# Clinical and Biomechanical Outcomes of Suture Button Fixation for Ligamentous Lisfranc Injury

## A Systematic Review and Meta-analysis

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**Background:** Flexible ligamentous fixation has increased in popularity for the treatment of ligamentous Lisfranc injury, but the optimal fixation strategy is unclear.

**Purpose:** To review the biomechanical, clinical, and radiographic results of ligamentous Lisfranc injuries treated with flexible fixation.

**Study Design:** Systematic review; Level of evidence, 4.

**Methods:** A systematic literature review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The PubMed/Medline and Google Scholar literature databases were queried for clinical and biomechanical (cadaveric) studies relating to flexible fixation of ligamentous Lisfranc injury. Outcomes of interest included patient-reported outcome scores, clinical/biomechanical results, radiographic alignment, and return to activity. Where appropriate, meta-analysis of the postoperative outcomes was performed.

**Results:** Of the 34 initial studies, 14 articles (243 feet) were included in the analysis. In the 11 clinical studies (216 patients), the mean postoperative American Orthopaedic Foot & Ankle Society score was 90.1 (n = 150; 6 studies) and the mean visual analog scale score was 1.5 (n = 137; 5 studies). The rate of return to activity was 100% (n = 35; 5 studies), and 100% of patients maintained radiographic alignment postoperatively (n = 62; 6 studies). No complications or subsequent hardware removals were reported. Of the 3 biomechanical studies (27 feet), 1 study found significantly greater change in diastasis under axial load between intact and postfixation ligaments with suture button versus screw fixation (+1.1 vs –0.1 mm; $P < .05$), another found no difference in the decrease in diastasis under axial load between the injured state and screw or suture button fixation (1.2 vs 1.0 mm; $P = .5$), and the third found no difference in displacement between intact and either screw or suture button fixation under either axial (intact vs screw: 1.0 vs 2.0 mm, $P = .1$; intact vs suture button: 0.6 vs 1.8 mm, $P = .1$) or abduction (intact vs screw: 1.5 vs 1.1 mm, $P = .5$; intact vs suture button: 1.3 vs 2.1 mm, $P = .1$) load.

**Conclusion:** Flexible fixation use in the treatment of ligamentous Lisfranc injury was found to have significant potential as a fixation option, as demonstrated by excellent clinical results. Biomechanical evidence was inconclusive but suggested a trend toward decreased diastasis in specimens fixed with screws compared with suture buttons.

**Keywords:** Lisfranc injury; suture button; fixation; biomechanics

Lisfranc injuries are of tremendous clinical significance, as failure to appropriately reduce and stabilize the columns of the midfoot can lead to progressive collapse and early-onset arthrosis.[2,34] The optimal fixation strategy for the subset of Lisfranc injuries without concomitant fracture, pure ligamentous, is as of yet unknown.[1,5,6,18,25,30]

Traditionally, operative treatment for stabilization of the affected joint has been performed by direct or indirect reduction followed by fixation with a "home run screw," which may range in size from 3.0 to 4.5 mm. This strategy effectively stabilizes the midfoot but has also been associated with damage to articular cartilage, hardware failure, and need for eventual hardware removal.[1,4,7,14,19,27,34] Because of the potential to alleviate some of these concerns, flexible fixation to reconstruct torn Lisfranc ligaments has become the subject of increased investigation.[‖]

Potential benefits of flexible fixation compared with screws include minimized trauma to the articular cartilage of the midfoot and near elimination of the need for hardware removal after recovery. Perhaps most important is the use

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[‖]References 1, 5–7, 9, 15, 20, 24, 25, 27, 34.

of a flexible fixation device across a joint that inherently experiences physiologic motion in its intact state.[¶] A similar thought process has led to increased research and ultimately intraoperative use of flexible fixation in ankle syndesmotic injuries, with overall positive results.[13,16,31,32] Currently, the clinical implications of this fixation technique for pure ligamentous Lisfranc injuries are unclear, as most publications have been able to report on only a small series of patients in a retrospective manner.[20,24,25,27,34]

The aims of the present review were to report on the outcomes in the existing literature of ligamentous Lisfranc injuries treated with flexible fixation and to pool these data in a meta-analysis to arrive at more robust conclusions. Additionally, we sought to assess and summarize the relevant biomechanical data published on this topic. We hypothesized that flexible fixation for the treatment of Lisfranc injuries would be safe and effective compared with traditional screw fixation and would have fewer complications related to trauma to the adjacent articular cartilage or need for hardware removal.

## METHODS

### Search Strategy

This systematic literature review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The search strategy was designed to identify studies regarding flexible fixation of Lisfranc injuries including biomechanics, radiographic, and clinical outcomes. We searched the following literature databases: PubMed/Medline and Google Scholar for studies published from 2010 until February 2022. The reference lists of relevant studies were also hand-searched for additional studies. Different combinations of keywords were searched to maximize the search results. The keywords used were as follows: “Lisfranc,” “ligamentous,” “flexible,” “suture button,” “suture tape,” “biomechanics,” “outcomes,” and “radiographic.” All publication dates were included.

### Eligibility Criteria

Prospective cohort and retrospective clinical studies were searched and reviewed for inclusion. Biomechanical cadaveric studies were also reviewed for inclusion. Studies were included if they were relevant to Lisfranc injury treated with flexible fixation (suture button or suture tape) and available in the English language. Studies that included ancillary fixation methods for other injuries (eg, intercuneiform screw fixation and tarsometatarsal joint [TMTJ] fixation) were included, and additional procedures were documented. Clinical studies were reviewed for patient-reported and radiographic outcomes. Studies that did not meet these inclusion criteria or clinical studies that lacked quantitative outcomes were excluded, as were published letters, comments, editorials, proceedings, and personal communications.

### Study Selection and Data Extraction

Studies that were identified by the search strategy were reviewed for eligibility by first evaluating abstracts of the studies and then by examining the full texts for eligibility for data extraction. Studies were assessed by 2 reviewers (1 orthopaedic surgery resident [D.V.C.] and 1 faculty member [B.C.L.]), and any conflicts were resolved by a third, independent reviewer. Duplicates were removed. The following data were extracted from studies that met the inclusion criteria: name of first author, year of publication, study design, American Orthopaedic Foot & Ankle Society (AOFAS) score, visual analog scale (VAS) pain score, patient satisfaction score, return to activities, and radiographic outcomes.

### Outcome Measures

For this meta-analysis, the primary outcome was return to activities (at the end of follow-up). Secondary outcomes were the AOFAS, VAS pain, and patient satisfaction scores, as well as radiographic alignment, revisions/failures, and complications.

### Quality Assessment

The Methodological Index for Non-Randomized Studies (MINORS) instrument was used to quantify the quality of the included clinical studies. For noncomparative studies, scores <9 were considered poor quality; 9 to 12, fair quality; and >12, good quality. For comparative studies, scores <14 were considered poor quality; 14 to 18, fair quality; and >18, good quality.[29]

[¶]References 1, 5–7, 10, 15, 20, 23–25, 27, 34.

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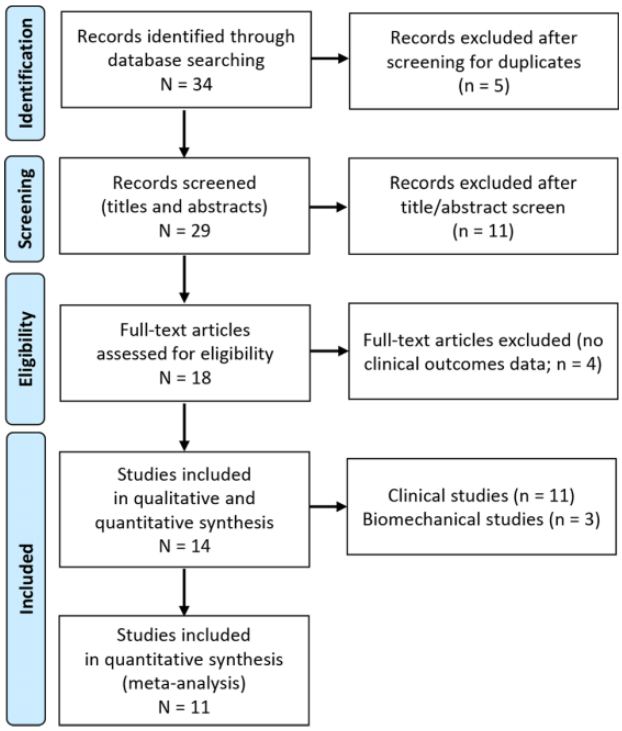


**Figure 1.** PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of study inclusion.

## Statistical Analysis

Weighted means were calculated for continuous variables (AOFAS and VAS), and overall percentages were calculated for categorical variables (return to activity and radiographic alignment). Because of inconsistent reporting of standard deviations and/or ranges, a weighted standard deviation could not be calculated. Calculations were performed using R Version 3.6.0 (The R Foundation for Statistical Computing).

# RESULTS

Of the 43 articles initially identified for review, 14 studies (13 articles and 1 clinical abstract) were included in the final analysis.[#] There were 11 clinical studies[**] and 3 biomechanical studies.[1,27,28] The results of the search process are displayed in Figure 1.

## Clinical Studies

The included clinical studies are summarized in Tables 1 and 2. The mean MINORS score of the 11 studies was 8.9 (range, 4-19). Open reduction was performed in 8 studies,[6-9,11,18,23,35] with 1 study[33] reporting percutaneous reduction and 2 studies[14,25] not specifying. All studies used the Mini TightRope (Arthrex) between the medial cuneiform and second metatarsal for fixation. Postoperative protocols varied, with most studies restricting patients to nonweightbearing status for 2 to 6 weeks.[6,7,14,18,23,25,33]

Notably, some differences did exist among surgical techniques. Cottom et al[11] performed simultaneous intercuneiform screw fixation between medial and intermediate cuneiforms in all 84 of their patients, with additional Kirschner wire fixation of third and fourth metatarsals in 1 patient. Gee et al[18] reported intercuneiform screw fixation in 50% of their 6 patients. Brin et al[6] also evaluated the first TMTJ and performed fixation in 3 of their 5 patients.

## Biomechanical Studies

The results of the included biomechanical studies are outlined in Table 3. Ahmed et al[1] compared fixation from the medial cuneiform to the second metatarsal with either the Mini Tightrope or a 4.0-mm partially threaded cannulated screw by measuring the distance between the first and second metatarsals. This was done in 8 matched-pair cadaveric specimens with intact, transected, and reconstructed Lisfranc ligaments. The authors applied a 600-N axial load and also performed load-to-failure testing at a rate of 50 mm/min and found that when comparing reconstructed with intact Lisfranc ligament diastases under axial load, screw fixation yielded a mean diastasis of –0.01 mm and suture button fixation of +1.1 mm, which was a statistically significant difference. Additionally, their comparisons of reconstructed specimens with and without axial load demonstrated that screw fixation resulted in +0.2-mm diastasis and suture button, +1.2 mm. This difference was statistically significant as well. Load-to-failure testing demonstrated no significant difference between the screw and suture button. The primary conclusion of the study was that fixation with a 4.0-mm partially threaded cannulated screw resulted in less displacement than the Mini Tightrope in this model of isolated Lisfranc ligament injuries.[1]

Panchbhavi et al[27] reported on 14 matched-pair cadaveric specimens fixed with either a Mini Tightrope or a 3.5-mm cannulated lag screw from the medical cuneiform to the second metatarsal base and measured displacement at the Lisfranc ligament attachment sites under an axial load of 343 N. They reported that both screw and suture button fixation demonstrated significant improvements in diastasis compared with the unfixed injury model. Compared with intact specimens, screw fixation yielded an increase in displacement of 0.1 mm and suture button, 0.3 mm. Neither displacement was significant compared with the intact model. Additionally, the difference between the 2 fixation methods was not statistically significant.[27]

Pelt et al[28] fixed 5 matched-pair cadaveric specimens with either the Mini Tightrope or a 3.5-mm fully threaded cortical screw between the medial cuneiform and second metatarsal. The suture button group also underwent fixation of the second TMTJ with 0.062-inch Kirschner wire, while the screw group underwent second TMTJ fixation with a 3.5-mm fully threaded cortical screw. The distance

[#]References 1, 6–9, 11, 14, 15, 18, 23, 27, 28, 33, 35.

[**]References 6–9, 11, 14, 15, 18, 23, 33, 35.

TABLE 1
Characteristics of the Clinical Studies (n = 11 studies; 216 patients)[a]

| Lead Author (Year) | MINORS Score | n | Mean Age, y | Patient Activity Level | Surgical Technique | Postoperative Protocol | Time to Intervention |
|---|---|---|---|---|---|---|---|
| Brin (2010)[6] | 7 | 5 | 35.4 | 2 professional athletes, 3 recreational athletes | Open reduction; suture button C1-MT2 ± C1-MT1 fusion (additional: 1st TMTJ fixation [60%]) | Wk 0-3: NWB, cast<br>Wk 3: cast removal, PT<br>Wk 5: WBAT | NR |
| Charlton (2015)[7] | 9 | 7 | 24.6 | 5 professional ballet dancers, 2 D1 college soccer players | Open reduction; suture button C1-MT2 | Wk 0-2: NWB, splint<br>Wk 2-6: boot, NWB<br>Wk 6-8: wean crutches, supportive shoe<br>3 mo: Barre work (dancers), low-impact training (athletes)<br>6 mo: full training/ participation | Minimum 6-mo (mean, 14 mo) nonop failure |
| Cho (2021)[8] | 19 | 31 | 40.9 | NR | Open reduction; suture button C1-MT2 | Wk2: ROM, pool therapy<br>Wk3: NWB splint, removal cast for next 3 wk<br>Wk 6-12: PWB<br>Wk 12-16: RTS | 6.2 days |
| Chun (2021)[9] | 7 | 12 | 31.6 | NR | Open reduction; suture button C1-MT2 | All patients returned to daily activities within median of 12.7 mo | NR |
| Cottom (2020)[11] | 4 | 84 | 39.69 | NR | Open reduction; suture button MT2-C1 (additional: C1-C2 screw | Mean time to protected FWB in CAM: 11 days | NR |
| Crates (2015)[14] | 9 | 11 | 29.6 | NR | Suture button C1-MT2 | Wk 0-3: NWB, splint<br>Wk 3-6: boot, WBAT<br>Wk 6-8: WBAT, orthotic, PT<br>Mo 3-4: RTS<br>Mo 4-6: full training/ participation | NR |
| Gee (2019)[18] | 13 | 6 | 29.7 | Active-duty military | Open reduction; suture button C1-MT2 (additional: C1-C2 screw fixation [50%]) | Mean time for NWB: 10 wk | NR |
| Jain (2017)[23] | 8 | 5 | 22.1 | Professional soccer or rugby players | Open reduction; suture button C1-MT2; targeting guide (Wright Medical) | Wk 0-2: NWB, splint<br>Wk 2-6: boot, NWB<br>Wk 6: boot, WBAT<br>Wk 10: nonimpact graduated resistance program<br>Wk 13-14: running<br>Wk 15-17: cutting, twisting, ball work | NR |
| Tzatzairis (2019)[33] | 5 | 1 | 13 | NR | Percutaneous reduction; suture button C1-MT2 | Wk 0-2: PWB, crutches, boot<br>Wk 2-4: WBAT, boot | NR |
| Yongfei (2021)[35] | 8 | 11 | 35.4 | NR | Open reduction; suture button C1-MT2 | Wk 6-8: plaster splint, PWB<br>3 mo: WBAT, return to activity | 4.5 days |
| Kreulen (2019)[25] | NR | 43 | NR | NR | Suture button C1-MT2 | NR | NR |

[a]CAM, controlled ankle movement boot; C1, medial cuneiform; C2, intermediate cuneiform; D1, Division I; FWB, full weightbearing; MINORS, Methodological Index for Non-Randomized Studies; MT1, first metatarsal; MT2, second metatarsal; nonop, nonoperative; NR, not reported; NWB, nonweightbearing; PT, physical therapy; PWB, partial weightbearing; RTS, return to sport; TMTJ, tarsometatarsal joint; WBAT, weightbearing as tolerated.

between the medial cuneiform and second metatarsal was measured under an axial load of 222.4 N and abduction load of 50 N. The effect of performing 1000 load cycles was then evaluated. They found that abduction stress results in greater diastasis in the injury model than axial. Under either axial or abduction loads, neither screw nor suture button demonstrated statistically significant differences in diastasis compared with the intact state, thereby suggesting that either fixation method may restore stability to a level comparable to the intact state. Additionally, cyclic loading did not have a statistically significant effect on measured diastasis. Their overall conclusions were that

TABLE 2
Summary of Outcomes for the Clinical Studies[a]

| Lead Author (Year) | Follow-up | Clinical Outcomes | Radiographic Outcomes | Complications |
|---|---|---|---|---|
| Brin (2010)[6] | 12 mo | • 6 mo: 100% return to activity<br>• 1-y satisfaction: 80% very high; 20% moderate<br>• 60% mild midfoot morning stiffness | NR | No wound healing or any early complications |
| Charlton (2015)[7] | 25 mo | • 6 mo: 100% return to activity<br>• Mean AOFAS midfoot score at last f/u: 97 (range, 90-100) | 100% maintained alignment | No wound healing, dehiscence, or other early complications |
| Cho (2021)[8] | 16 mo | • Mean AOFAS score: 86.2 ± 2.3 (screw) vs 84.3 ± 2.0 (suture button); $P = .125$<br>• Mean VAS score: 2.1 ± 1.3 (screw) vs 2.3 ± 1.6 (suture button), $P = .319$ | • No difference vs screw group in diastasis or side-to-side difference on WB AP XR<br>• No significant difference on WB CT | • Screw: 4 screw breakages (1 recurrent diastasis), 2 early arthritic changes (1st and 2nd TMTJs)<br>• Suture button: 2 cases of suture button subsidence over C1 in older patients<br>• No postop infection or wound problems |
| Chun (2021)[9] | 13.2 mo | • 100% return to activity<br>• AOFAS score: 93.5 ± 2.3 | Significant decrease in diastases | No reported complications |
| Cottom (2020)[11] | 3.4 y | 3 y: VAS score, 1.3 ± 1.57; AOFAS score, 90.64 ± 12.18 | Final WB XR demonstrated significant step-off of 0.43 mm | • Screw: 10.7% (n = 9) underwent hardware removal (4.0-mm screw) for loosening or pain<br>• Suture button: no evidence of suture button failure or removal in any patients |
| Crates (2015)[14] | 33 mo | NR | NR | • Screw: hardware removal in 7 of 9 (77.8%) patients<br>• Suture button: no button removal |
| Gee (2019)[18] | 12.4 mo | • 100% return to full activity (mean 181 days)<br>• Last f/u: VAS pain, 1.6 | 100% maintained alignment | • Screw: hardware removal in 5 of 6 (83.3%) patients; apidus arthrodesis in 1 (16.7%) patient for symptomatic posttraumatic arthritis (1st TMTJ), loss of reduction in 1 (16.7%) patient with early 1st TMTJ arthritis<br>• Suture button: no complications |
| Jain (2017)[23] | 24 mo | • 100% return to full activity; 100% excellent result<br>• Return to training: 16.1 wk; return to full competition: 20.4 wk<br>• AOFAS score: 94; VAS score: 0.6 | 100% maintained alignment | • 1 (20%) patient had transient deep peroneal nerve sensation<br>• No other early complication or implant removal |
| Tzatzairis (2019)[33] | 3 mo | Symptom-free | Maintained alignment | No reported complications |
| Yongfei (2021)[35] | 20.5 mo | Last f/u: AOFAS score, 92.4 ± 4.3; Maryland foot score, 94.1 ± 3.5; VAS score, 1.5 ± 0.7 | Distance between MT1 and MT2 significantly shorter than preop | No wound or implant complications |
| Kreulen (2019)[25] | 9 mo | NR | Reduction accuracy (injured vs noninjured)<br>• 6 wk postop: C1-M2, 0.77 mm; M1-M2, 0.44 mm<br>• Final f/u: M1-M2, 0.22 mm ($P = .435$ vs 6 wk); C1-M2, 0.27 mm ($P = .352$ vs 6 wk) | No reported complications |

[a]AOFAS, American Orthopaedic Foot & Ankle Society; AP, anterior-posterior; C2, intermediate cuneiform; CT, computed tomography; f/u, follow-up; MT1, first metatarsal; MT2, second metatarsal; postop, postoperative; preop, preoperative; TMTJ, tarsometatarsal joint; VAS, visual analog scale; WB, weightbearing; XR, radiograph.

TABLE 3
Characteristics of the Biomechanical Studies (n = 3 studies; 27 feet)[a]

| Lead Author (Year) | No. of Feet | Comparison | Measurements | Load | Results | Conclusion |
|---|---|---|---|---|---|---|
| Ahmed (2010)[1] | 8 | Suture button vs 4.0-mm partially threaded cannulated screw C1-MT2 | M1-M2 distance, load to failure | Axial: 600 N; load to failure: 50 mm/min | • Fixed vs intact loaded mean diastasis: –0.1 mm (screw), +1.1 mm (suture button)<br>• Fixed loaded vs fixed unloaded screw diastasis: –0.2 mm (screw), –1.2 mm (suture button)<br>• Load to failure: no difference | Screw resulted in less displacement than suture button in isolated Lisfranc ligament injuries |
| Panchbhavi (2009)[27] | 14 | Suture button vs 3.5-mm canulated lag screw C1-MT2 | C1-MT2 Lisfranc ligament attachment site displacement | Axial: 343 N | • Cut unfixed +1.2-mm difference from screw fixation<br>• Cut unfixed +1.0-mm difference from suture button fixation<br>• Screw vs suture button difference not significant (screw 0.2 mm less) | Suture button and screw did not differ significantly in displacement in isolated Lisfranc ligament injuries |
| Pelt (2011)[28] | 5 | Suture button C1-MT2 with K-wire MT2-C2 vs 3.5-mm full threaded cortical screw ×2—C1-MT2, MT2-C2 | C1-MT2 distance | Axial: 222.4 N; abduction: 50 N; 1000 cycles, then retested | • Abduction load yielded greater displacement than axial after injury (6.8 vs 2.0 mm)<br>• Axial load: screw/suture button vs intact not significant (2.0/1.8 vs 1.0 mm); suture button vs screw not significant (1.8 vs 2.0 mm)<br>• Abduction load: screw vs intact not significant (1.1 vs 1.5 mm); suture button vs intact not significant (2.1 vs 1.5 mm)<br>• Cyclic loading (1000 cycles): suture button/ screw preop vs postop not significant | • Abduction stress resulted in greater motion than axial<br>• No difference between fixation (suture button and screw) and intact states in displacement in ligamentous Lisfranc injuries |

[a]C1, medial cuneiform; C2, intermediate cuneiform; K-wire, Kirschner wire; M1/MT1, first metatarsal; M2/MT2, second metatarsal; postop, postoperative; preop, preoperative; TMTJ, tarsometatarsal joint.

abduction stress results in greater displacement at the Lisfranc joint than axial and that neither suture button nor screw fixation states differ significantly from intact displacement under load.[28]

## Clinical Results

A total of 216 patients were included between the 11 clinical studies.[††] The mean age of all included patients was 36.7 years (range, 11-57 years), and the mean time to follow-up was 25.4 months (range, 3-60 months). Data were pooled and meta-analysis was performed where possible, with results outlined in Table 4. Among the 5 clinical studies[6,7,9,18,23] that reported return-to-activity rates, all 35 patients reported full return. Two studies[6,23] reported satisfaction rates, and among their 10 combined patients, only 1 reported less than very high or excellent subjective results. AOFAS scores were pooled from 6 studies,[7-9,11,23,35] with a mean score among 150 patients of 90.1 at a mean time of 30.7 months; this indicates an excellent result.[10] VAS scores were reported in 5 studies,[8,11,18,23,35] and among the 137 patients, the mean score was 1.5 at a time of 30.8 months; this is consistent with minimal or no pain.[17,24]

Cho et al[8] found significantly inferior clinical outcomes associated with conventional screw fixation in comparison with suture button fixation. Interestingly, they also examined plantar foot pressure 4 to 6 months postoperatively and found significantly elevated foot pressure in the conventional screw fixation group at the great toe and first metatarsal head area compared with the contralateral foot. They proposed that inferior clinical outcomes of screw fixation could be associated with the increased metatarsal foot

[††]References 6–9, 12, 14, 15, 18, 23, 33, 35.

TABLE 4
Results of Meta-analysis of Suture Button Fixation[a]

| | AOFAS | VAS | Return to Activity | Radiographic Results |
|---|---|---|---|---|
| No. of studies | 6 | 5 | 5 | 6 |
| No. of patients | 150 | 137 | 35 | 62 |
| Mean age, y | 37.7 | 38.5 | 29.1 | 34.2 |
| Mean time of follow-up, mo | 30.7 | 30.8 | NR | NR |
| Mean outcome score | 90.1 | 1.5 | 100% return | 100% maintained alignment |

[a]AOFAS, American Orthopaedic Foot & Ankle Society Score; NR, not reported; VAS, visual analog scale.

pressure, which may have been secondary to the increased rigidity of the Lisfranc and TMTJs.[8]

## Radiographic Results

Radiographically, all 62 patients in 6 studies with radiographic data were found to have maintained alignment at final radiographic follow-up.[7,13-15,18,23] Kreulen et al[25] compared injured and uninjured feet in their 43 patients at 6 weeks postoperatively. The distance between the medial cuneiform and second metatarsal, as well as that between the first and second metatarsals, was measured and found to not differ significantly between sides. Chun et al[9] compared Lisfranc diastasis on the standing foot radiograph preoperatively and 1 year postoperatively with mean diastases of 2.91 versus 0.14 respectively, showing a significant mean difference.

Cho et al[8] also compared radiologic parameters between suture button and traditional screw fixation and found no significant difference between groups in terms of diastasis and side-to-side difference measured on weightbearing anterior-posterior radiographs. Dorsal and plantar diastasis measured on weightbearing computed tomography also showed no significant difference.

In the largest cohort of patients examined by Cottom et al[11] at a minimum 3-year follow-up, they found an increase in step-off at the final follow-up. They found that there was a 0.2-mm increase in diastasis on average; however, they indicate that this is possibly related to patient positioning for radiographs and changes in weightbearing status from initial to final radiographs.[12]

## DISCUSSION

The present systematic review on flexible fixation of ligamentous Lisfranc injury (14 articles: 11 clinical retrospective series [216 patients] and 3 biomechanical studies [27 feet]) demonstrated excellent clinical and radiographic outcomes for patients undergoing suture button fixation, while biomechanical studies have yielded mixed findings when comparing suture button with traditional screw fixation in cadaveric models. This study contributes to the existing literature on flexible fixation of ligamentous Lisfranc injury by summarizing the results of biomechanical and clinical studies and meta-analyzing clinical outcomes. To our knowledge, it is the first to do so in a comprehensive manner and lays the foundation for future clinical and biomechanical studies on this topic.

The biomechanical publications report mixed results when comparing diastasis resulting from screw fixation, suture button fixation, and intact Lisfranc ligament states.[1,27,28] While Ahmed et al[1] reported a decrease in displacement in screw compared with suture button fixation in their model of ligamentous Lisfranc injury, Panchbhavi et al,[27] did not demonstrate such a difference. Of note, both of these studies used only axial load for testing purposes. Pelt et al,[28] who also reported on results of abduction load, were unable to demonstrate a statistically significant difference between specimens with intact Lisfranc ligaments and either screw or suture button fixation. However, they did not directly compare diastases of screw and suture button fixation under abduction load. Their results would appear to trend toward significance, with screw fixation yielding –0.4-mm diastasis and suture button fixation yielding +0.6-mm diastasis compared with intact specimens. However, these results may be confounded by the fact that the screw group had a 3.5-mm cortical screw stabilizing the second TMTJ, while the suture button group had only a 0.062-inch Kirschner wire. Furthermore, it is also possible that this study was underpowered with a sample size of only 5 matched pairs. Notably, neither load to failure nor effect of cyclic loading was demonstrated to cause a difference in either group. The biomechanical data, as a whole, are inconclusive, with only 1 study[1] demonstrating a statistically significant difference in diastasis between fixation types. That is, screw fixation resulted in reduced M1-M2 diastasis compared with suture button fixation, although this difference was not >1.2 mm. The clinical significance of this difference is uncertain, as biomechanical data indicate that specimens with intact Lisfranc ligaments yield nearly 3 mm of intermetatarsal diastasis and approximately 1 mm of medial cuneiform–second metatarsal diastasis under axial load.[3,28]

Overall, clinical outcomes of ligamentous Lisfranc injury treated with suture button fixation have been encouraging in each of the individual studies included here.[‡‡] All these studies are retrospective case series with relatively small sample sizes. However, when considering them as a whole and combining results into meta-analysis, the same conclusion is reached, with a mean AOFAS score of 90.1 (excellent), a mean VAS score of 1.5 (minimal or no pain), and

‡‡References 6–9, 12, 14, 15, 18, 23, 33, 35.

100% return to activity with no reported hardware complication or removal.[10,17,24] This is also true of the radiographic results reported by these studies, with all studies reporting maintained alignment on final images.[7,13-15,18,23]

The overall clinical and radiographic results of suture button fixation of ligamentous Lisfranc injury suggest that it may be a reliable fixation construct and warrants direct comparison with clinical results after screw fixation. A prospective randomized study is lacking but would contribute greatly to determining a definitive answer to the question of whether suture button fixation is superior or equivalent to screw fixation when used in practice. Biomechanical data to date have provided mixed results but demonstrate that it is essential for future studies to compare the screw not only against suture button fixation but also against the intact state, as there exists some physiologic motion between the first and second metatarsals and the second metatarsal and medial cuneiform.[1,26-28] Furthermore, based on the results of Pelt et al,[28] future studies should include abduction stress testing as part of the examination, as this was found to result in greater diastasis than axial load in the injury model (6.8 vs 2.0 mm, a statistically significant result). Further investigation has begun on the impact of varying the form of flexible fixation on postoperative results.[21,22] The use of the Arthrex Internal Brace (Arthrex), for example, has been described with the reported advantages of allowing for collagen ingrowth along the suture tape while decreasing iatrogenic bone and cartilage loss associated with suture button placement.[21,22] However, it remains to be seen to what degree such alternative methods of flexible fixation will be used in clinical practice given the difficulty of achieving an anatomic reduction, which is critical for the Lisfranc articulation.

Although the present review contributes to the existing literature, it is not without its own weaknesses. The studies included are retrospective and have small sample sizes. In addition, there is heterogeneity in surgical techniques and postoperative rehabilitation protocols (eg, weightbearing status and cast/splint immobilization) of uncertain significance among the included studies, and meta-analysis was limited by the lack of standardized reporting measures in these publications. VAS and AOFAS scores are potentially meaningful markers but were used inconsistently in outcome measurement. The nature of a systematic review and meta-analysis is such that the final outcome is limited by the preexisting literature, which in this case is primarily composed of low-quality evidence. However, this study does successfully summarize the most current knowledge on a topic of research interest and surgical relevance and, where possible, combines results from a series of small studies into a larger sample size from which more robust conclusions may be drawn.

## CONCLUSION

The results of the present investigation demonstrate that suture button fixation is comparable to traditional screw fixation for the treatment of ligamentous Lisfranc injuries based on clinical and radiographic results. Biomechanical evidence has been inconclusive to date due in part to limited focus on abduction stress testing and in some cases small sample sizes. A prospective randomized clinical trial is lacking but is recommended based on the findings presented here.

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