Gait & Posture 108 (2024) 145–150

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Effects of rigid and kinesio taping on plantar pressure distribution in patients with Lisfranc fracture sequelae

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ARTICLE INFO

Keywords:
Lisfranc fracture
Plantar pressure
Foot
Taping
Pronation

ABSTRACT

Background: Patients with Lisfranc fractures may regain functional status after anatomical fixation, but they may experience sequelae such as flatfoot deformity and pain associated with foot pressure distribution during weight-bearing.
Research question:: What is the impact of Lisfranc fracture sequelae on both the injured and uninjured sides, and how does the antipronation taping affect plantar pressure distribution parameters?
Methods: Twenty-six patients who underwent anatomical fixation for Lisfranc fracture, displaying pronation on the injured side based on the Foot Posture Index-6 test, as well as 15 healthy subjects, participated in this study. Plantar pressure distribution measurements were conducted during barefoot walking for the healthy subjects. In the patient group, measurements were taken under two antipronation taping conditions (kinesio and rigid taping), as well as during barefoot walking.
Results: Participants who received anatomical fixation after Lisfranc fracture exhibited significant alterations in plantar pressure distribution parameters on both the injured and uninjured sides, as compared to the control group. After the application of Kinesio Taping to the injured side, there was no significant change observed in the plantar pressure distribution values ($p > 0.05$). The analysis of the rigid taping on the injured side revealed statistically worse values in peak pressure of the hindfoot ($p = 0.027$) and maximum force of the midfoot and toes ($p = 0.005$ and $p = 0.013$, respectively) compared to the injured barefoot condition.
Significance: Lisfranc fracture sequelae affected plantar pressure distribution on both injured and uninjured sides. Anti-pronation taping (kinesio and rigit), commonly used for foot conditions, did not lead to foot pressure distribution becoming more similar to that of the control group.

1. Introduction

Lisfranc injuries encompass bony or ligamentous injury of the tarsometatarsal joint complex, including stable partial midfoot sprains as well as displaced fractures of the joint structure [1–4]. Despite being misdiagnosed in up to 20 % of cases [5,6] and considered a rare pathology, Lisfranc injuries are the most common type of serious midfoot injury [7].

The majority of patients who receive appropriate management after a Lisfranc fracture can return to their previous level of function or employment status [8]. However, some patients may develop radiographic evidence of post-traumatic arthritis [9]. Additionally, certain

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https://doi.org/10.1016/j.gaitpost.2023.11.018
Received 11 June 2023; Received in revised form 18 October 2023; Accepted 22 November 2023
Available online 28 November 2023

cases can result in flatfoot deformity [10], accompanied by reported stiffness and pain during weight bearing [11]. Patients who have completed treatment for a Lisfranc fracture may not exhibit the typical rollover pattern when walking. Instead, they exhibit pedobarographic characteristics such as increased midfoot contact area, reduced contact time, and changes in the metatarsal area [12]. Furthermore, the maximum pressure on the injured side tends to shift towards the midfoot [13]. While previous studies have examined the effects of Lisfranc injuries on plantar pressure distribution, these studies typically compared the injured side to the uninjured side. However, this approach may not account for the change in weight bearing that occurs on the uninjured side after a lower leg injury. Mehlhorn et al. [36] showed a significant loss of muscle strength in the injured side plantar flexors. On the other hand, a study found that artificially reducing muscle strength in the triceps surae resulted in significant spatiotemporal and kinematic differences on the contralateral side [14]. Therefore, it is highly possible that structural changes in the foot due to Lisfranc injuries can also lead to changes in gait parameters on the uninjured side. Using the plantar pressure distribution data from the uninjured side as normative data may result in misinterpretation of the results for the injured side.

Postoperative radiographic findings of Lisfranc fractures appear to be excellent, but they do not guarantee highly satisfactory outcomes [15]. After surgery patients are typically recommended to undergo intensive rehabilitation, although this aspect is not well described in the literature [16]. Anti-pronation taping is a conventional treatment to correct the posture of patients with flatfoot or pes planus, which is a characteristic feature/one of the most common problems in the postoperative process of Lisfranc injuries [17]. Taping provides mechanical support to the musculoskeletal system and helps control the height of the navicular bone [18]. Unlike therapeutic insoles, which can be challenging to apply during indoor activities, taping offers greater ease of application [19]. However, literature reports on the effects of anti-pronation taping on contact time, area, and peak plantar pressure after its application vary [20–22]. For instance, Lange et al. [20] reported that heel and forefoot peak plantar pressures significantly decreased in healthy subjects with navicular drop, while in another study, an increase in peak plantar pressure was observed under the heel and lateral midfoot area [21]. Van Lunen et al. [22] mentioned that peak plantar pressure decreased in patients with plantar fasciitis who underwent anti-pronation taping. Based on this information, it can be assumed that the use of anti-pronation taping may lead to foot pressure distribution becoming more similar to that of the control group following anatomical fixation of Lisfranc injuries. However, the effects of taping on various biomechanical parameters, such as contact time, contact area, and peak plantar pressure, may differ between healthy and pathological conditions. To the best of our knowledge, there have been no studies investigating the effects of anti-pronation taping on plantar pressure distribution in patients who have undergone anatomical fixation of Lisfranc fractures.

While patients with Lisfranc fractures often receive adequate surgical fixation, long-term issues with foot pressure distribution can persist. Anti-pronation taping is a conventional treatment for managing pathological plantar pressure distribution, but its effect in patients with Lisfranc fractures remains unclear. This study aims to explore the effects of Lisfranc fracture sequelae on both the injured and uninjured sides, while also assessing the immediate impact of antipronation taping on plantar pressure distribution parameters.

2. Methods

Patients who had undergone surgery for a Lisfranc fracture at least 6 months prior and were attending the Orthopaedic and Traumatology Department were included in the study. The inclusion criteria were as follows: (i) surgical treatment for a Lisfranc fracture at least 6 months ago; (ii) pronated foot type based on the FPI-6 test; and (iii) age between 18 and 65 years. The exclusion criteria were: (i) presence of systemic diseases that could affect the foot; (ii) presence of degenerative bone/joint diseases; and (iii) knee and hip injuries causing morphological changes. A control group was also recruited, consisting of healthy participants with no orthopaedic or neurological conditions. Both feet of the patients and healthy participants were examined. The study protocol was approved by the local ethics committee, and all participants were provided with detailed information and gave written informed consent.

During the screening session, the Modified Foot Posture Index (FPI) was used to assess the foot posture of the injured side in patients. The Modified Foot Posture Index is a six-item foot posture assessment tool that provides a score between –12 and +12. The assessment items include talonavicular bulge, calcaneal angle, medial longitudinal arch, palpation of the talus head, lateral malleoli curves, and forefoot and hindfoot alignment [23]. Positive values on the FPI indicate pronation, with a minimum score of +2 considered indicative of pronation.[2] It is emphasised that the FPI has good intra-rater (ICC = 0.893–0.958) and moderate inter-rater (ICC = 0.360–0.758) validity and reliability [23]. Patients included in the study for taping and pedobarographic assessment procedure were those who exhibited a pronated foot on the injured side based on the FPI assessment. The classification of Lisfranc injuries from initial radiographs was performed using the classification systems of Myerson et al. [24].

2.1. Measurements and procedure

Plantar pressure distribution measurements were conducted using Emed 50 (Novel Inc., GmbH, Germany). The Novel Emed software, which assesses the foot in four plantar regions (hindfoot, midfoot, forefoot, and toes), was utilized for data recording and analysis (Fig. 1). Contact area (CA), peak pressure (PP) and maximum force (normalised to body weight) (MaxF) were calculated for these regions and for the total foot. Plantar pressure distribution measurements in the control group were performed on both feet in a barefoot condition during walking. In the patient group, the evaluation was performed while walking under three conditions: barefoot, modified reverse-6 taping using rigid tape, and antipronation kinesiotaping of the injured side. Participants were instructed to walk on the pedobarography platform at a self-selected speed until five trials were recorded for each foot [25,26].

The initial assessment was performed in the barefoot condition. After a 15-minute rest period, the modified reverse-6 taping technique was applied, and the pedobarographic measurement was immediately repeated. The modified reverse-6 method was implemented by OO, following the description provided by Meier [27]. Rigid tape (RT) was applied three times to provide support to the medial longitudinal arch in the modified reverse-6 condition. The final measurement was performed in the Kinesio Taping (KT) condition after a 15-minute rest period from the second measurement. The final measurement was performed in the Kinesio Taping (KT) condition after a 15-minute rest period following the second measurement. The application of the anti-pronation taping was performed by TO. Kinesio® Tape (5 cm wide and 0.5 mm thick) was used, applying a strip on the medial side of the injured foot from the first metatarsal around the medial malleolus to the end of the posterior tibial tendon with a 40 % stretch. For the initial positioning, patients were instructed to keep their foot in a neutral position, and for the final part of the application, they were asked to dorsiflex the foot. To ensure optimal adhesion, the tape was warmed by rubbing immediately after application.

Statistical analysis was conducted using SPSS 11.0. The Mann-Whitney U test was used to compare the pedobarographic measurements of the injured side, the uninjured side, and the control group. The Wilcoxon test was used to compare the effects of RT and KT. For all tests, the statistical level was set at $p = 0.05$.

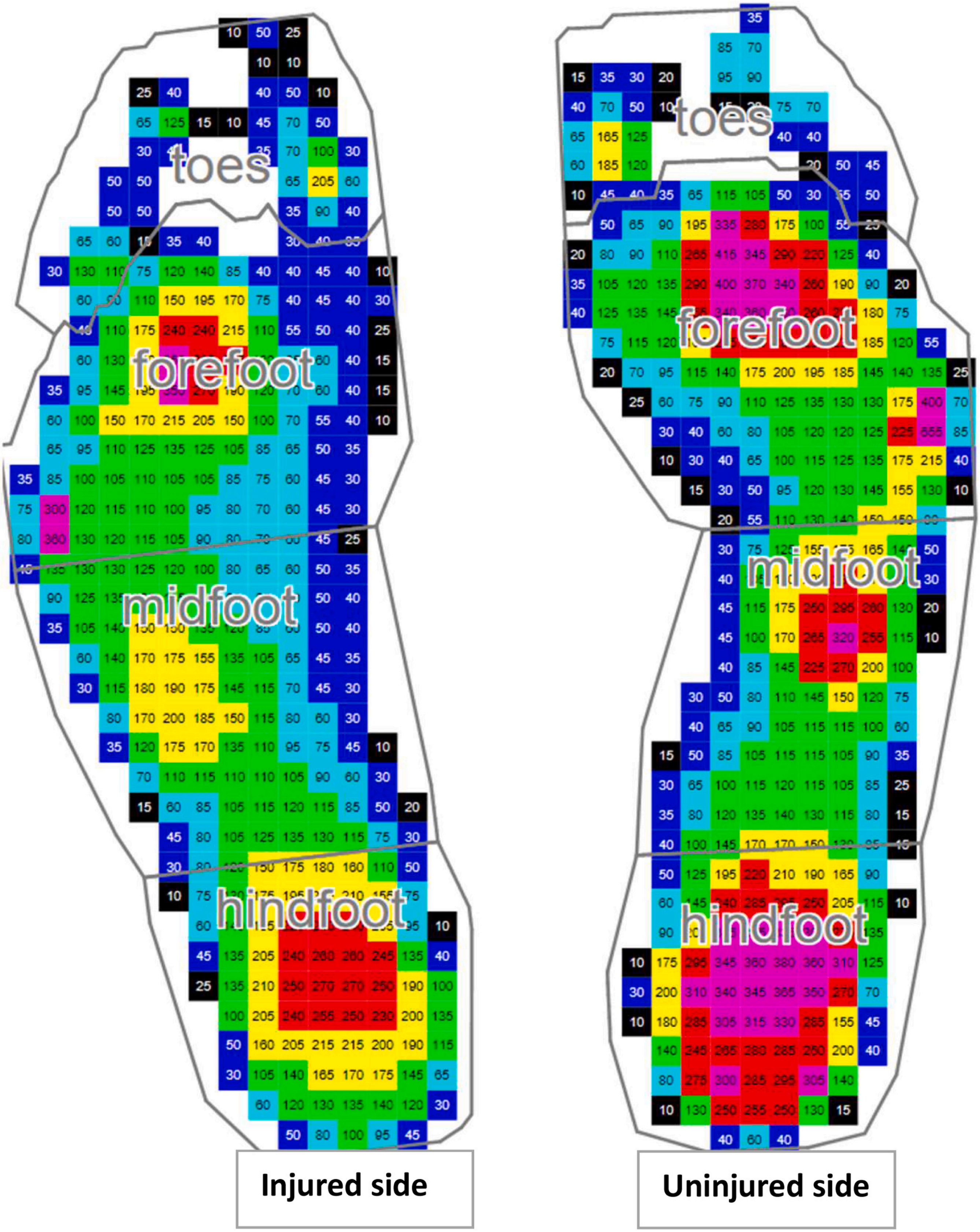

Fig. 1. The plantar pressure distribution in four plantar regions (hindfoot, midfoot, forefoot, and toes) of a 35-year-old female participant. Duration between anatomical fixation and pedobarographic measurement is 16 months.

3. Results

3.1. Demographic data

A total of 26 patients were included in the study. The mean age of the 26 patients (8 females and 18 males) was 35.03 ± 1.67 years, with a body mass index (BMI) of 26.48 ± 5.40 kg/m^2. The control group consisted of 15 males with a mean age of 21.53 ± 0.83 years and a BMI of 24.38 ± 2.69 kg/m^2. The trauma mechanisms reported by the participants were as follows: road traffic accident (9 patients), fall from height (6 patients), crush injury (6 patients), and low energy trauma (stumble and fall) (5 patients). According to the classification system by Myerson et al. [24], 2 patients were classified as type A, 8 as type B1, 12 as type B2, and 1 as type C1. All patients received orthopaedic treatment through open reduction and internal fixation. The average time between the surgery and the pedobarographic evaluation of the patients was 42.07 ± 25.71 months.

3.2. Plantar pressure distribution

The results of plantar pressure distribution (MaxF, CA, and PP) in different foot areas (total foot, hindfoot, midfoot, forefoot, and toes) of the injured and uninjured foot, compared to the control group, are presented in Table 1. Comparing the injured side of the patients with the control group, the barefoot measurement showed increased MaxF values in the total foot and midfoot ($p = 0.001$ and $p = 0.015$, respectively), and decreased MaxF in the hindfoot ($p = 0.006$) and toes ($p = 0.036$). CA of the total foot, hindfoot, and toes on the injured side significantly decreased ($p = 0.005$, $p = 0.001$, and $p = 0.001$, respectively), and PP of the hindfoot also decreased significantly ($p = 0.001$), compared to the control group. The barefoot results for the uninjured side of the patients showed a significant increase in MaxF of the total foot ($p = 0.001$), but CA of the total foot, hindfoot, and toes of the uninjured side significantly decreased ($p = 0.033$, $p = 0.001$, and $p = 0.001$, respectively), compared to the control group. Although PP of the uninjured side decreased statistically in the hindfoot ($p = 0.026$), it increased significantly in the toes ($p = 0.048$).

The effects of RT and KT on the parameters of the injured side, which were significantly different from the control group, are shown in Table 2. There was no significant change in the plantar pressure distribution values of the injured foot after the application of KT. Analysis of RT on the injured side showed statistically significant differences from the injured barefoot in PP of the hindfoot ($p = 0.027$) and MaxF of the midfoot and toes ($p = 0.005$ and $p = 0.013$, respectively). Taping with rigid and Kinesio® tape on the injured side did not change the plantar pressure distribution values on the uninjured side ($p > 0.05$).

4. Discussion

Lisfranc injuries, despite surgical intervention, can result in persistent foot pressure distribution problems [9–11]. This study aimed to investigate the effects of Lisfranc fracture sequelae on plantar pressure distribution in patients, considering both the injured and uninjured sides.

The primary finding of this study suggests that anti-pronation taping, incorporating both KT and RT, did not lead to plantar pressure distribution parameters becoming more similar to those of the control group. Furthermore, following anatomical fixation of Lisfranc fractures, significant differences were observed in the plantar pressure distributions of both the injured and uninjured sides compared to the control group.

In addition to the generally poor clinical outcomes associated with surgical treatment of Lisfranc fractures [28,29], previous studies have used the uninjured side of plantar pressure distribution as normative data to assess the impact of Lisfranc injuries [12,16,30]. However, as even foot dominance can affect foot pressure distribution [31], it is important to consider that any type of foot injury can lead to changes in plantar pressure distribution in both feet, including differences in lower limb weight bearing. To the best of our knowledge, this study is the first to demonstrate alterations in plantar pressure distribution on both feet after anatomical fixation of the Lisfranc fracture, providing a comparison to healthy subjects. Plantar pressure is closely related to contact area (CA) of the foot and maximum force (MaxF). In the injured side, CA decreased in the total foot, hindfoot, and toe regions, while MaxF increased in the total foot and midfoot, and decreased in the hindfoot and toe regions. Peak plantar pressure exhibited a significant change only under the hindfoot of the injured side. On the uninjured side, CA of the total foot, hindfoot, and toe regions decreased, while MaxF increased in the total foot. Peak pressure decreased in the hindfoot and increased

Table 1
Comparison of Plantar Pressure Data within the Injured, Uninjured and Control Feet in the Barefoot Condition.

Parameters	Foot Area	Injured	Uninjured	Control	p value*	p valueϒ
Maximum Force (normalized to BW) (%BW)	**Total Foot**	109.00 (107.75–113.25)	109.50 (108.00–114.00)	106.30 (103.75–108.30)	0.001*	0.001ϒ
	Hindfoot	64.00 (55.25–69.25)	64.50 (57.75–73.25)	70.75 (65.45–74.33)	0.006*	0.053
	Midfoot	26.00 (18.50–37.75)	22.50 (16.75–32.50)	18.05 (14.27–22.32)	0.015*	0.053
	Forefoot	86.50 (81.00–91.25)	85.00 (80.25–91.25)	86.20 (79.65–92.10)	0.980	0.651
	Toes	17.50 (9.00–26.50)	24.00 (22.00–27.25)	23.10 (19.22–30.82)	0.036*	0.711
Peak Pressure (kPa)	**Total Foot**	529.50 (376.50–611.00)	467.00 (374.24–617.15)	425.00 (396.25–460.00)	0.083	0.139
	Hindfoot	269.50 (233.00–307.75)	288.50 (228.50–335.50)	307.50 (295.00–395.00)	0.001*	0.026ϒ
	Midfoot	145.50 (120.00–187.25)	155.50 (114.00–183.50)	140.00 (110.00–165.00)	0.742	0.543
	Forefoot	387.50 (329.25–506.75)	427.00 (310.00–487.50)	380.00 (302.50–443.75)	0.304	0.275
	Toes	287.50 (157.50–542.75)	368.00 (270.00–520.75)	312.50 (248.75–421.25)	0.634	0.048ϒ
Contact Area (cm^2)	**Total Foot**	146.00 (131.5–157.00)	148.00 (135.75–159.50)	159.04 (144.45–169.52)	0.005*	0.033ϒ
	Hindfoot	36.00 (33.75–37.25)	36.00 (33.75–37.50)	40.37 (36.43–41.48)	0.001*	0.001ϒ
	Midfoot	31.50 (26.50–38.25)	31.00 (26.00–38.25)	30.68 (28.45–35.68)	0.882	0.882
	Forefoot	55.50 (49.75–59.25)	54.50 (48.00–60.25)	56.87 (53.21–63.18)	0.131	0.186
	Toes	21.00 (17.50–24.25)	23.00 (20.00–25.25)	27.46 (24.82–30.93)	0.001*	0.001ϒ

The Mann-Whitney U test was used for statistical analysis. Values are expressed as median with 1st and 3rd percentiles in parentheses. * indicates significant differences ($p < 0.05$) between injured and control feet, and ϒ indicates significant differences ($p < 0.05$) between uninjured and control feet. BW: Body Weight, kPa: Kilopascal, cm: centimetre.

Table 2
Effects of Rigid and Kinesio Taping on the Injured Side of Patients with Lisfranc Sequelae.

Parameters	Foot Area	Bare Foot	Rigid Taping	Kinesio Taping	p value*	p value^{ϒ}
Maximum Force (normalized to BW) (%BW)	**Total Foot**	109.00 (107.75–113.25)	110.00 (107.75–113.00)	110.00 (107.75–113.25)	0.388	0.944
	Hindfoot	64.00 (55.25–69.25)	62.00 (55.50–69.00)	64.00 (58.25–71.50)	0.127	0.365
	Midfoot	26.00 (18.50–37.75)	27.50 (22.50–36.75)	26.00 (20.50–34.25)	0.005*	0.293
	Toes	17.50 (9.00–26.50)	14.50 (9.00–23.25)	15.50 (8.50–23.75)	0.013*	0.083
Peak Pressure (kPa)	**Hindfoot**	269.50 (233.00–307.75)	258.50 (224.00–298.25)	272.50 (230–307.25)	0.027*	0.382
Contact Area (cm^2)	**Total Foot**	146.00 (131.50–157.00)	150.50 (126.75–159.25)	146.00 (129.25–156.25)	0.419	0.935
	Hindfoot	36.00 (33.75–37.25)	35.50 (33.75–40.00)	36.00 (33.75–37.25)	0.726	0.532
	Toes	21.00 (17.50–24.25)	21.00 (16.75–24.50)	19.50 (16.50–24.25)	0.818	0.169

The Wilcoxon test was used for statistical analysis. Values are expressed as median with 1st and 3rd percentiles in parentheses. * indicates significant differences ($p < 0.05$) between barefoot and rigidly taped foot measurements on the injured side, and ϒ indicates significant differences ($p < 0.05$) between barefoot and kinesio taped foot measurements on the injured side. BW: Body Weight, kPa: Kilopascal, cm: Centimetre.

in the toe region. Although we were unable to measure the differences in weight-bearing between the injured and uninjured sides, we hypothesize that this alteration is not solely due to anatomical changes in the injured foot following orthopaedic treatment, but may also be attributed to increased weight-bearing on the uninjured side. While dynamic weight-bearing was not assessed in this study, Schepers et al. [13] reported that patients tend to avoid loading the Lisfranc joint.

Taping, through the application of external tension on the skin, assists in regulating joint movements and offering mechanical support [32]. Based on the literature we currently possess, this study is the first to investigate the immediate effects of KT and RT on plantar pressure in patients who have undergone anatomical fixation of Lisfranc fractures. The results revealed significant changes in the hindfoot, midfoot, and toe areas following the application of RT. However, it should be noted that RT led to worsened values compared to the control group. The observed changes in plantar pressure distribution after KT application in this study differ from previous studies on pronated foot posture [20,33,34]. The general agreements in the literature is that KT typically leads to an increase in peak plantar pressure under the lateral midfoot and a decrease under the hindfoot and medial forefoot [20]. However, it is important to consider that these previous studies primarily focused on healthy participants with pronated feet and not individuals with diagnosed foot pathology [20,34]. Despite methodological differences, Aguilar et al. [35] found that anti-pronation KT did not significantly alter peak plantar pressure distribution following a running task. Additionally, previous research does not support a consistent systematic change in plantar pressure distribution after taping [20,33,34]. Furthermore, it is worth noting that the biomechanical effects of taping differ between healthy and pathological conditions [35], which may explain the inconsistent results observed in these previous studies.

There are some limitations to this study. One limitation is related to the outdated software used, which only allowed for dividing the foot area into four zones in the anterior-posterior direction. Therefore, it was not possible to determine whether significant changes in peak pressure (PP) occurred on the medial or lateral side in the toe and midfoot zones. Additionally, the study did not include an analysis of spatio-temporal parameters in patients with Lisfranc fractures, which could have provided insights into the effects of Lisfranc injuries on the uninjured side. As authors, we believe that combining pedobarographic and spatio-temporal parameters would allow for a more comprehensive assessment of the rehabilitation process and its outcomes. Another limitation of the study is the heterogeneity of the patients in terms of lesion classification (type A, type B1, type B2 and type C1). Since this situation may affect the sequelae that may occur after surgery, it may also affect the pedobarographic results. This variation underscores the complexity of Lisfranc fractures and the need for future studies with larger, more homogenous patient groups to further elucidate the impact of these factors.

5. Conclusion

The sequelae of Lisfranc fracture caused the plantar pressure distribution to deteriorate not only on the injured side but also on the uninjured side. Despite the common use of anti-pronation taping, including both KT and RT, to address pronated foot conditions, our study found that it did not lead to the desired improvement in the pedobarographic data, and, in some cases, led to a worsening of the values compared to the control group. Therefore, new approaches should be explored to provide external support to the feet of patients with sequelae of Lisfranc injuries.

Ethical approval

Ethical approval for this study was obtained from Marmara University Faculty of Medicine Clinical Research Ethics Committee (APPROVAL NUMBER: 09.2019.1084).

CRediT authorship contribution statement

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version for publication. Dr Orhan OZTURK had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study conception and design: Orhan OZTURK, Tugce OZEN, Tugba Kuru COLAK, Engin ECEVIZ, Ilker COLAK, Mine Gulden POLAT. Acquisition of data: Orhan OZTURK, Tugce OZEN, Tugba Kuru COLAK, Engin ECEVIZ. Analysis and interpretation of data: Orhan OZTURK, Tugce OZEN, Tugba Kuru COLAK, Engin ECEVIZ, Ilker COLAK, Mine Gulden POLAT.

Declaration of Competing Interest

All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. All of the authors declare no conflict of interests.

Acknowledgements

We would like to express our gratitude to all the individuals who have contributed to this research project. First and foremost, we extend our deepest appreciation to the patients who participated in this study and made this research possible. We are also grateful to the research assistants who helped with the data collection.

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