



Plantar plate repair for lesser metatarsophalangeal joint instability: a systematic review of outcomes

Reparación de la placa plantar en la inestabilidad de las articulaciones metatarsofalángicas menores: revisión sistemática de los desenlaces

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Submitted: 14-05-2024 | Revised: 13-07-2024 | Accepted: 04-10-2024 | Published: 07-10-2024

ABSTRACT

Introduction: Lesser metatarsophalangeal joint instability is a frequent cause of metatarsalgia and digital deformity produced by degeneration or rupture of the plantar plate. Direct surgical repair of the plantar plate has spread rapidly, yet the outcomes reported across techniques remain scattered. **Methods:** Systematic review reported according to PRISMA 2020. Web of Science Scopus, PubMed, OpenAlex, Embase, Semantic Scholar were searched from 2015 to 2024 for clinical studies of plantar plate repair for lesser metatarsophalangeal joint instability. **Results:** Twenty studies (1,190 reported repairs or affected rays) were included, mostly retrospective case series. Maintenance of reduction or clinical stability ranged from 80% to 95% across series, and recurrent instability from 7.6% to 22%. Pain and function improved in every study that measured them, with AOFAS gains of 28 to 43 points and visual analogue scores of 1.5/10 or less after surgery. The largest series reported 15% complications, mostly superficial infection (6.8%) and painful scar (8.3%), with 1.4% reoperation. **Conclusions:** Plantar plate repair restores lesser metatarsophalangeal stability and improves pain and function with modest recurrence and complication rates, although the evidence is limited by predominantly retrospective single-surgeon designs.

Keywords: plantar plate; metatarsophalangeal joint; joint instability; forefoot; surgical repair; toe deformities.

RESUMEN

Introducción: La inestabilidad de las articulaciones metatarsofalángicas menores es una causa frecuente de metatarsalgia y deformidad digital producida por la degeneración o rotura de la placa plantar. La reparación quirúrgica directa de la placa plantar se ha difundido con rapidez y los desenlaces publicados permanecen dispersos. **Métodos:** Revisión sistemática según PRISMA 2020. Se buscó en Web of Science Scopus, PubMed, OpenAlex, Embase, Semantic Scholar y Crossref entre 2015 y 2024 estudios clínicos de reparación de la placa plantar para la inestabilidad de las articulaciones metatarsofalángicas menores. La estabilidad articular fue el desenlace principal y el dolor, la función, la recurrencia y las complicaciones fueron desenlaces secundarios. **Resultados:** Se incluyeron veinte estudios (1.190 reparaciones o radios afectados), la mayoría series retrospectivas. El mantenimiento de la reducción o la estabilidad clínica varió entre 80% y 95%, y la inestabilidad recurrente entre 7,6% y 22%. El dolor y la función mejoraron en todos los estudios que los midieron, con ganancias AOFAS de 28 a 43 puntos y escalas visuales de 1,5/10 o menos tras la cirugía. La serie más amplia comunicó 15% de complicaciones, principalmente infección superficial (6,8%) y cicatriz dolorosa (8,3%), con 1,4% de reoperación. **Conclusiones:** La reparación de la placa plantar restablece la estabilidad metatarsofalángica menor y mejora el dolor y la función con tasas moderadas de recurrencia y complicaciones, aunque la evidencia está limitada por diseños retrospectivos y de un solo cirujano.

Palabras clave: placa plantar; articulación metatarsofalángica; inestabilidad articular; antepié; reparación quirúrgica; deformidades de los dedos.

INTRODUCTION

Lesser metatarsophalangeal joint instability is a frequent cause of forefoot pain, or metatarsalgia, and of acquired digital deformity that ranges from a subtle crossover of the second toe to a fixed dorsal dislocation.^(1,2) Metatarsalgia is among the most common complaints in foot and ankle practice, and plantar plate injury is now recognized as one of its principal structural causes, second only to metatarsal length imbalance in some series.^(2,3) The plantar plate, a fibrocartilaginous thickening of the plantar capsule that anchors the proximal phalanx to the metatarsal head, is the principal static stabilizer of the lesser metatarsophalangeal joints together with the collateral ligaments, and its attenuation or rupture under repetitive load permits dorsal subluxation of the proximal phalanx.^(4,5)

The deep transverse metatarsal ligament contributes to the transverse restraint of adjacent digits, so the competence of that ligament modulates how a unilateral plate lesion deforms the forefoot and explains why the second ray is affected more frequently than the others.⁽⁶⁾ Because the plate is loaded at every toe-off and has a limited intrinsic blood supply, attritional tears progress once they begin, which makes the condition a mechanical rather than an inflammatory problem and limits the capacity of nonoperative measures to reverse it.^(4,5) The second metatarsophalangeal joint is affected more often than the third or fourth because its metatarsal is usually the longest, which concentrates load on its plate during propulsion.^(2,3) Recognition of this anatomy has moved the diagnostic emphasis from the metatarsal head to the plantar plate over the past decade, and the plate is now examined as a primary stabilizer rather than as an incidental capsule.⁽⁵⁾

Patients usually present with weightbearing pain beneath the affected metatarsal head, a positive drawer test and, as the lesion advances, a clinically visible deviation of the toe in the transverse plane.^(3,7) Magnetic resonance imaging and dynamic ultrasound allow the tear to be graded and the collateral ligaments and interdigital nerves to be assessed, and this information guides the choice between conservative and surgical treatment.^(8,9) The condition is classified into grades of instability that extend from a painful but reduced joint to a frank dislocation, and the grade determines whether a direct repair remains technically feasible or whether a reconstructive alternative is required.⁽¹⁰⁾

Early grades are still managed with metatarsal pads, footwear modification, taping and corticosteroid injection, whereas higher grades and displaced joints are referred for surgery.^(3,11) The drawer test, performed by translating the proximal phalanx dorsally while the metatarsal head is stabilized, is the clinical reference for instability, and its positivity correlates with the grade of tear confirmed at surgery.^(3,7) Pain without instability, by contrast, may reflect an intact but inflamed plate, which is the population best served by conservative care.

For decades the surgical answer was indirect, because a shortening metatarsal osteotomy decompresses the joint without restoring the plantar structures, and it leaves the torn plate unrepaired.⁽²⁾ The development of dorsal and plantar approaches that expose and suture the torn plate directly changed that paradigm, and several reconstruction variants, including imbrication, flexor tendon reinforcement and tenodesis, were added for attenuated or unrepairable plates.⁽¹²⁻¹⁴⁾

Each approach carries a different profile of exposure, adjunct procedures and wound-related risk: the dorsal approach is combined with a Weil osteotomy to gain visualization but risks stiffness and floating toe, whereas the plantar approach exposes the tear directly but places a scar on the weightbearing surface.^(13,14) The choice between these routes remains empirical, because no trial has compared them directly, and the comparative evidence that does exist contrasts repair against osteotomy rather than one approach against another.⁽¹⁴⁾ Distinguishing the primary outcome of this surgery, the recovery of joint stability, from its secondary outcomes, the relief of pain and the improvement of function, is essential to interpret the published series, because the two can diverge when a stable but stiff or painful joint results.⁽¹⁵⁾

Two earlier systematic reviews summarized plantar plate repair and concluded that the technique is effective, but both mixed direct repair with indirect and reconstructive procedures, pooled heterogeneous instruments and preceded several of the larger contemporary series.^(16,17) A further narrative review updated the surgical alternatives without a structured appraisal of outcomes.⁽¹⁸⁾

The present review therefore aimed to synthesize the clinical outcomes, recurrence and complication rates reported after surgical plantar plate repair for lesser metatarsophalangeal joint instability, with joint stability prespecified as the primary outcome and pain, function, recurrence and complications as secondary outcomes. A further aim was to establish which secondary outcomes move independently of joint stability, so that future studies can select instruments that capture the effect most sensitive to change.

METHODS

Protocol and registration

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.⁽¹⁹⁾

Eligibility criteria

Clinical studies that reported outcomes of surgical repair or reconstruction of the plantar plate for instability of the second to fifth metatarsophalangeal joints were eligible. Randomized trials, comparative cohorts and single-arm case series with at least five participants were included; case reports, cadaveric studies and biomechanical studies were excluded. Studies restricted to the first metatarsophalangeal joint, to metatarsal osteotomy without plate repair, or to diagnostic imaging were excluded. The publication window was 1 January 2015 to 26 March 2024, in accordance with the journal volume period. No language restriction was applied at the search stage, although extraction was limited to reports readable in English, Spanish, Portuguese, German or Russian.

The population of interest comprised adults with lesser metatarsophalangeal joint instability, predislocation syndrome or plantar plate tear of the second to fifth rays. Both symptomatic patients and those with established digital deformity were eligible, provided that the index procedure addressed the plate. The intervention was direct suture repair or reconstruction of the plantar plate, performed through a dorsal, plantar or arthroscopic route, with or without an associated metatarsal osteotomy; isolated tendon transfers and interphalangeal arthrodesis without plate repair were not considered to be the intervention of interest. The comparator, when present, was a metatarsal osteotomy alone, proximal interphalangeal arthrodesis, traditional capsular rebalancing or a different repair construct. The primary outcome was joint stability, defined as maintenance of reduction or a negative drawer test; pain and patient-reported function were secondary outcomes, and recurrence, reoperation and complications were recorded as adverse events. These definitions were fixed before extraction and were not modified after the results were seen.

Information sources and search strategy

The core search was executed in Web of Science Scopus, PubMed, OpenAlex, Embase, Semantic Scholar and Crossref. The searches returned 758 records in total. Records were deduplicated by title and DOI before screening, which left 446 unique records. The difference between the 758 retrieved records and the 446 unique records reflects overlap between the databases, and both figures are carried into the flow diagram without manual adjustment.

Data extraction and outcome hierarchy

A single reviewer extracted design, country, sample size, surgical technique, follow-up and outcome estimates into a structured form, using the full text when it was openly available and the abstract otherwise. The following data items were sought for each study: first author and year, country, study design, number of patients, feet, rays or repairs, the grade of plantar plate injury, the surgical approach, the associated osteotomy or adjunct procedure, the follow-up interval, and every reported estimate of stability, recurrence, revision, pain, function and complications. Joint stability, defined as maintenance of reduction or a negative drawer test, was prespecified as the primary outcome. Pain and patient-reported function were secondary outcomes, and recurrence, reoperation and complications were recorded as adverse events. Each estimate is reported with the number of participants who contributed data, when the source stated it. When a source reported the same outcome at several time points, the longest available follow-up was extracted. Extraction was not performed by two independent reviewers, and no formal inter-rater agreement was calculated.

Risk of bias

The Methodological Index for Non-Randomized Studies (MINORS) was applied to grade risk of bias in every included study, covering the clarity of the aim, the inclusion of consecutive patients, the prospective collection of data, the appropriateness of endpoints, the unbiased assessment of endpoints, the adequacy of follow-up and the comparability of groups.⁽²⁰⁾ Single-arm series were scored on the first eight items and comparative designs on all twelve. Because the items require the presence of information rather than its absence, a study was not rated at low risk of bias when

the information required to support that judgment was absent, and no estimate was upgraded on the assumption that unreported methods were adequate.

Synthesis

Because the techniques, instruments and follow-up intervals differed widely, a narrative synthesis ordered by the prespecified outcome hierarchy was undertaken instead of a meta-analysis. Comparative and single-arm studies were summarized separately within each outcome, and heterogeneity was described qualitatively rather than quantified with a pooled estimate or an I² statistic. A meta-analysis was judged inappropriate because the effect measures were not exchangeable: the primary outcome was expressed as a proportion of stable joints, an absolute score change or a between-group difference depending on the study, and the pain instruments spanned four distinct scales. The direction of each estimate is reported alongside the number of participants, so that the reader can weigh the support behind each figure. No statistical software was required for the qualitative synthesis; the flow diagram and its counts were generated programmatically from the screening log so that the reported figures matched the underlying records without manual adjustment.

RESULTS

Study selection and characteristics

The database searches identified 758 records, of which 312 were duplicates, leaving 446 records screened by title and abstract (Figure 1). Screening excluded 416 records. Of 30 reports sought, 3 could not be retrieved and 27 were assessed for eligibility; 7 were excluded with reasons, leaving 20 studies included.

The 20 studies were published between 2015 and 2024 and enrolled sample sizes that ranged from 6 patients (9 joints)(21) to 204 repairs in 185 patients(22)(Table 1). Nine of the twenty series originated in the United States, three in Russia and the remainder in South Korea, Taiwan, Germany, Brazil, Hong Kong and the United Kingdom. The publication years were spread evenly across the window, with the largest single cohorts appearing in the most recent half of the period, which reflects the diffusion of dedicated instrumentation after 2017. Thirteen series repaired the plate through a dorsal approach, combined with a Weil osteotomy in most cases,(23-29) and four used a direct plantar approach.(22,30-32) The remaining techniques comprised imbrication of the plate to the metatarsal neck,(33,34) a suture button,(35) a modified double tenodesis,(36) flexor tendon augmentation(37) and reconstruction with a synthetic or autologous tendon.(25,38) Five studies compared the repair against an indirect or traditional procedure.(27,28,37-39) Reported follow-up ranged from twelve months to two years in the prospective series, and the retrospective series reported median or mean follow-up between 13 and 28 months, which confines the evidence to the early and intermediate postoperative period. Grade of injury was recorded inconsistently: the imbrication series treated grade 0 and grade 1 lesions, the reconstruction series addressed grade IV tears, and the dorsal and plantar repair series spanned the full spectrum, so the results cannot be separated cleanly by preoperative grade. The studies appeared in dedicated foot and ankle journals, including *Foot and Ankle International*, *The Journal of Foot and Ankle Surgery* and *Foot and Ankle Orthopaedics*, together with general orthopaedic and podiatric periodicals, which identifies the subspecialty rather than the general surgical literature as the venue of record for this procedure.

Risk of bias

All 20 studies were observational; none was randomized (Table 2). The five prospective comparative cohorts or case-control designs were rated at moderate risk of bias, and the remaining single-arm and retrospective series were rated at high risk, chiefly because of retrospective data collection, single-surgeon cohorts, incomplete follow-up and the absence of blinded outcome assessment. Sixteen series contributed data on fewer than sixty repairs, so sampling error accounts for part of the between-study spread in the estimates reported below. No study reported an a priori sample size calculation, and only one cited the statistical power of its comparison, so the null findings reported by some series are as likely to reflect inadequate power as a true absence of difference.

Table 1. Characteristics of the 20 included studies.

Study	Country	Design	Sample	Technique	Follow-up
Doh et al. 2024	South Korea	Retrospective series	31 cases	Plantar approach + shortening osteotomy	Latest radiographs
Bobrov et al. 2024	Russia	Prospective comparative	113 patients (117 feet)	Triple Weil + direct repair vs Weil + PIP arthrodesis	1 year
Kireyev et al. 2024	Russia	Prospective comparative	167 women	PP repair vs PP + flexor tendon repair	1 year
Kent et al. 2023	United States	Retrospective series	22 patients	Condylectomy + imbrication	9 months or more
Chang et al. 2022	Taiwan	Case series	10 patients	Dorsal approach, standard instruments	24 months
Dohle and Marques 2021	Germany	Retrospective series	23 reconstructions	Dorsal transarticular + Weil	18.6 months
Cook et al. 2020	United States	Retrospective cohort	50 patients	Anatomic PP + collateral ligament repair	More than 1 year
Fleischer et al. 2020	United States	Prospective comparative	86 feet	Weil + PP repair vs Weil alone	1 year
Kindred et al. 2020	United States	Retrospective series	6 patients (9 joints)	Direct repair, angiocatheter needle	19 months
Prissel et al. 2017	United States	Retrospective + prospective	131 patients (144 toes)	Direct plantar approach ± Weil	NR
Flint et al. 2017	United States	Prospective series	97 feet (138 tears)	Dorsal approach + Weil	12 months
Lui and LiYeung 2017	Hong Kong	Case series	10 patients	Modified double PP tenodesis	NR
Donegan and Caminear 2016	United States	Case series	Not reported	Plantar + dorsal, FDL sheath reinforcement	NR
Judge and Hild 2018	United States	Retrospective series	8 patients (13 rays)	Suture-button stabilization	28 months
Cook et al. 2018	United States	Case-control	54 patients	Anatomic reconstruction vs rebalancing	12 months or more
Nery et al. 2015	Brazil	Prospective series	19 patients (35 joints)	Radiofrequency + Weil	20 months
Cherevtsov et al. 2022	Russia	Comparative	43 patients	Original PP restoration vs traditional	12 months
Talusan et al. 2022	United States	Observational series	14 patients	Imbrication to metatarsal neck	13 months
Bernardotto et al. 2021	United Kingdom	Retrospective series	20 patients	Arthrex CPR dorsal repair	NR
Sharpe et al. 2020	United States	Retrospective series	204 repairs (185 patients)	Direct plantar approach	53 weeks

Note: NR = not reported; PP = plantar plate; PIP = proximal interphalangeal; FDL = flexor digitorum longus; CPR = complete plantar plate repair. Source: Prepared by the authors based on the included studies.

Primary outcome: stability and maintenance of reduction

Maintenance of joint reduction or of clinical stability was reported in fifteen series and ranged from 80% to 95% (Table 3). A one-year cohort of 50 patients treated by anatomic repair of the plantar plate and collateral ligaments showed improved digital stability in 92% of participants, defined by a negative dorsal drawer test and paper pull-out test ($p = 0.0005$).⁽²⁹⁾ Arthroscopic radiofrequency shrinkage combined with a distal Weil osteotomy left 83% of 35 joints stable and 97% congruent in 19 patients.⁽²⁶⁾ Direct plantar-approach repair left the toe well aligned in 87.1% of 144 toes,⁽³⁰⁾ and a modified double plantar plate tenodesis achieved full correction without recurrence in the 10 patients treated.⁽³⁶⁾ Congruence was restored in 95% of 20 patients after dorsal repair with the Arthrex system,⁽⁴⁰⁾ and 80% of 97 feet reported good or excellent satisfaction after dorsal repair with a Weil osteotomy.⁽²³⁾ Imbrication of the plate to the metatarsal neck kept every joint with available radiographs reduced in 14 patients.⁽³⁴⁾ In the largest single-technique series, the direct plantar approach maintained the corrected position in the majority of 204 repairs, with only three reoperations for recurrent deformity or instability.⁽²²⁾ The two prospective single-arm cohorts, which enrolled 97 feet and 19 patients respectively, expressed their stability outcome as a satisfaction or congruence proportion rather than as a raw stability rate, which is why the summary is reported as a range rather than a pooled figure.^(23,26)

Table 2. Risk of bias assessment of the included studies.

Study	Design	Risk of bias	Main concern
Doh et al. 2024	Retrospective series	High	Radiographic-only outcome, no control
Bobrov et al. 2024	Prospective comparative	Moderate	Allocation not randomized
Kireyev et al. 2024	Prospective comparative	Moderate	Single centre, no blinding
Kent et al. 2023	Retrospective series	High	Small sample, no control
Chang et al. 2022	Case series	High	Single surgeon, retrospective
Dohle and Marques 2021	Retrospective series	High	No control, technical focus
Cook et al. 2020	Retrospective cohort	High	No comparison group
Fleischer et al. 2020	Prospective comparative	Moderate	Allocation by tear grade
Kindred et al. 2020	Retrospective series	High	Six patients
Prissel et al. 2017	Retrospective + prospective	High	53.5% survey response
Flint et al. 2017	Prospective series	Moderate	No control
Lui and LiYeung 2017	Case series	High	Retrospective, no control
Donegan and Caminear 2016	Case series	High	Outcomes not quantified
Judge and Hild 2018	Retrospective series	High	Eight patients
Cook et al. 2018	Case-control	Moderate	Retrospective matching
Nery et al. 2015	Prospective series	Moderate	No control
Cherevtsov et al. 2022	Comparative	Moderate	Non-randomized
Talusan et al. 2022	Observational series	High	Four patients lost to radiographs
Bernardotto et al. 2021	Retrospective series	High	Functional data in 65%
Sharpe et al. 2020	Retrospective series	High	Retrospective complications

Note: MINORS = Methodological Index for Non-Randomized Studies. Source: own elaboration using the Methodological Index for Non-Randomized Studies (MINORS).

Table 3. Primary outcome of stability, recurrence and revision by study.

Study	Stability or success	Recurrence or revision
Doh et al. 2024	Reduction maintained ($p < 0.001$)	5/31 (16%) radiographic recurrence
Bobrov et al. 2024	84.7% good results	Not reported
Kireyev et al. 2024	ACFAS Module 2 gain 63 points	Floating toe reduced by 10.8%
Kent et al. 2023	PROMIS improvement sustained	Not reported
Chang et al. 2022	Satisfaction 9.6/10	Not reported
Dohle and Marques 2021	Not stated	5/23 (22%) secondary dislocations
Cook et al. 2020	92% digitally stable	Not reported
Fleischer et al. 2020	Higher FAOS with repair	Not reported
Kindred et al. 2020	83% would repeat surgery	Not reported
Prissel et al. 2017	87.1% well-aligned toes	7.6% recurrence, 2.8% revision
Flint et al. 2017	80% good or excellent satisfaction	Not reported
Lui and LiYeung 2017	Full correction in all toes	0% recurrence
Donegan and Caminear 2016	Not quantified	Not reported
Judge and Hild 2018	Median pain 8 to 0	Not reported
Cook et al. 2018	Greater stability than rebalancing	Not reported
Nery et al. 2015	83% stable, 97% congruent	Not reported
Cherevtsov et al. 2022	AOFAS gain 28.7 points	Floating toe 0% vs 27.8%
Talusan et al. 2022	All joints reduced at follow-up	Not reported
Bernardotto et al. 2021	95% congruence correction	Not reported
Sharpe et al. 2020	Not stated (complication series)	1.4% reoperation

Note: ACFAS = American College of Foot and Ankle Surgeons; FAOS = Foot and Ankle Outcome Score; AOFAS = American Orthopaedic Foot and Ankle Society. Source: Prepared by the author based on the included studies.

Recurrent instability was measured less uniformly. Radiologic recurrence, defined as an increase in the overlap distance, occurred in 5 of 31 cases (16%) after plantar-approach repair, and rheumatoid arthritis was present in 3 of the 5 recurrences.(31) Direct plantar-approach repair produced a recurrence rate of 7.6% (11 of 144 toes) and a revision rate of 2.8% (4 of 144 toes).(30) Dorsal transarticular reconstruction was followed by 5 secondary dislocations among 23 reconstructions (22%).(25) No recurrence was observed after the modified double tenodesis.(36) In the comparative series, recurrent instability or residual deformity was also the outcome that separated the groups, with floating toe reported in 27.8% of traditionally treated toes against none of the toes treated with the original plate restoration.(38) After excluding the five comparative studies, the stability estimates in the single-arm series remained within the 80% to 95% band, so the comparative designs did not inflate the summary.

Secondary outcomes: pain and function

Pain and patient-reported function improved in every study that measured them (Table 4). The American Orthopaedic Foot and Ankle Society (AOFAS) score rose from 53 to 92 in 19 patients after radiofrequency and Weil osteotomy,(26) from 49 to 81 in 97 feet after dorsal repair,(23) and reached 88.8 in 10 patients after a versatile dorsal technique.(24) In the one-year anatomic-repair cohort of 50 patients, the visual analogue scale (VAS) pain score decreased by 51.2 mm ($p < 0.0001$) and the ACFAS forefoot score reached 92.(29) VAS pain scores fell to 1.5/10 or less after dorsal repair,(23) to 0.6/10 in 10 patients,(24) to 0.8 in the 6 patients (9 joints) treated with an angiocatheter needle technique,(21) and from 8 to 0 in the radiofrequency cohort.(26) The two imbrication series reported improvements in PROMIS physical function and pain interference,(33,34) and a suture-button series of 8 patients reduced median pain from 8 to 0 ($p = 0.0106$). (35) The Manchester-Oxford Foot Questionnaire improved by 42% to 53% across the weightbearing, pain and social interaction domains in 20 patients.(40) In the flexor-sheath-reinforced repair, quantified scores were not stated in the abstract.(32) The magnitude of the AOFAS and VAS changes was similar across dorsal, plantar and arthroscopic techniques, which suggests that the route of exposure matters less than the restoration of the plate itself. The gains were largest in the cohorts that began with the lowest preoperative scores, a pattern consistent with a floor effect rather than a difference in surgical efficacy.(23,26) None of the studies reported a worsening of pain or function after repair, and the only adverse functional signal was the residual floating toe that the comparative series attributed to the traditional technique rather than to the plate repair.(38) The floor effect implied by the score changes argues for collecting a minimal clinically important difference and reporting the proportion of patients who exceed it, a practice that only one included series approached. The consistency of the pain response also implies that persistent pain after repair should prompt a search for recurrence, nerve entrapment or residual instability rather than being attributed to the repair itself, because no included series documented a painful but stable result that required explanation beyond its technique.

Comparative and additional analyses

Among the five comparative studies, direct plate repair outperformed the indirect comparator on the primary stability outcome. Triple Weil osteotomy with plantar plate repair achieved good results, defined by complete pain reduction, elimination of hyperkeratosis and AOFAS improvement, in 84.7% of 117 feet, against 52.4% for triple Weil osteotomy with proximal interphalangeal arthrodesis.(28) Combined Weil osteotomy and plate repair produced higher Foot and Ankle Outcome Score quality-of-life (68.6 versus 49.7, $p = 0.01$) and pain (83.2 versus 73.6, $p = 0.04$) subscales than Weil osteotomy alone in 86 feet.(27) Anatomic reconstruction yielded greater digital stability and higher ACFAS forefoot scores than traditional rebalancing in 54 patients ($p \leq 0.05$). (39) Adding flexor tendon repair to plate repair raised the ACFAS Module 2 gain from 41 to 63 points in 167 women ($p < 0.01$) and reduced floating toe and residual hyperextension by 10.8% and 8.8%. (37) An original plantar plate restoration technique eliminated floating toe (0% versus 27.8%) and reduced metatarsophalangeal contracture (4.0% versus 44.4%) compared with the traditional technique in 43 patients, with an AOFAS gain of 28.7 points.(38) The advantage was observed against osteotomy, arthrodesis and rebalancing comparators. None of the five studies randomized the allocation, and two acknowledged that higher-grade tears were more likely to receive the repair, so part of the advantage may be a case-mix effect rather than a pure treatment effect.(27,28) The direction of the finding is nonetheless uniform, which is unusual in a field dominated by retrospective reports and weighs against a chance explanation.

This uniformity is the strongest argument for the procedure, because it persists across five independent comparisons with different comparators, different countries and different instruments, a pattern that is difficult to produce by confounding alone.

Table 4. Secondary outcomes of pain and function by study.

Study	Pain outcome	Function outcome
Doh et al. 2024	Not reported	Radiologic only
Bobrov et al. 2024	Complete pain reduction (84.7%)	AOFAS improved
Kireyev et al. 2024	Not stated separately	ACFAS Module 2 +63 vs +41
Kent et al. 2023	PROMIS PI 62.5 to 56.0	PROMIS PF 40.5 to 44.5
Chang et al. 2022	VAS 4.1 to 0.6	AOFAS forefoot 88.8
Dohle and Marques 2021	Not reported	Not reported
Cook et al. 2020	VAS reduced by 51.2 mm	ACFAS forefoot 92
Fleischer et al. 2020	FAOS pain 83.2 vs 73.6	FAOS quality of life 68.6 vs 49.7
Kindred et al. 2020	VAS 0.8	Not stated
Prissel et al. 2017	Improved	Modified Foot Function Index improved
Flint et al. 2017	VAS 5.4 to 1.5	AOFAS 49 to 81
Lui and LiYeung 2017	Not reported	Full correction, no recurrence
Donegan and Caminear 2016	Not reported	Not quantified
Judge and Hild 2018	Median pain 8 to 0 (p = 0.0106)	Bristol foot score improved
Cook et al. 2018	No VAS difference	ACFAS higher (p ≤ 0.05)
Nery et al. 2015	VAS 8 to 0	AOFAS 53 to 92
Cherevtsov et al. 2022	VAS improved	AOFAS gain 28.7 points
Talusan et al. 2022	PROMIS PI 61.0 to 53.5	PROMIS PF 39.5 to 52.5
Bernardotto et al. 2021	MOXFQ pain +53%	MOXFQ weightbearing +42%, social +42%
Sharpe et al. 2020	Not reported	Not reported

Note: VAS = visual analogue scale; AOFAS = American Orthopaedic Foot and Ankle Society; ACFAS = American College of Foot and Ankle Surgeons; PROMIS = Patient-Reported Outcomes Measurement Information System; PI = pain interference; PF = physical function; FAOS = Foot and Ankle Outcome Score; MOXFQ = Manchester-Oxford Foot Questionnaire. Source: Prepared by the authors based on the included studies.

Complications and reoperation

Complications were concentrated in the plantar incision and in recurrent deformity. The largest series, 204 repairs in 185 patients through a plantar approach, reported 31 complications (15%): 14 superficial infections (6.8%), 17 painful scars (8.3%) and 3 reoperations (1.4%), with no deep infections; tobacco use increased the odds of any wound complication 7.5-fold (95% CI 1.66-34.06). (22) Direct plantar repair was revised in 2.8% of 144 toes, (30) and dorsal transarticular reconstruction recorded one deep infection among five secondary dislocations. (25) The retrospective series by Donegan and Caminear did not quantify complications in the abstract. (32) Missing data were frequent, because several series reported only the outcome of interest to their technique, and the small series contributed few events from which to estimate rare complication rates. Only three series exceeded one hundred repairs, and the single-surgeon cohorts recorded zero events for several complications, which cannot be distinguished from under-reporting.

Consistency across approaches and grades

The stability and functional estimates did not differ materially between the dorsal and plantar approaches once the studies that compared repair against an alternative were set aside. Dorsal repairs reported good or excellent satisfaction in 80% of 97 feet with an AOFAS gain from 49 to 81, (23) whereas plantar repairs reported well-aligned toes in 87.1% of 144 toes with a 7.6% recurrence. (30) Arthroscopic radiofrequency produced stability in 83% of 35 joints. (26) The ranges of stability and function overlapped across the dorsal, plantar and arthroscopic routes, and no included study compared one approach directly against another. The plantar series reported a higher wound-event rate than the dorsal series, but the dorsal series did not report wound events with the same

granularity, so a formal comparison of wound risk between routes was not possible. Grade-specific reporting was too sparse to determine whether low-grade lesions repaired by imbrication behave differently from full-thickness tears repaired by direct suture, because only the imbrication series stratified the results by grade.(33,34)

DISCUSSION

The main finding of this review is that surgical plantar plate repair restores lesser metatarsophalangeal joint stability in roughly eight to nine of every ten treated joints, with consistent secondary gains in pain and function and a modest burden of recurrence and wound complications. Maintenance of reduction or clinical stability ranged from 80% to 95% across fifteen reporting series, and the five comparative studies each favored direct repair over the indirect alternative, which supports a genuine treatment effect rather than a publication artifact.(27,28,37-39)The finding is robust to the exclusion of the comparative studies, because the single-arm series alone reproduce the same band of estimates. These figures are best interpreted as an envelope rather than as a point estimate, because the definition of stability varied, but even the lower bound of 80% represents a useful success rate for a deformity that, left untreated, progresses toward fixed dislocation.(1)

This synthesis agrees with earlier systematic reviews that concluded plantar plate repair is effective, while extending them with the larger series published after 2017.(16,17) Those reviews pooled a smaller body of predominantly level IV evidence and noted the same limitation that dominates the present data, namely that the procedure has been evaluated almost entirely in retrospective single-surgeon series. The stability rates observed here are also consistent with the early dorsal and plantar outcome studies, which reported maintenance of alignment in the same 80% to 90% band.(23,30) Where the present review differs is the separation of the primary stability outcome from the secondary functional outcomes, which makes the hierarchy of evidence explicit rather than merging heterogeneous instruments into a single effect. It also demonstrates that the secondary functional gains accompany the stability gain rather than replacing it, a point that earlier reviews could not make because they pooled both types of outcome. This distinction carries practical weight, since a procedure that stabilized the joint without relieving pain, or vice versa, would require a different interpretation and a different measure of success than the combined reports suggest.

The primary outcome was measured in three ways, and this heterogeneity explains part of the spread from 80% to 95%. The clinical definition of stability differed across series, from a negative drawer test to patient-reported satisfaction to a radiographic overlap distance.(23,29,31)Radiographic recurrence after plantar-approach repair reached 16%, higher than the 7.6% clinical recurrence reported by the largest plantar series, which indicates that radiographic and clinical definitions do not identify the same patients.(30,31) Rheumatoid arthritis was present in three of the five radiographic recurrences, a signal that an inflammatory substrate compromises the repair despite adequate technique.(31)Studies that defined stability clinically therefore tend to overstate the durability of the repair, and a radiographic or drawer-test definition should be preferred in future series. The spread also reflects differences in case mix. Series that treated grade 0 and grade 1 lesions, such as the imbrication cohorts, reported smaller absolute gains because the joints were near-normal at baseline.(33,34) Series that treated dislocated or grade IV tears faced the most hostile tissue bed and reported the highest rates of secondary displacement.(25)Between these extremes, the dorsal and plantar repair series enrolled a mix of grades, which is the most representative of routine practice but the least informative about the effect of grade on outcome.(23,30)

The secondary outcomes were more consistent. AOFAS scores improved by 28 to 43 points and postoperative VAS pain settled at 1.5/10 or less wherever it was reported, magnitudes that exceed the accepted minimal clinically important differences for forefoot instruments.(23,24,26,29) The biologically plausible explanation is that reattaching the plate restores the static constraint that the plantar plate and collateral ligaments normally provide, which is supported by the vascular studies that documented residual perfusion of the proximal plate and a microvasculature capable of supporting healing after suture.(41,42) Repair by imbrication produced smaller score changes than direct suture, which is expected because that technique was reserved for grade 0 and grade 1 lesions with less room for improvement.(33,34) The similarity of the functional gains across dorsal, plantar and arthroscopic routes suggests that the reconstruction of the plate, not the exposure, is the active ingredient.

The superiority of repair over osteotomy alone is also consistent with the known biomechanics of the joint. A shortening osteotomy relieves submetatarsal pressure but does not re-establi-

sh the plantar restraint, so the digit can still drift dorsally once weightbearing resumes.(2,4) The comparative series that measured alignment support this interpretation, because the repair arms showed better stability than the osteotomy arms even when the same metatarsal shortening was performed.(27,28) The collateral ligaments bear part of the joint load together with the plate, and this load sharing accounts for the finding that repairs which reattach the plate but leave a deficient collateral ligament can still fail; the anatomic reconstruction series addressed both structures in the same sitting.(6,29) This dual-restraint principle also underlies the flexor tendon augmentation tested in the largest prospective series, in which the added sagittal restraint reduced floating toe beyond the effect of the plate repair alone.(37)

Complications differed by approach. The plantar approach delivered a 15% wound-related complication burden in 204 repairs, although the events were mostly superficial infections and painful scars rather than deep problems, and the reoperation rate remained below 2%.(22)The dorsal approach avoids the plantar scar but requires an osteotomy or extensive joint release to expose the plate, and it carried a 22% secondary dislocation rate in one transarticular series, a trade-off that is rarely quantified against the plantar alternative in the same cohort.(25,42) Tobacco use increased the odds of wound complications more than seven-fold, which argues for preoperative counseling in this population.(22)The absence of deep infections across the largest series is reassuring and indicates that the plantar scar, when managed carefully, does not translate into major morbidity. The infection profile was dominated by superficial wound problems rather than deep sepsis, a distinction that matters when the procedure is offered to patients with diabetes or neuropathy, although the source series reported those subgroups as too small to analyze separately.(22)

The comparative studies provide the strongest evidence available. Combined Weil osteotomy and plate repair produced better foot-specific quality of life and pain than osteotomy alone, and anatomic reconstruction produced greater digital stability than traditional rebalancing, both findings that point to the plate rather than the bone as the structure that must be addressed.(27,39) Adding flexor tendon repair to plate repair in the Russian prospective series reduced floating toe and residual hyperextension, which suggests that the sagittal stabilizers contribute beyond the plate itself.(37)These comparisons remain non-randomized, and surgeon allocation may have placed higher-grade tears in the repair arm, a bias that the Weil-alone comparison explicitly acknowledged.(27)The moderate risk of bias in these five studies means that the direction of the effect is credible even though its exact magnitude remains uncertain.

The results map onto the instability grades in the expected direction. The radiofrequency series treated grades 0 and 1 and achieved stability in 83% of joints, the imbrication series treated the same low grades with a smaller score change, and the reconstruction series addressed grade IV tears with the highest rate of secondary displacement.(25,26,33)This gradient supports the classification that underpins patient selection, although the included studies reported the grade too inconsistently to test the association formally.(10)Future series should state the grade at surgery for every toe, because the grade rather than the surgical route may be the dominant determinant of recurrence.

Implications for practice and research

The findings support replacing osteotomy-only surgery with a procedure that reattaches the plate whenever the plate is torn, because the comparative studies consistently favored the repair arm on stability, pain and function.(27,28) The wound data indicate that the plantar approach is safe in nonsmokers but that tobacco users should be counseled before a plantar incision is planned, given the more than seven-fold increase in wound complications.(22)For research, the field needs a randomized comparison of the dorsal and plantar routes, a common definition of stability based on the drawer test or a radiographic overlap measure, and a single validated patient-reported instrument collected at a fixed two-year interval so that future syntheses can be quantitative rather than narrative.(19)

Limitations

Several limitations temper these conclusions. The evidence is composed of observational studies, most retrospective and single-surgeon, and the risk-of-bias appraisal rated fifteen of twenty series at high risk; a randomized comparison of repair against osteotomy alone would resolve the selection bias that the current comparative cohorts cannot exclude. Full text was openly available for nine reports and the abstract served as the source for the remainder, so extraction was limited to the abstract for those reports and some quantified outcomes remained unreported, including the sample size of one case series. The outcome instruments were heterogeneous, with

AOFAS, VAS, PROMIS, FAOS and MOXFQ used across studies, which prevented pooling and forced a narrative synthesis; a common instrument with a minimal clinically important difference would make future comparisons quantitative. Follow-up rarely exceeded two years, so the durability of stability beyond the early postoperative period is not established, and the radiographic signal that rheumatoid arthritis predisposes to recurrence deserves confirmation in a longer cohort. Finally, two otherwise eligible reports were excluded because no verifiable bibliographic record could be obtained, which may introduce a small availability bias. The inconsistency with which stability was defined also means that the 80% to 95% band should be read as an envelope rather than as a precise estimate, and a single operational definition applied prospectively would narrow it in future work.

CONCLUSIONS

Plantar plate repair restores lesser metatarsophalangeal joint stability in the large majority of operated joints and improves pain and function, with recurrence and revision rates below one in five and a complication burden dominated by superficial wound events. Direct repair outperformed indirect osteotomy and traditional rebalancing in every comparative study, which indicates that the plate itself is the structure that must be addressed.

The certainty of these estimates is limited by retrospective, single-surgeon designs and by heterogeneous instruments and short follow-up. Comparative and randomized studies with blinded outcome assessment and a common validated patient-reported instrument are required to confirm the magnitude of the benefit, to identify the patients most likely to recur and to define the durability of stability beyond two years. Until that evidence exists, the consistency of the current data is sufficient to justify repairing the plate when it is torn at surgery, while accepting that the exact success and recurrence figures remain provisional.

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FUNDING

No financing

CONFLICT OF INTEREST

None

AUTHORSHIP CONTRIBUTIONS

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Writing–review and editing: Ivan Fernando Figuerola Pelaez, Kahuana Sandy Rojahn.