic nature, garner prompt attention and treatment. Delay in treatment of ankle fractures has been studied with regard to effect on complication and infection rates, operative time, length of stay, and healthcare expenditure.[1,2,4-10] Fewer studies discuss the effects of delay on functional outcomes, and those that do invariably use patient-reported outcome measures (PROs), with mixed results; some find decrease in function[3,6], whereas others are equivocal[1,8]. This study uses IMU and position data, reduced by the iPhone to quantitative gait metrics, captured during the daily lives of individuals recovering from ankle fracture, to determine if gait characteristics show decreased functional recovery in patients with longer treatment delays.

METHODS: Gait variables Walking Speed (WS), Walking Double Support Percentage (DSP), Walking Step Length (SL), and Walking Asymmetry Percentage (AP) were extracted from the iPhones of adults who presented with ankle fracture. Daily recorded gait data spanned from 4 weeks pre-injury to 6 months post-treatment. Additional data collected included date of injury (DOI), date of treatment (DOT), type of treatment (surgical vs non-surgical), and fracture classification (Weber and AO). The effect of treatment delay (DOT minus DOI) on recovery of post-injury gait metrics back to pre-injury baselines was evaluated using a linear mixed model in R. Fixed effects included recovery phase post-injury (0 – 6 weeks, 6 weeks – 3 months, or 3 months – 6 months), treatment delay in days, and the interaction of the two. For recovery phase alone, results were obtained in the form of absolute change in gait metric over each phase compared to baseline. For recovery phase:treatment delay interaction, results were the absolute change in gait metric with each additional day of treatment delay. P-values were calculated for each estimate, with $p < 0.05$ considered statistically significant. Patient ID was added as a random effect to account for patient-to-patient variability. Subgroup analyses were stratified by treatment type, fracture severity, or age. This study was approved by the PeaceHealth IRB.

RESULTS: Fifty-five patients participated in the study, patient characteristics outlined in Table 1. Duration of treatment delays averaged 8.2 days with a standard deviation of 5.2 days and a range from 1 day to 31 days. Full linear mixed model demonstrated significant drop in WS and SL as well as significant increase in DSP and AP during the 0 – 6 weeks and 6 weeks – 3 months phases of recovery, with no difference from baseline found in any variables by the 3 month – 6 month phase. Additional days of treatment delay did not have a statistically significant effect on change in gait in any phase of recovery. Effects on change in WS, SL, DSP, and AP overall were -0.0010 m/s ($p = 0.78$), -0.00096 m ($p = 0.61$), 0.079% ($p = 0.17$), and 0.26% ($p = 0.24$), respectively. As depicted in Figure 1, duration of treatment delay is distributed equally above and below each gait metric time point, whereas a color gradient would be expected in the case of a significant association. Age, treatment type, and fracture severity were individually incorporated into the linear mixed model, but none showed any significant effect modification of treatment delay on gait recovery.

DISCUSSION: Gait was significantly altered across all variables in the acute and subacute period following ankle fracture when no modifying factors were considered. This result follows logical expectations and adds validity to the analysis. In answer to the research question, it was found that treatment delay did not have a significant impact on the degree of gait alteration. This remained the case even when possible effect modifiers (age, severity, and treatment type) were taken into account. Smartphone-based gait metrics have been increasingly validated[11] and this study adds to the body of literature on treatment delay of ankle fractures with the novel use of longitudinal, objective measurements, allowing for a higher resolution picture of recovery trajectory compared to PROs collected at discreet time points. There are several limitations to this study. While the analysis was adequately powered to detect moderate effect sizes, it may not have detected subtle changes that could be nonetheless meaningful to the patient. Treatment delays in this study were relatively short, averaging 8.2 days with maximum of 31 days, and results may not be generalizable to prolonged time periods. Other possible effect modifiers were not considered, such as initial management prior to definitive treatment, i.e. closed reduction, immobilization, physical therapy, etc. In all, results suggest that moderate treatment delay may not have significant negative impact on recovery following ankle fracture, regardless of patient age, fracture severity, or surgical versus non-operative treatment.

SIGNIFICANCE/CLINICAL RELEVANCE: This study demonstrates that treatment delays under 30 days may not adversely impact recovery of normal gait after ankle fracture. It also provides evidence that smartphone-based, objective gait metrics can provide longitudinal insight into functional recovery after ankle fracture. This information can guide clinical decision making and surgical timing as well as reassure patients and physicians.

REFERENCES: [1]Sugino 2024, *Foot Ankle Spec*; [2]Edelstein 2025, *Arch Orthop Trauma Surg;* [3]Hawkins 2023, *J Foot Ankle Surg*; [4]Chen 2021, *PLoS One*; [5]Singh 2005, *Eur J Orthop Surg Traumatol*; [6]Schepers 2013, *Int Orthop*; [7]James 2001, *Injury*; [8]Tada, *IOSR-JDMS*; [9]Saithna 2009, *Eur J Orthop Surg Traumatol*; [10]Stewart 2025, *J Orthop Rep*; [11]Werner 2023, *Scientific Reports*

Table 1. Patient Characteristics

Characteristic	N = 55[1]
Age	52.2 (18.7)
Sex	
Female	37 (67%)
Male	18 (33%)
Treatment Delay	8.2 (5.2)
Treatment Type	
Non-operative	28 (51%)
Surgical	27 (49%)
Weber	
Weber A	10 (18%)
Weber B	34 (62%)
Weber C	9 (16%)

[1] Mean (SD); n (%)

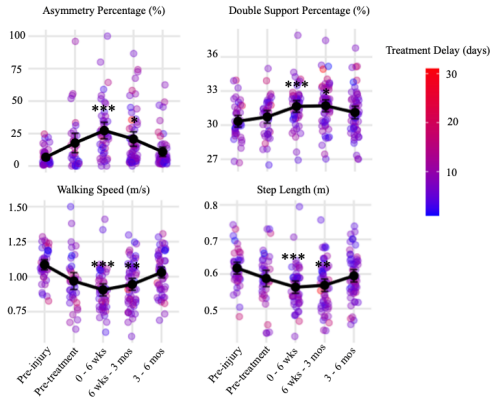

Figure 1. Trend in gait recovery in context of individual treatment delay. Colored dots represent the average of individual patient gait values for the indicated recovery phase. Black lines and black dots are population averages. Error bars are 5% to 95% confidence intervals. Asterisks indicate significant difference ($p < 0.05$) from pre-injury baseline.