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Multifactorial Non-union After First Metatarsophalangeal Arthrodesis Revised With Structural Iliac Crest Autograft: A Case Report and Comprehensive Literature Review

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Learning Point of the Article:

This case shows that failure of first metatarsophalangeal arthrodesis may result from combined biological, mechanical, and biomechanical factors rather than a single isolated cause. In a heavy smoker with painful pseudarthrosis, osteolysis, and dorsal plate breakage, revision with debridement, structural tricortical iliac crest autografting, compression screw fixation, revision dorsal plating, correction of associated lesser-ray deformity, and prolonged protection achieved computed tomography-confirmed union and improved the AOFAS-HMI score

Abstract

Introduction: First metatarsophalangeal (MTP-I) arthrodesis is a reliable procedure for end-stage hallux rigidus and selected complex first-ray deformities. Non-union is uncommon but clinically important, particularly when associated with pain, osteolysis, implant fatigue, and loss of correction. Revision is challenging because failure is usually multifactorial rather than the consequence of an isolated implant problem.

Case Report: A 62-year-old woman with a 45 pack-year smoking history underwent MTP-I arthrodesis for advanced hallux rigidus with hallux varus and associated lesser-toe deformity. The index procedure used cup-and-cone joint preparation and dorsal plate fixation. Radiographs at 3 months showed maintained alignment but incomplete consolidation. Progressive pain and swelling developed during weight-bearing, and at 6 months radiographs demonstrated dorsal plate breakage. Computed tomography (CT) confirmed established pseudarthrosis with osteolysis involving the base of the proximal phalanx. Before revision, white blood cell count, erythrocyte sedimentation rate, and C-reactive protein were normal; intraoperative cultures obtained during revision were negative. Revision included removal of failed hardware, complete debridement of fibrous pseudarthrosis and sclerotic bone, insertion of a tricortical iliac crest autograft to restore length and bone stock, interfragmentary compression screw fixation, stronger revision dorsal plating, correction of the second-ray deformity, and prolonged post-operative protection. Smoking cessation was achieved after revision.

Outcome: The post-operative course was uncomplicated. At 3 months, the patient walked in regular footwear without pain or swelling. CT at 6 months demonstrated graft incorporation, bridging trabecular bone and stable fixation. The American Orthopaedic Foot and Ankle Society hallux metatarsophalangeal-interphalangeal score improved from 29/100 before revision (pain 0, function 29, and alignment 0) to 85/100 after revision (pain 30, function 40, and alignment 15).

Conclusion: Failed MTP-I arthrodesis should be analyzed systematically through biological, mechanical, and whole-forefoot factors. Structural autografting, compression-based revision fixation, correction of associated deformity, and individualized protection can achieve union even after plate breakage and established pseudarthrosis.

Keywords: Hallux rigidus, first metatarsophalangeal arthrodesis, non-union, pseudarthrosis, revision arthrodesis, iliac crest graft, plate breakage, smoking, case report.

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Author's Photo Gallery

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Introduction

First metatarsophalangeal (MTP) arthrodesis is a standard procedure for end-stage hallux rigidus and a reconstructive option in severe deformity, inflammatory arthritis, neuromuscular disease, and failed forefoot surgery [1].

Although union rates are high, non-union can cause pain, swelling, transfer metatarsalgia, implant fatigue, and loss of correction [2,3]. Revision is challenging because bone loss, osteolysis, sclerosis, shortening, malalignment, scarring and failed implants may coexist [3,4].

This case illustrates a multifactorial failed MTP-I fusion treated by biological, mechanical and whole-forefoot reconstruction, followed by a focused literature review and revision framework.

Case Report

Patient information and initial presentation

A 62-year-old woman presented with progressive right MTP-I pain, stiffness and walking limitation after failed conservative treatment.

Examination showed advanced hallux rigidus with hallux varus and second-toe varus/claw deformity. Weight-bearing radiographs confirmed end-stage MTP-I arthritis (Fig. 1).

She had a 45 pack-year smoking history. Distal pulses were palpable and arterial duplex ultrasonography was normal. MTP-I arthrodesis was recommended.

Index arthrodesis and early post-operative course

The index procedure used cup-and-cone preparation and low-profile dorsal plate fixation. Intraoperative alignment was considered satisfactory, with dorsiflexion relative to the floor and neutral transverse alignment relative to the second ray.

Postoperatively, she remained non-weight-bearing for 4 weeks before progressive loading. At 3 months, alignment and fixation were maintained, but osseous consolidation was incomplete; retrospectively, dorsiflexion appeared slightly greater than ideal.

Diagnosis of failure

At 4 months, weight-bearing pain and swelling increased. Radiographs were initially inconclusive, but at 6 months showed dorsal plate fracture and persistent fusion line. Computed tomography (CT) confirmed pseudarthrosis, absent bridging trabecular bone, and proximal phalangeal osteolysis (Fig 2). There were no clinical signs of infection; white blood cell, erythrocyte sedimentation rate, and C-reactive protein were normal. Symptomatic aseptic non-union with implant fatigue failure was diagnosed.

Failure analysis

Failure was considered multifactorial. Persistent smoking was the main modifiable biological risk. CT showed local biological failure with pseudarthrosis, sclerosis, and osteolysis. Plate fracture was interpreted as the endpoint of micromotion and cyclic loading, not the primary cause. Subtle sagittal malposition and untreated second-ray deformity may have increased forefoot loading.

Revision surgical technique

Revision was performed through the previous dorsal approach. Failed hardware was removed, fibrous pseudarthrosis and

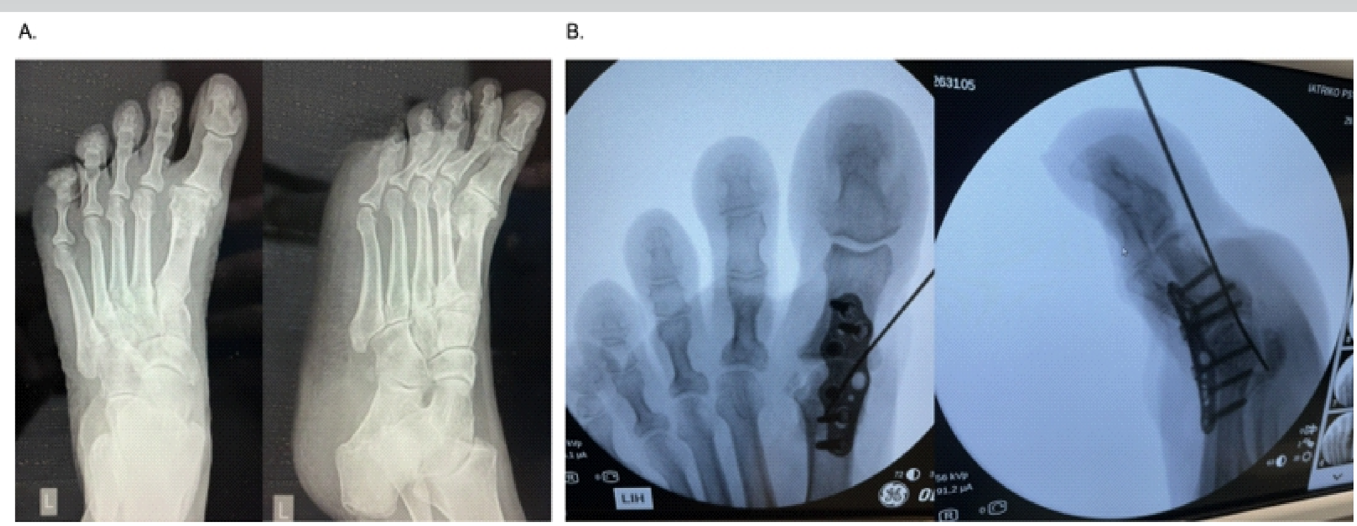

Figure 1: Pre-operative weight-bearing anteroposterior and lateral radiographs demonstrating advanced hallux rigidus with hallux varus deformity and associated second- and third-toe deformity. Intraoperative fluoroscopy following primary first metatarsophalangeal arthrodesis performed using cup-and-cone preparation and low-profile dorsal plate fixation.

Figure 2: Failure of primary arthrodesis. Computed tomography – 3D reconstruction demonstrating established pseudarthrosis with plate breakage.

sclerotic margins were excised, intraoperative cultures were obtained, and all non-viable bone was debrided to bleeding cancellous surfaces. Cultures were negative.

Because compression alone would have shortened the first ray, a tricortical iliac crest graft of approximately 1.8 × 1.2 cm was used to restore length and bone stock. Fixation used an interfragmentary compression screw and a stronger dorsal revision plate.

The second-ray deformity was corrected with subcapital second metatarsal osteotomy and proximal interphalangeal arthrodesis stabilized by K-wire to improve forefoot balance.

A conservative post-operative protocol was used: Eight weeks non-weight-bearing in a boot followed by gradual loading. Smoking cessation was achieved and maintained during healing.

Outcome and follow-up

Recovery was uncomplicated. At 3 months, she walked fully weight-bearing in normal footwear without pain or swelling, and radiographs showed maintained alignment with progressive graft incorporation (Fig. 3).

At 6 months, CT showed bridging trabecular bone, graft incorporation, closure of the fusion gap, and stable fixation without recurrent osteolysis (Fig. 4). At 1 year, she remained asymptomatic in regular footwear. The American Orthopaedic Foot and Ankle Society hallux metatarsophalangeal-interphalangeal score improved from 29/100 to 85/100 (Table 1).

Patient perspective and functional assessment

The patient reported resolution of weight-bearing pain and swelling, return to regular footwear, and improved walking tolerance.

Discussion

Why this case is more than an isolated hardware failure

Plate breakage should not be treated as a diagnosis. It is usually the visible endpoint of an unhealed fusion exposed to repetitive loading. Implant exchange alone may miss the underlying causes: Impaired biology, insufficient compression, bone loss, malalignment, premature loading, or adjacent-ray pathology.

Here, incomplete consolidation preceded symptoms, and symptoms preceded radiographic plate failure. CT then

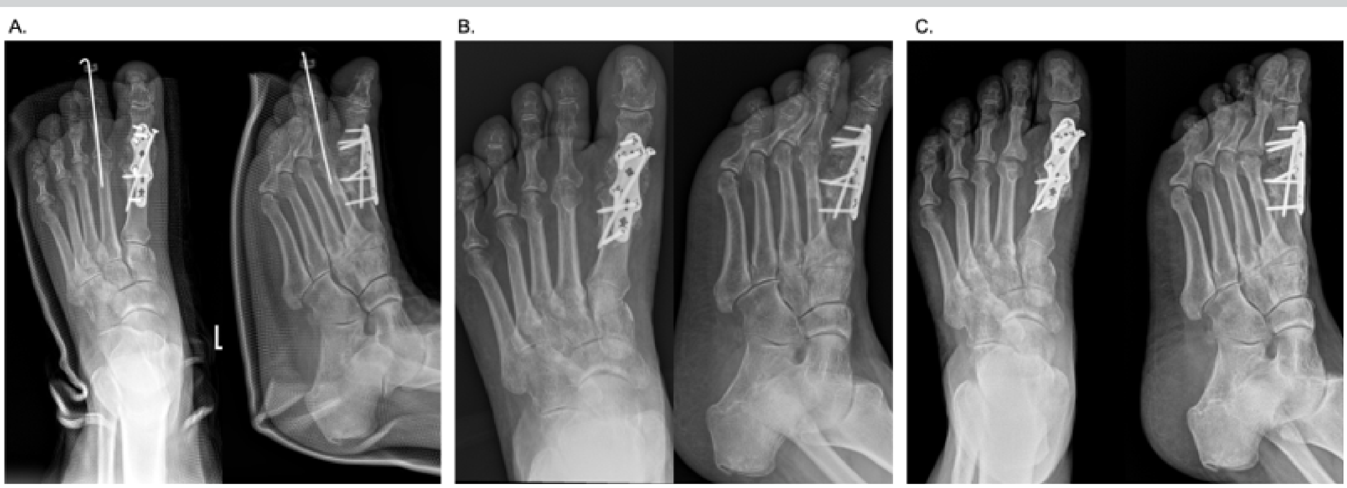

Figure 3: Revision arthrodesis. Serial post-operative anteroposterior and lateral radiographs, immediate post-operative; 3-month post-operative and 6-month post-operative radiographs demonstrating maintenance of alignment and progressive graft incorporation.

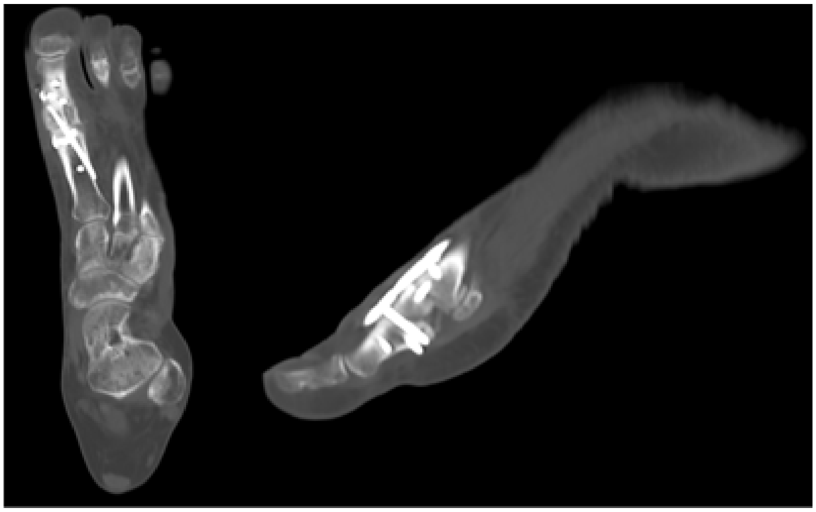

Figure 4: Six-month post-operative computed tomography demonstrating graft incorporation, bridging trabecular bone across the arthrodesis site, closure of the previous fusion gap and stable implant position.

confirmed pseudarthrosis and osteolysis, supporting biological failure and micromotion before fatigue fracture.

Biological risk: Smoking and host factors

Smoking is a major modifiable risk factor for impaired osseous healing through vasoconstriction, reduced tissue oxygenation, impaired osteoblast activity, diminished collagen synthesis, and reduced angiogenesis [5,6]. Even when MTP-I-specific studies vary, broader foot-and-ankle fusion data support cessation before elective arthrodesis.

Normal pulses and duplex findings reduced concern for major arterial disease but did not exclude smoking-related microvascular or cellular impairment.

Local biology and joint preparation

Fusion requires cartilage and sclerotic bone removal, viable cancellous surfaces, and stable contact. Cup-and-cone preparation preserves bone stock and assists alignment, whereas planar cuts may improve cancellous apposition and compression [7,8,9,10]. In revision, the specific preparation method is less important than complete debridement to bleeding bone. In this case, excision of fibrous tissue and sclerosis converted an inactive pseudarthrosis into a viable graft bed.

Fixation and compression in revision arthrodesis

Stable fixation and compression are central to MTP-I fusion. Evidence generally supports constructs combining compression with dorsal plating, particularly in revisions or biologically compromised patients [11,12]. The revised construct used an interfragmentary compression screw and stronger dorsal plate to compress the graft interfaces and resist bending during rollover.

Structural grafting: Restoring biology, bone stock and length

Revision often involves bone loss, osteolysis, shortening and sclerosis. When compression would shorten the first ray, structural grafting is required. Tricortical iliac crest autograft provides support and osteogenic, osteoconductive and osteoinductive properties [13]. CT-confirmed incorporation and bridging trabeculation showed that the graft served both structural and biological roles.

Table 1: Clinical timeline

Time point	Clinical event	Interpretation
Pre-operative	Advanced hallux rigidus with hallux varus and second-/third-toe deformity; 45 pack-year smoker; normal arterial duplex.	Complex forefoot deformity with major modifiable biological risk factor.
Index surgery	First MTP arthrodesis using cup-and-cone preparation and low-profile dorsal plate fixation.	Primary fusion with standard preparation and plate fixation.
4 weeks	Non-weight-bearing followed by progressive weight-bearing.	Routine primary rehabilitation protocol.
3 months	Alignment maintained; fixation intact; complete osseous consolidation not evident.	Delayed or incomplete early fusion.
4 months	Increasing pain and swelling during weight-bearing.	Symptomatic mechanical activity at the fusion site suspected.
6 months	Radiographs demonstrated dorsal plate breakage; CT confirmed pseudarthrosis, absent bridging bone and proximal phalangeal osteolysis. WBC, ESR and CRP were normal before revision.	Aseptic symptomatic non-union with implant fatigue failure suspected.
Revision	Hardware removal, pseudarthrosis debridement, tricortical iliac crest graft, compression screw, stronger dorsal revision plate, second-ray correction and intraoperative cultures.	Biology, length, compression, fixation stability and forefoot loading addressed; intraoperative cultures were negative.
Post-revision	Eight weeks non-weight-bearing; smoking cessation maintained.	Risk-adjusted protection and host optimization.
3 months after revision	Full weight-bearing in regular footwear without pain or swelling.	Clinical recovery.
6 months after revision	CT-confirmed graft incorporation, bridging trabecular bone and stable fixation; pain-free walking in regular footwear; AOFAS-HMI improved from 29/100 to 85/100.	Radiographic union with major clinical and functional improvement.

CT: Computed tomography, WBC: White blood cell, ESR: Erythrocyte sedimentation rate, CRP: C-reactive protein, MTP: Metatarsophalangeal, AOFAS-HMI: American Orthopaedic Foot and Ankle Society hallux metatarsophalangeal-interphalangeal score

Table 2: Failure analysis and revision response		
Problem identified	**Evidence in the present case**	**Revision response**
Host biological risk	45 pack-year smoking history and continued smoking after primary surgery.	Smoking cessation after revision and prolonged protection.
Local biological failure	CT-confirmed pseudarthrosis, sclerosis and osteolysis.	Excision of fibrous tissue and sclerotic bone to bleeding cancellous surfaces.
Structural bone loss	Osteolysis involving the base of the proximal phalanx.	Tricortical iliac crest graft to restore bone stock and length.
Mechanical instability	Persistent symptoms followed by dorsal plate breakage.	Interfragmentary compression screw and stronger dorsal revision plate.
Possible sagittal malposition	Retrospective concern for excessive dorsiflexion.	Realignment during graft insertion and revision fixation.
Adjacent forefoot deformity	Second-ray varus/claw-toe deformity.	Second metatarsal osteotomy and PIP arthrodesis.
Rehabilitation risk	Primary protocol used 4 weeks non-weight-bearing; delayed consolidation became evident.	Eight weeks non-weight-bearing after revision before gradual loading.
Need for objective union assessment	Radiographs were initially inconclusive.	CT used to confirm both non-union and later union.
Infection as differential diagnosis	No clinical infection; pre-revision WBC, ESR, and CRP were normal; no intraoperative purulence; intraoperative cultures negative.	Single-stage aseptic revision rather than staged septic reconstruction.
Functional impairment	Pre-revision AOFAS-HMI 29/100 (pain 0, function 29, alignment 0).	Post-revision improvement to 85/100 (pain 30, function 40, alignment 15).

CT: Computed tomography, WBC: White blood cell, ESR: Erythrocyte sedimentation rate, CRP: C-reactive protein, MTP: Metatarsophalangeal, AOFAS-HMI: American Orthopaedic Foot and Ankle Society hallux metatarsophalangeal-interphalangeal score, PIP: Proximal interphalangeal

Proposed revision framework

On the basis of the present case and the available literature, failed MTP-I arthrodesis should be assessed using a structured framework. The surgeon should determine whether failure is symptomatic, confirm non-union with CT when radiographs are equivocal, exclude infection, evaluate host biology, assess bone loss and first-ray length, analyze fixation and alignment, identify adjacent-ray deformity, and individualize the post-operative protocol. Revision should be designed to restore both biology and mechanics (Table 2).

Comparison with published revision literature

Literature on failed MTP-I arthrodesis is limited. Takács and Swierstra used inlay grafting for pseudoarthrosis, supporting biological augmentation

Forefoot biomechanics and second-ray deformity

MTP-I arthrodesis should be assessed within the whole forefoot. Adjacent lesser-ray deformity may alter rollover mechanics and plantar pressure, although direct causality cannot be proven from a single case. Correcting the second-ray deformity was intended to improve balance and reduce abnormal loading across the revised first ray.

Post-operative protection

Although early protected weight-bearing may be safe after selected primary fusions [14,15], this evidence should not be applied uncritically to high-risk revisions. Smoking history, pseudarthrosis, bone loss, and structural grafting justified 8 weeks of non-weight-bearing before gradual loading.

Table 3: Selected literature relevant to failed or revised first MTP arthrodesis and salvage reconstruction			
Author/year	**Type of problem**	**Revision or salvage strategy**	**Relevance to present case**
Prat *et al*., 2023 [10]	Revision-first MTP arthrodesis cohort.	Revision arthrodesis with variable techniques.	Demonstrates that revision first MTP fusion has higher complication risk than primary fusion.
Takács and Swierstra, 2011 [16]	Pseudoarthrosis after failed MTP-1 arthrodesis.	Inlay bone grafting technique for repair.	Directly supports graft-based revision for failed first MTP fusion.
Gaudin *et al*., 2018 [17]	Multicenter series of 158 revision procedures after first MTP arthrodesis.	Revision for hardware problems, non-union, malunion, and related complications.	Shows that revision after first MTP fusion is not negligible and may address more than one failure mechanism.
Saccomanno and Bitterman, 2023 [18]	Infected non-union after first MTP arthrodesis.	Staged revision with antibiotic spacer and tricortical iliac crest autograft.	Closest comparator for structural iliac crest autograft in failed fusion, although infected and staged.
Hirao *et al*., 2014 [19]	Malunited pronation deformity after first MTP arthrodesis.	3D-CT planning, custom guide, deformity correction and re-fusion.	Highlights the importance of three-dimensional alignment analysis in revision.
Kaiser and Levin, 2023 [20]	Persistent/recalcitrant osseous non-union of the first MTP joint.	Medial femoral condyle free flap.	Represents advanced vascularized biological salvage when local biology is severely compromised.
Mao *et al*., 2020 [21]	Failed first MTP arthroplasty.	Systematic review of salvage arthrodesis with or without structural graft.	Supports the role of salvage arthrodesis in bone-loss revision settings.
Yurteri *et al*., 2024 [22]	Failed first MTP total arthroplasty.	Arthrodesis using iliac crest autograft.	Contemporary series supporting iliac crest grafting in revision first MTP reconstruction.
Johnson *et al*., 2023 [23]	Osseous defects in revision first MTP fusion.	Custom three-dimensional printed implant.	Modern comparator for reconstructing bone loss and first-ray length when standard grafting is insufficient.
Adamson *et al*., 2021 [24]	Failed first MTP arthroplasty with bone loss preventing fixation.	Arthrodesis using allograft struts without hardware.	Demonstrates the centrality of length and position restoration when fixation options are limited by bone loss.

Table 4: Revision series and case-series evidence supporting the reconstruction strategy			
Study	**Design/population**	**Main contribution**	**Relevance to present case**
Takacs and Swierstra, 2011 [16]	Technical note/case series of 26 patients with pseudoarthrosis after failed MTP-1 arthrodesis.	Described a turnaround inlay graft bridging the pseudoarthrosis, with fixation and protected heel weight-bearing.	Directly supports graft-based biological reconstruction for established first MTP pseudarthrosis.
Gaudin *et al*., 2018 [17]	Multicenter study of 158 revision procedures after first MTP arthrodesis.	Showed that revision indications include hardware discomfort, non-union, malunion, metatarsalgia/claw-toe deformity, and IP-joint disorders.	Supports analyzing failed fusion as a spectrum of mechanical, alignment, and adjacent-ray problems rather than only broken hardware.
Kaiser and Levin, 2023 [20]	Level IV preliminary case series for persistent osseous non-union of the first MTP joint.	Reported medial femoral condyle free-flap reconstruction as a vascularized biological salvage option.	Defines the upper end of biological escalation for recalcitrant non-union; the present case achieved union without vascularized transfer.
Malhotra *et al*., 2015 [25]	Retrospective case series: 24 patients/25 feet undergoing interposition bone-block arthrodesis.	Used non-vascularized tricortical autologous iliac crest graft to maintain first-ray length in failed hallux MTP surgery.	Strongly supports the use of structural iliac crest autograft when bone loss or shortening would make simple compression inadequate.
MTP-1: First metatarsophalangeal			

and stable graft-host contact [16]. Larger revision cohorts by Waizy et al. and Gaudin et al. show that revision is clinically important and carries higher complication risk than primary fusion [4,17].

Saccomanno and Bitterman treated infected non-union with staged revision, antibiotic spacer placement, and tricortical iliac crest autograft [18]. Their report supports structural grafting but differs because infection required staging. In the present aseptic case, normal inflammatory markers, absence of purulence, and negative cultures supported single-stage revision.

Malunion is another failure mode. Hirao et al. used CT-based planning and a custom guide for malunited pronation deformity after MTP-I arthrodesis, emphasizing three-dimensional alignment assessment [19]. In this case, suspected excessive dorsiflexion prompted careful sagittal restoration during grafting and fixation.

For recalcitrant non-union with hostile biology, Kaiser and Levin reported medial femoral condyle free-flap reconstruction [20]. By contrast, this case united with non-vascularized tricortical iliac crest autograft because infection was excluded, macrovascular supply was preserved, bone loss was reconstructable and stable compression fixation was achievable.

Salvage arthrodesis after failed MTP-I arthroplasty also informs bone-loss reconstruction. Mao et al., Yurteri et al., Johnson et al. and Adamson et al. highlight strategies including structural grafting, custom implants and length maintenance when bone stock is compromised [21,22,23,24] (Table 3).

This case was distinct because aseptic failed primary arthrodesis occurred in a heavy smoker with CT-confirmed pseudarthrosis, osteolysis, and plate fatigue and second-ray deformity. Union was achieved without staged infection treatment, vascularized bone transfer, or arthroplasty conversion by combining debridement to viable bone, structural autograft, compression, enhanced fixation, adjacent deformity correction, smoking cessation, and prolonged protection.

Revision series support a whole-forefoot, stepwise escalation approach (Table 4). Gaudin et al. identified revision indications beyond hardware problems, including non-union, malunion, metatarsalgia, claw-toe deformity, and interphalangeal disorders [17]. Takács, Swierstra, and Malhotra et al. support graft-based repair and length-preserving bone-block arthrodesis [16,25], whereas Kaiser and Levin represent escalation to vascularized bone for rare hostile non-unions [20] (Table 4).

Conclusion

Non-union after MTP-I arthrodesis is usually multifactorial. Revision should restore viable bone surfaces, bone stock, first-ray length, alignment, compression, and fixation stability while correcting modifiable host and biomechanical risk factors. In the present case, successful union was achieved after pseudarthrosis excision, structural tricortical iliac crest autografting, compression screw fixation, revision dorsal plating, smoking cessation, correction of associated second-ray deformity and prolonged post-operative protection.

Clinical Message

Revision should not be limited to hardware exchange. Surgeons should systematically assess infection, biological risk factors, bone loss, fixation stability, alignment, post-operative loading and adjacent forefoot deformity. In high-risk cases, successful revision may require structural autografting, stable compression fixation, deformity correction, and smoking cessation and prolonged protected weight-bearing.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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