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Novel technique for deltoid spring complex reconstruction in progressive collapsing foot disorder

Ankit Jaiswal *, Girish Motwani, Vivek Maurya

Department of Orthopaedics, Suyog Hospital, Nagpur, Maharashtra, India

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ABSTRACT

Introduction: Adult Acquired Flatfoot Deformity (AAFD) is a progressive condition characterized by the collapse of the medial foot arch, often caused by posterior tibial tendon dysfunction or deltoid spring ligament incompetency. Flexible type 2 AAFD results in peritalar subluxation and instability. The deltoid and spring ligament complex plays a critical role in foot stability. Current surgical treatments include ligament reconstructions, tendon transfers, and osteotomies, but comprehensive approaches for advanced cases are limited. This study compares two novel techniques—Quadrangular and Triangular repairs—using fiber tape or wire for reconstruction of the deltoid spring complex, combined with medial displacement calcaneal osteotomy (MCDO) for Stage II AAFD.

Materials and methods: Forty patients (mean age 44.6 years) with Stage II AAFD, unresponsive to conservative treatment, were enrolled between December 2023 and 2024. Both surgical techniques, combined with MCDO (excluding lateral column lengthening), were performed. Clinical and radiological assessments were made preoperatively, at 3 months, and at 12 months. The AOFAS Ankle-Hindfoot scale assessed functional outcomes, while radiological parameters such as Meary's angle, talonavicular coverage, and tibial-calcaneal angle were evaluated.

Results: At 3 and 12 months post-surgery, both techniques showed significant improvements in clinical (AOFAS) and radiological outcomes, including Meary's angle and hindfoot alignment ($p < 0.01$). Triangular repair demonstrated slightly better functional outcomes, but both techniques effectively restored foot biomechanics and alignment. Complications included wound dehiscence, metal irritation, and persistent subtalar pain, which resolved with conservative treatment.

Conclusion: Quadrangular and Triangular repair techniques, augmented with fiber tape or wire and combined with MCDO, are effective for Stage II AAFD. Both methods improve clinical and radiological outcomes, with Quadrangular repair showing a slight advantage in functional recovery in severe deformity. These findings suggest that a personalized approach based on talonavicular coverage optimizes AAFD management.

1. Introduction

Adult Acquired Flatfoot Deformity (AAFD) is a condition defined by "medial foot arch insufficiency, which is commonly caused by posterior tibial tendon dysfunction (PTTD)" or deltoid spring ligament complex incompetency [1]. Both etiologies have undergone substantial research to better understand their course and treatment. In severe AAFD, increasing tension on the interosseous and spring ligaments causes progressive peritalar subluxation, followed by deltoid and spring ligament insufficiency [2]. Understanding the architecture of the joints, which includes the talonavicular, subtalar, and tibiotalar joints, might help understand the increasing kinematic alterations and the need of restoring peritalar stability in advanced AAFD surgical therapies [3].

Anatomical research has shown that the deltoid ligament integrates with the spring ligament to provide medial tibiotalar and talonavicular stability [4,5]. A comprehensive understanding of the anatomy of the "spring ligament and deltoid complex" is essential for effectively treating deformities affecting the foot and ankle [5]. Since these ligaments are interconnected, examining their anatomical features together rather than separately provides a more thorough understanding [7]. The deltoid ligament consists of several ligaments originating from the medial malleolus, while the spring ligament complex is a group of ligaments

* Corresponding author.
E-mail address: jaiswalankit414@gmail.com (A. Jaiswal).

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that link the navicular to the sustentaculum tali of the calcaneus. Both are crucial for stabilizing the medial ankle and the medial column of the foot [9,10]. The deltoid spring complex is a group of ligaments in the foot and ankle that provide stability to medial longitudinal arch [11,12]

Treatment options for AAFD are diverse, ranging from non-operative therapies in the early stages to surgical techniques. Various techniques have been described to stabilize the medial ligament in AAFD, including isolated reconstruction of the spring or deltoid ligaments, Flexor digitorum longus (FDL) tendon transfer, often combined with calcaneal osteotomy [6–8]. Another approach to managing stage II AAFD involves lateral column lengthening combined with other procedures. The previous study introduced a FiberTape scaffold technique for medial column repair. Building upon that preliminary work, the current study investigates a refined technique for deltoid spring complex reconstruction using a new, independent cohort of 40 patients with Progressive Collapsing Foot Disorder [13]

In the present study, we use two different techniques for reconstructing a deltoid spring complex, as follows. A) Quadrangular repair that is replacing Deltoid + Talocalcaneonavicular spring component reconstruction and B) Triangular that is replacing Deltoid + talonavicular spring component reconstructions, this reconstruction was done by fibrtape or fibrewire is combined with a bony surgery in the form of medial displacement calcaneal osteotomy (MCDO) without lateral column lengthening. This study also aims to develop a unique approach and strategy for managing AAFD stage II with setting an algorithm based on talonavicular coverage percentage.

2. Materials and methods

Between December 2023 to December 2024, 40 patients provided informed consent to participate in this study. The mean age at surgery was "44.6 years (range 35–55 years)", with 18 males and 22 females.

Inclusion criteria comprised:

– Symptomatic patients with AAFD stage II who had failed conservative treatment

Exclusion criteria included:

- Patients with recurrent deformity after prior surgery,
- Active foot infection,
- Subtalar or chopart joint arthritis,
- Neurological diseases,
- Refusal to participate,
- Loss to follow-up,
- And incomplete data or radiographs at the last follow-up.

Informed written consent was obtained before surgery and for the use of their data for research purposes.

Clinical assessment included a full musculoskeletal examination, foot clinical assessment, and functional evaluation using the American Orthoapedics Foot and Ankle Society's (AOFAS) Ankle-Hindfoot scale [14]. Radiological assessment involved five parameters in three views (anteroposterior, lateral, and Hindfoot Alignment view) while the patient was weight-bearing [15].Forty consecutive patients diagnosed with Stage II PCFD were included between December 2023 to December 2024. This cohort is entirely distinct from patients included in prior studies[13]. Unlike the earlier pilot cohort, this study involved a new group of 40 patients and focused on refining the surgical technique and comparing triangular versus quadrangular reconstruction outcomes [13]. Figs. 1–3

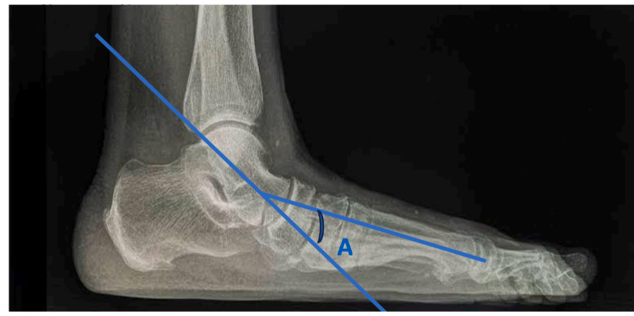


Fig. 1. Talo-First Metatarsus Angle (Meary's Angle): "Measured between the talus and first metatarsal axes [15].

Fig. 2. TaloNavicarlarCoverage Angle(TNCA): Measured between lines connecting the edges of the talus and navicular articular surfaces [16].

- MRI was performed routinely to evaluate the tibialis posterior tendon, deltoid ligament, spring ligament, cartilage condition and bony or fibrous coalition. Radiographic measurements were conducted by a foot and ankle fellow other than the operating surgeon.

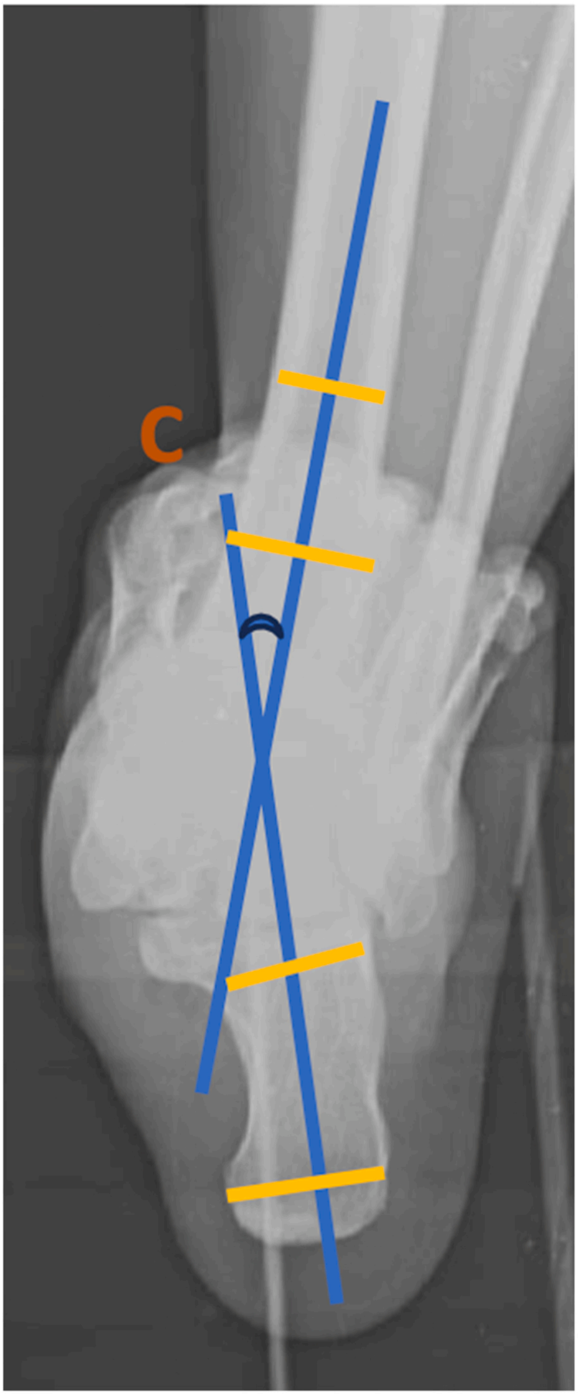


Fig. 3. Tibio-Calcaneal Angle: Measured between the tibial shaft axis and the calcaneal axis, as described by Cobey [17].

3. Surgical technique

All 40 feet underwent a minimally invasive medial displacement calcaneal osteotomy (MDCO) to correct the valgus deformity of the hindfoot, along with Deltoid Spring complex (Fig. 4) reconstruction using 2 different techniques that is Quadrangular repair or Triangular repair on basis of talonavicular coverage angle(Fig. 7) as needed to address associated conditions.

1. **Medial Displacement Calcaneal Osteotomy (MDCO):**

Fig. 4. Showing ligament of Deltoid Spring Complex.

- Approximately 2 cm incision was made behind and 3 cm distal to the lateral malleolus, posterior to sural nerve
- Periosteum was gently raised and reflected. transverse osteotomy was performed with mini saw at 45-degree angle to the sole
- Osteotomy done at posterior 1/3rd and anterior 2/3rd junction of calcaneum
- Medial sliding was done 1–1.5 cm and fixed with 6.5 mm cannulated cancellous screws minimum 2 screws.

2. **Quadrangular Repair (Deltoid + Tibiocalcaneonavicular spring complex reconstruction)** (Fig. 5):

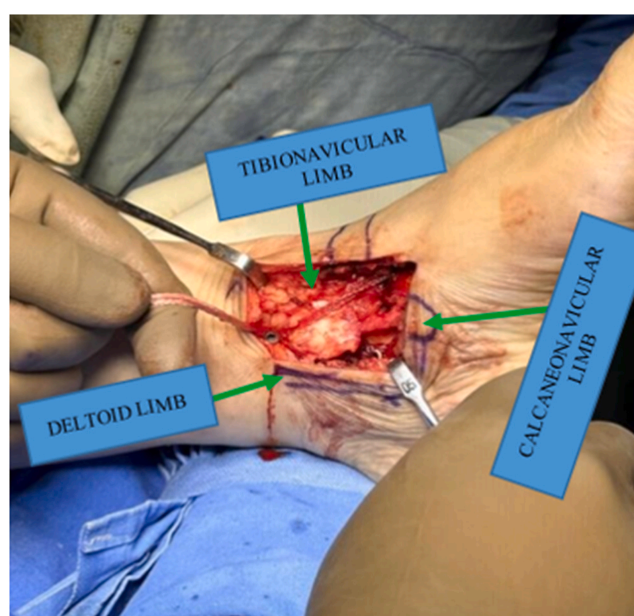


Fig. 5. Figure showing schematic and intraoperative Quadrangular Repair (deltoid + tibiocalcaneonavicular spring complex reconstruction).

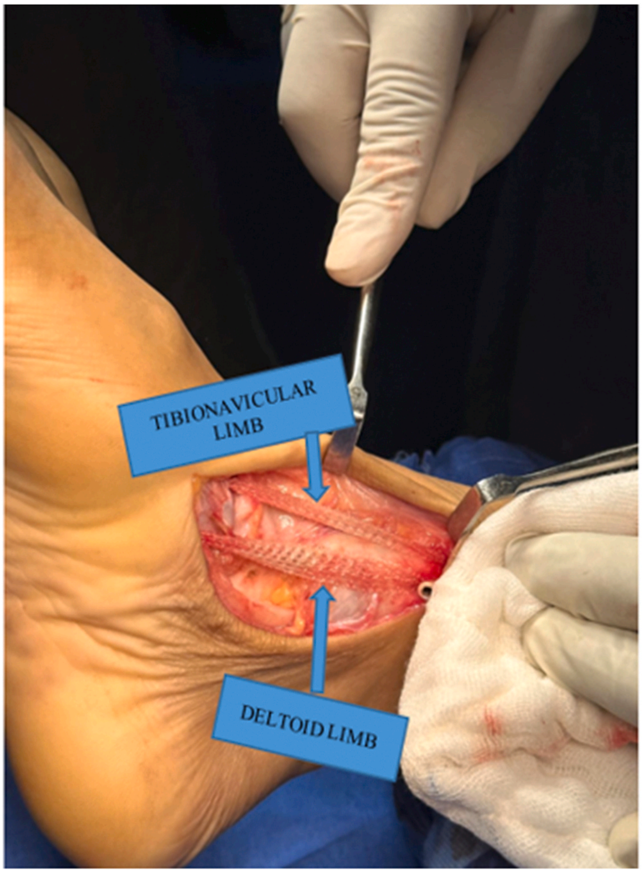


Fig. 6. – Figure showing intraoperative Triangular Repair (deltoid + Tibionavicular spring complex reconstruction).

- A synthetic fibretape or polytape (3 mm) was secured to the sustentaculum tali A synthetic fibertape or polytape (3 mm) was attached to the sustentaculum tali using a 4.5 mm knotless Swive Lock suture anchor. This anchor supplied two limbs of fibertape for the repair.
- A bone tunnel (4–6 mm) was made in the navicular bone to build a quadrangular fibertape scaffold for TCNL repair.
- To preserve the flexor hallucis longus (FHL) tendon and tibial nerve, the sustentaculum tali was carefully drilled without penetrating the inferior cortex.
- The calcaneonavicular component of the deltoid spring complex was formed by passing one leg of the fibertape through the navicular tunnel from plantar to dorsal side. The limb was then stretched towards the tibia, forming the tibionavicular component
- The fibertape's second leg was stretched from the calcaneum to the tibia, starting with the sustentaculum tali. This procedure created a quadrangular repair by attaching both arms of the fiber tape to the tibia.
- A 4.5 mm knotless suture anchor was inserted in the intercollicular groove of the medial malleolus to bind the two fibertape limbs.
- Stimulated weight bearing Fluoroscopy was used to align Meary's angle and correct talar inclination and medial displacement, resulting in successful fixation.

3. **Triangular Repair (Deltoid + Tibionavicular (TNL) spring complex reconstruction) (Fig. 6):**

– A bone tunnel (4 mm) was made in the navicular bone. A 3 mm synthetic fibertape has passed through navicular bone tunnel.
– The fibertape's both limbs were extended from the navicular straight to the tibia, starting with the navicular by securing both fibertape limbs to the tibia, this technique created a repair of the deltoid and talonavicular component which builds a triangular construct.
– To hold the fibertape limbs in place, a last 4.5 mm knotless suture anchor was positioned in the medial malleolus intercollicular groove.
– Using Stimulated weight bearing fluoroscopy to confirm adequate talar covering and alignment of Meary's angle, fixation was accomplished while adjusting the talar inclination and medial displacement.

4. **Additional Procedures:**

o When indicated, the flexor digitorum longus (FDL) tendon was repaired to the remnant tibialis posterior tendon under appropriate tension to reinforce the medial column and enhance stability.
o Gastrocnemius recession (GR) or tendon Achilles lengthening (TAL) was performed to address equinus contracture, thereby improving overall foot
o 1st TMT Open dorsal wedge osteotomy was done in few cases
o This surgical approach provided a minimally invasive yet comprehensive correction of deformities associated with flatfoot, addressing both bone and soft tissue abnormalities to restore foot alignment and function.

4. Postoperative and follow-up evaluation

Postoperative follow-up appointments were conducted at intervals of:

- 3 months,
- 12 months.

Patients were initially placed in a splint for 6 weeks with no weight-bearing, followed by a gradual transition to weight-bearing using a walker, accompanied by physiotherapy to enhance muscle strength and restore range of motion. Full weight-bearing in standard footwear was permitted after 3 months. Functional and radiological outcomes were evaluated preoperatively and during each follow-up, with comparisons made between preoperative data and those at 3 and 12 months postoperatively. Reported complications included loss of correction, implant failure, and the development of arthritis in adjacent joints. Computed tomography (CT) scans were performed for patients experiencing persistent pain that did not respond to conservative treatment. Statistical analyses were performed using SPSS software, employing paired t-tests to compare preoperative and postoperative radiological measurements, with significance defined as a p-value ≤ 0.05.

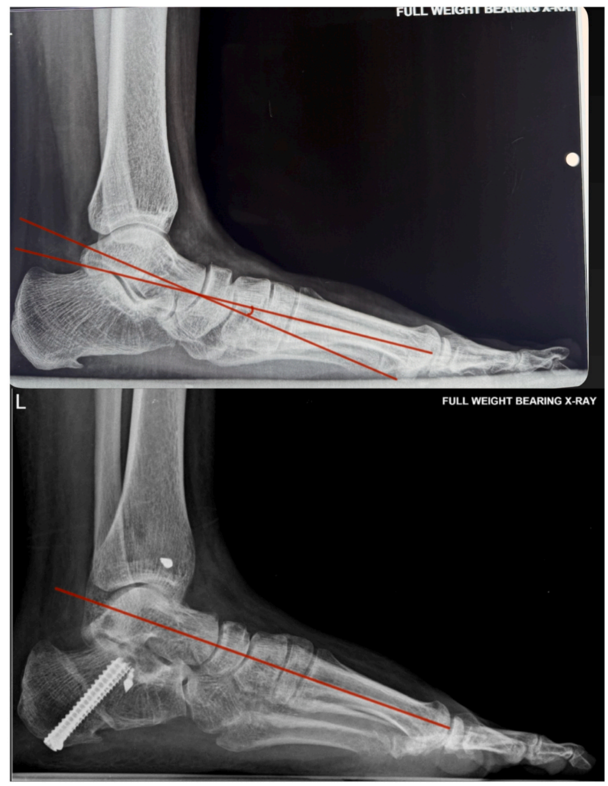
Radiological evaluation

Quadrangular Repair (deltoid + tibiocalcaneonavicular spring complex reconstruction)

Lateral x ray:

1. Meary's Angle

Angle A- preoperative Meary's angle −24°, Angle A' - postoperative Meary's angle −0



Anteroposterior Radiographs:

1. Talo-Navicular Coverage Angle (TNCA)

Angle B- preoperative talonavicular coverage angle 52°, Angle B'- postoperative talonavicular coverage angle 2°,

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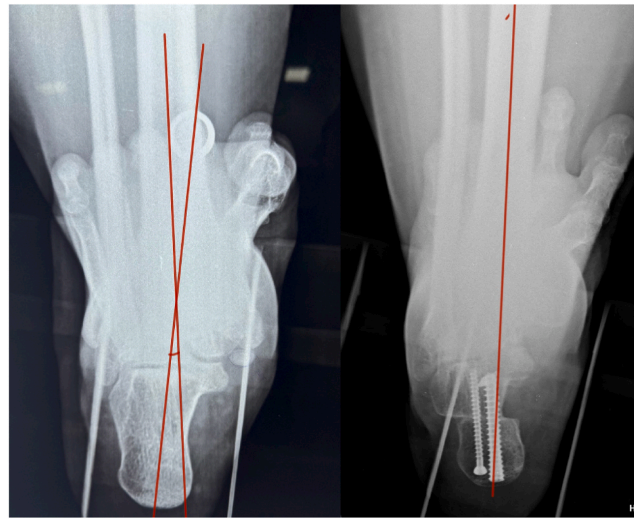
Hindfoot Alignment Radiographs: 1. Tibio-Calcaneal Angle Angle C- preoperative tibio-calcaneal angle −12 °,Angle C'- postoperative tibio-calcaneal angle −0°	

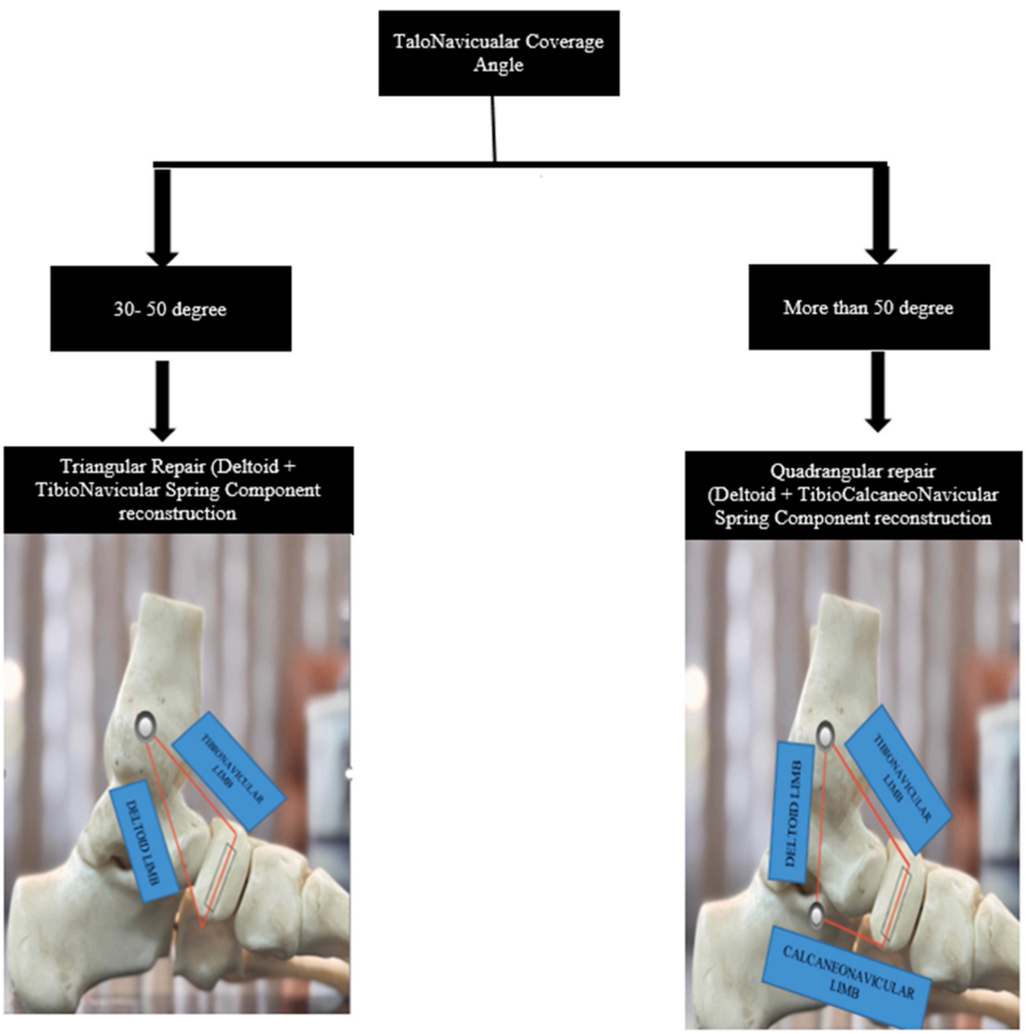


Fig. 7. Algorithm for type 2 AAFD as per Talonavicular coverage Angle with Schematic Representation of both repair.

5. Case illustration

1. Case No 18: 38Yr/F

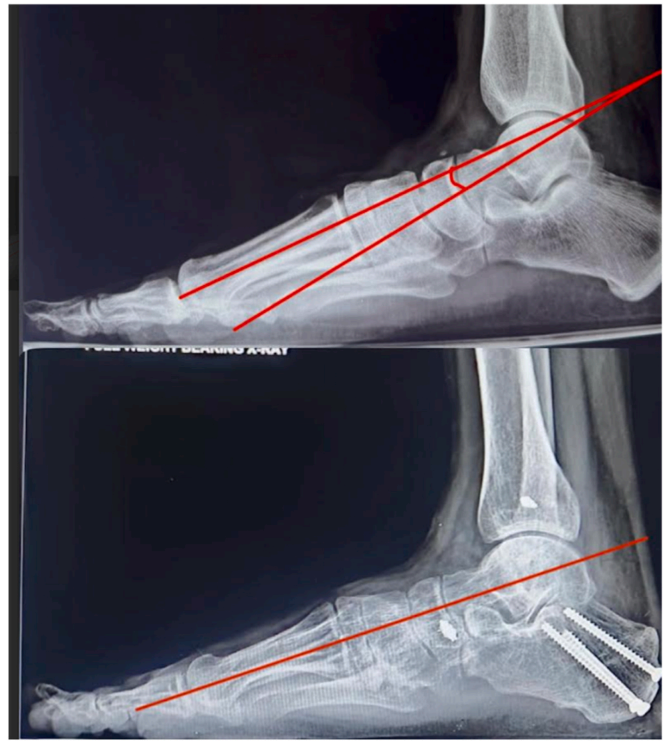
Radiological evaluation

Triangular Repair (Deltoid + Tibionavicular Spring Complex Reconstruction)

Lateral x ray:

Meary's Angle

Angle A- preoperative Meary's angle −17°, Angle A' - postoperative Meary's angle −0°



Anteroposterior Radiographs:

Talo-Navicular Coverage Angle (TNCA)

Angle B- preoperative talonavicular coverage angle 34°, Angle B'- postoperative talonavicular coverage angle 6°,

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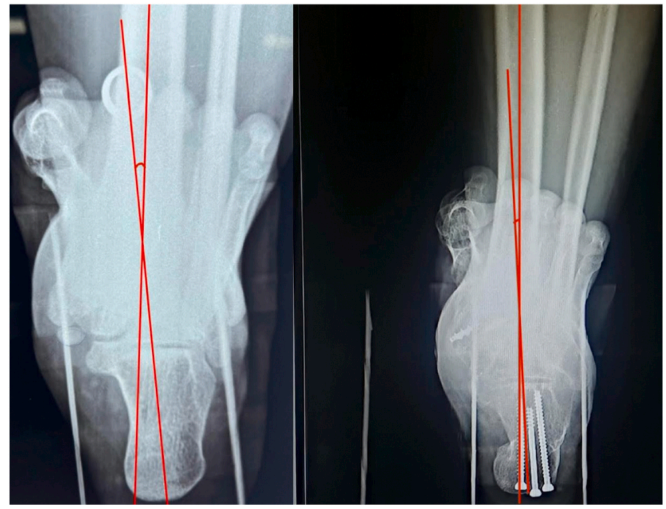
Axial Radiographs: Tibio-Calcaneal Angle Angle C- preoperative tibio-calcaneal angle −24°,Angle C'- postoperative tibio-calcaneal angle −2°	

Case No 32: 42 Yr/F

6. Results

The mean participant age was 44.23 ± 4.8 years. Radiographic measurements showed significant improvements in all angles at 3 months and 12 months compared to preoperative values. Preoperative and follow-up AOFAS scores, Meary's angles, TN coverage, and tibial calcaneal angles demonstrated in both surgical techniques found to be statistically significant improvements ($p < 0.01$).

The results highlight significant improvements in clinical and radiological outcomes,

demonstrating the effectiveness of the novel fibretape scaffold with two different techniques in reconstructing medial ligament function in stage II AAFD (Table 1).

The outcomes of Triangular Repair and Quadrangular repair demonstrate significant improvement in both functional and radiographic parameters, reflecting the efficacy of these procedures in restoring foot biomechanics and alignment. A detailed analysis of each parameter reveals subtle differences between the two techniques (Graph 1).

1. AOFAS Score (Functional Outcome):
   The AOFAS score showed substantial improvement in both groups, indicating enhanced pain relief and functional recovery. Preoperative scores were lower for the quadrangular repair group (**40.45** ± **8.9**) compared to the triangular repair group (**60.45** ± **8.9**), likely due to the more extensive involvement of the quadrangular repair in hindfoot stability. Post-operatively, both groups reached similar levels of improvement at 3 months (**91.21** ± **6.5**) and remained stable at 12 months (**92.32** ± **6.8** for triangular repair vs. **94.32** ± **6.8** for quadrangular repair; **p < 0.01**). This suggests that while both surgeries effectively restore function, triangular repair reconstruction may result in slightly superior long-term functional recovery. Although a minority of patients reported mild or occasional pain, this did not significantly affect total AOFAS scores, in line with guideline allowances for minor discomfort.
2. **Meary's Angle (Arch Alignment):**
   Pre-operative Meary's angle was significantly worse in the quadrangular repair group (**24** ± **2.3**) compared to the triangular repair group (**16** ± **2.3**), reflecting greater deformity. Post-operatively, both groups achieved comparable correction at 3 months (**3.24** ± **1.2** for Triangular Repair vs. **3.84** ± **1.2** for Quadrangular Repair, with minor differences at 12 months (**4.24** ± **1.2** vs. **4.14** ± **1.2**, respectively). These findings highlight the effective realignment achieved through both procedures.
3. **Talonavicular Coverage (Midfoot Stability):**
   Talonavicular coverage improved significantly post-operatively in both groups, with larger pre-operative values noted in the quadrangular repair group (**56.23** ± **2.2**) compared to the triangular repair group (**29.23** ± **2.2**), indicating more severe midfoot instability. By 12 months, TN coverage values were comparable between the groups (**13.64** ± **3.8** for triangular repair vs. **13.36** ± **3.8** for quadrangular repair; **p < 0.01**). This suggests that both procedures effectively restore midfoot stability, though Quadrangular Repair (deltoid + tibiocalcaneonavicular spring complex reconstruction) addresses more extensive initial instability.
4. **Tibial Calcaneal Angle (Hindfoot Valgus):**

Hindfoot valgus correction was notable in both groups. Pre-operative deformity was more pronounced in the quadrangular repair group (**18.23** ± **2.2**) than in the triangular repair group (**14.23** ± **2.2**), reflecting the greater involvement of hindfoot alignment in the former. Post-operative values were well corrected by 3 months and sustained at 12 months, with similar final values (**5.48** ± **3.4** for the triangular repair group vs. **4.48** ± **3.4** for quadrangular repair group; **p < 0.01**).

Differences in Reconstruction Techniques:

- **The Triangular repair group**: Primarily targets midfoot instability and deformity correction, resulting in effective functional recovery and realignment. It is associated with almost equal long-term functional outcomes (AOFAS scores) with moderate deformity.
- **The Quadrangular repair group:** Addresses both midfoot and hindfoot instability, making it a more extensive procedure. It is typically required for more severe deformities (as evidenced by worse pre-operative Meary's angles and TN coverage) and provides effective correction, albeit with slightly good functional recovery scores over time.
- Regarding complications, wound dehiscence from the medial side was reported in one patient (2.5 %) in which required surgical debridement and wound closure. Metal irritation was reported in two patients which required MCDO screw removal at 6 months' post op after having confirming union at osteotomy site radiologically. Two (5 %) patients complained of persistent subtalar pain upto 8 months which resolve after intraarticular steroid injection.

7. Discussion

Adult Acquired Flatfoot Deformity (AAFD) is a progressive and debilitating condition that leads to the collapse of the medial longitudinal arch, hindfoot valgus, and forefoot abduction. Type 2 AAFD, in particular, is often associated with dysfunction of the posterior tibial tendon, leading to peritalar subluxation, especially involving the talonavicular (TN) and subtalar joints. This instability can exacerbate the deformity and severely limit the efficacy of traditional tendon repair and medial soft tissue reinforcement. Addressing peritalar subluxation is, therefore, critical to achieving successful outcomes in the surgical management of AAFD. In recent years, fiber tape augmentation has emerged as a promising solution in AAFD reconstruction. It functions as an internal brace, offering dynamic stabilization while preserving joint motion. Additionally, incorporating talonavicular joint (TNJ) coverage into surgical decision-making provides a more personalized approach, enabling the surgeon to tailor the reconstruction technique based on the severity of the deformity and the degree of joint congruence.

Fiber tape is increasingly used to augment ligamentous structures, including the deltoid ligament, subtalar joint stabilizers, and medial column repairs. This approach is particularly effective in patients with significant ligamentous laxity or subtle subluxations. By acting as a mechanical stabilizer, fiber tape helps in restoring alignment and supporting biological ligament repair. Furthermore, when combined with soft tissue procedures such as flexor digitorum longus (FDL) tendon transfer, fiber tape contributes significantly to overall arch restoration.

The degree of talonavicular coverage—evaluated both radiographically and intraoperatively—serves as a critical factor in determining the appropriate surgical intervention for AAFD. In cases with less than 50 % TNJ coverage, joint-sparing procedures are often sufficient. These procedures typically include FDL tendon transfer, medializing calcaneal osteotomy, and deltoid ligament repair augmented with fiber tape. These approaches aim to restore alignment and function while preserving joint mobility. However, in more severe cases where TNJ coverage exceeds 50 % or where significant arthritic changes are present, more aggressive interventions are required. These may include subtalar fusion, TN joint arthrodesis, or a combination of fusion and tendon transfer. In these cases, fiber tape can still play a vital role by reinforcing soft tissue stability around the reconstructed joints.

Our study investigates the clinical and radiological outcomes of a novel surgical approach to managing Stage II Adult Acquired Flatfoot Deformity (AAFD) that combines Quadrangular Repair (deltoid + tibiocalcaneonavicular spring complex reconstruction) with fiber tape or fiber wire augmentation, or Triangular Repair (deltoid + tibionavicular spring complex reconstruction) with fiber tape or fiber wire, along with Minimally Invasive Calcaneal Displacement Osteotomy (MCDO). This combined approach addresses significant gaps in current surgical techniques by focusing on improving peritalar stability, particularly for severe AAFD cases. Our findings are consistent with previous studies, such as those by Baxter et al., who demonstrated the superiority of Triangular Repair (deltoid + tibionavicular spring complex reconstruction) over traditional spring ligament reconstruction in restoring normal foot kinematics [18,19].

The MCDO is an extra-articular procedure that aims to correct hindfoot deformities by medially shifting the calcaneal tubercle. This shift increases the lever arm for the Achilles tendon and enhances the inverter action of the triceps surae muscle group [20,21]. By correcting the hindfoot valgus and medializing the subtalar joint axis, MCDO plays a crucial role in restoring the height of the medial longitudinal arch and correcting midfoot abduction [22]. Our approach further innovates by simultaneously reconstructing both the spring ligament and the superficial deltoid ligament, contrasting with conventional methods that typically focus on one of these structures.

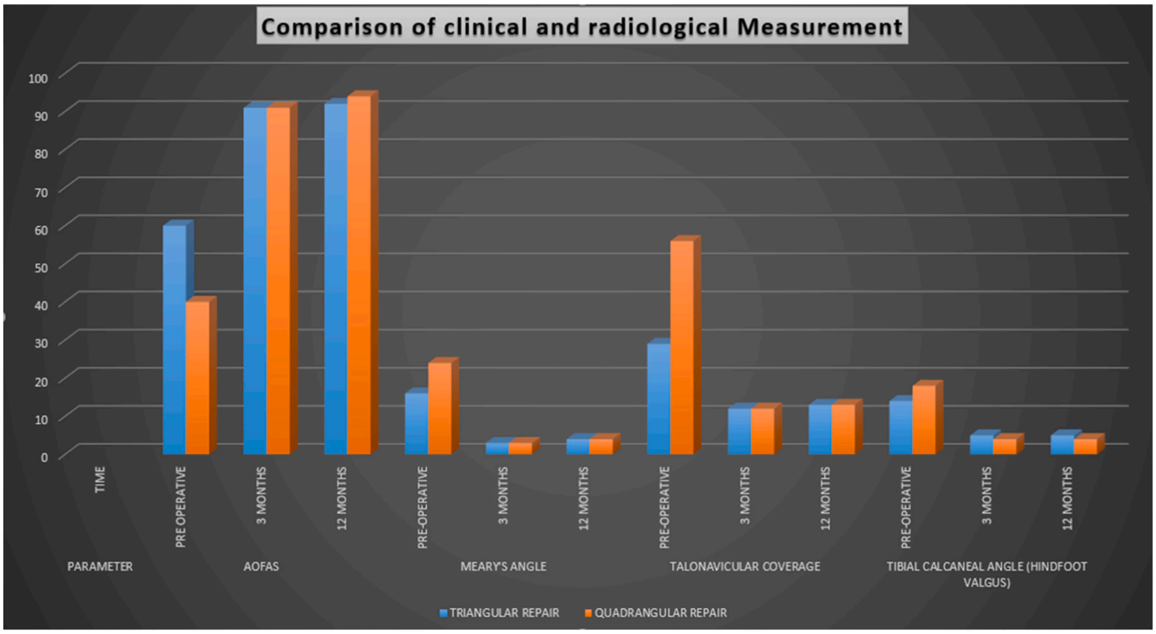
In our study, we aimed to develop a surgical algorithm based on talonavicular coverage, as described in the methodology section. The results demonstrate significant improvements in functional outcomes, as evidenced by the American Orthopedics Foot & Ankle Society (AOFAS) scores at the final follow-up. Radiographic evaluations confirmed substantial corrections in key parameters, which corroborate the efficacy of this combined surgical approach in restoring both anatomical alignment and functional stability. A total of 40 patients were prospectively evaluated in our study, all treated by a single surgeon, ensuring procedural consistency.

The study revealed that the quadrangular repair was more effective in managing severe deformities where talonavicular coverage exceeded 50 degrees. On the other hand, the triangular repair produced favorable results for patients with talonavicular coverage between 30–50 degrees. These findings underscore the importance of tailoring the reconstruction techniques based on preoperative radiological parameters, thereby optimizing surgical outcomes.The decision to perform triangular vs quadrangular repair was based on patient-specific anatomical and pathological factors. Triangular repair offers several advantages over quadrangular repair, including reduced surgical time, less soft tissue dissection (avoiding tarsal tunnel exploration), decreased stress on the navicular, prevention of medial column over-constraint, and better accommodation of foot biomechanics during correction in mild to moderate deformity.

One notable aspect of our study is that we did not perform lateral column lengthening (LCL) in our cohort. LCL procedures, while commonly used in AAFD surgery, have been associated with increased pressure across the calcaneocuboid joint (CCJ), leading to a higher risk of secondary degenerative changes [23]. Additionally, LCL procedures address only the forefoot abduction deformity and partially restore the longitudinal arch. However, they fail to correct the entire medial arch and may result in increased rigidity during supination, with the potential for CCJ subluxation or fusion [24,25]. We support the theory that the length of the lateral column does not play a role in the etiopathogenesis of adult acquired flatfoot. Any perceived shortening of the lateral column is attributed to the forefoot abduction and hindfoot valgus deformities associated with the condition [26]. In contrast, our

Table 1
Summary of clinical and radiological measurement.

		TRIANGULAR REPAIR	QUADRANGULAR REPAIR	
PARAMETER	TIME	VALUE MEAN ± SD	VALUE MEAN ± SD	P-VALUE
AOFAS	PRE OPERATIVE	60.45 ± 8.9	40.45 ± 8.9	
	3 MONTHS	91.21 ± 6.5	91.21 ± 6.5	
	12 MONTHS	92.32 ± 6.8	94.32 ± 6.8	< 0.01
MEARY'S ANGLE	PRE-OPERATIVE	16 ± 2.3	24 ± 2.3	
	3 MONTHS	3.24 ± 1.2	3.84 ± 1.2	
	12 MONTHS	4.24 ± 1.2	4.14 ± 1.2	< 0.01
TALONAVICULAR COVERAGE	PRE-OPERATIVE	29.23 ± 2.2	56.23 ± 2.2	
	3 MONTHS	12.24 ± 2.1	12.24 ± 2.1	
	12 MONTHS	13.64 ± 3.8	13.36 ± 3.8	< 0.01
TIBIAL CALCANEAL	PRE-OPERATIVE	14.23 ± 2.2	18.23 ± 2.2	
ANGLE (HINDFOOT VALGUS)	3 MONTHS	5.48 ± 3.4	4.48 ± 3.4	
	12 MONTHS	5.48 ± 3.4	4.48 ± 3.4	< 0.01



Graph 1. Comparison of clinical and radiological Measurement.

approach, which focuses solely on correcting the medial side pathology, avoids these complications and has demonstrated excellent outcomes. The decision to avoid lateral column lengthening in our cohort highlights the potential for addressing the primary deformity without introducing additional risks.

8. Conclusion

The results of this study emphasize the effectiveness of fiber tape augmentation combined with spring complex reconstruction and deltoid spring ligament reconstruction for the management of Stage II AAFD with peritalar subluxation. The personalized approach based on talonavicular coverage ensures the optimization of surgical outcomes while minimizing unnecessary complications. This study contributes to a growing body of evidence supporting the efficacy of innovative techniques in AAFD reconstruction, providing a valuable framework for future clinical practice.

CRediT authorship contribution statement

Maurya Dr. Vivek: Writing – original draft. **Jaiswal Ankit:** Writing – review & editing, Writing – original draft, Conceptualization. **Motwani Dr. Girish:** Conceptualization.

Declaration of Competing Interest

The authors declare that there are no conflicts of interest with any organizations, institutions, or individuals related to this research. No financial relationships or non-financial relationships with any entities or organizations influenced the outcomes or conclusions of this study. All authors confirm that they have contributed to the conceptualization, methodology, and final writing of this report and affirm that there is no commercial or professional interest that could be perceived as influencing the content of this research.

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