Management of Ankle Osteoarthritis

Prognostic Factor Evidence Summary

Supplement to:
The American Academy of Orthopaedic Surgeons Clinical Practice Guideline on the Management of Ankle Osteoarthritis

The introduction as seen in this Evidence Summary has been excerpted from the AAOS Clinical Practice Guideline on the Management Ankle Osteoarthritis. The full CPG can be found here: American Academy of Orthopaedic Surgeons Management of Ankle Osteoarthritis Evidenced-Based Clinical Practice Guideline. https://www.aaos.org/ankleoacpg Published June 4, 2026

View background material via the CPG eAppendix 1
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Disclosure Requirement

In accordance with AAOS policy, all individuals whose names appear as authors or contributors to the clinical practice guideline filed a disclosure statement as part of the submission process. All panel members provided full disclosure of potential conflicts of interest prior to voting on the recommendations contained within this clinical practice guideline.

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Introduction

BURDEN OF DISEASE

Ankle OA is a debilitating condition that significantly impairs mobility, gait mechanics, and quality of life.[1] Given the ankle's critical role in gait efficiency and balance, even a modest loss of ankle motion or alignment can result in substantial functional impairment.

Although ankle OA is less prevalent than hip or knee OA, it disproportionately affects younger, working-age individuals, mainly due to its post-traumatic etiology.[2] As a result, the economic burden of ankle OA extends beyond direct medical costs related to diagnostic workup, conservative treatment, and surgery. Also, it includes substantial indirect costs related to lost productivity, work absenteeism, reduced functional independence, and long-term disability.[3] Given the younger age at onset for many patients, the cumulative lifetime burden may be substantial.

ETIOLOGY

Unlike hip and knee OA, which are predominantly idiopathic or age-related, up to 70–80% of ankle OA cases are post-traumatic, most commonly following ankle fractures, ligamentous injuries, or chronic instability.[2,4] Malalignment, residual deformity, cartilage injury, and altered joint mechanics contribute to progressive degeneration of the tibiotalar joint. Less commonly, ankle OA may result from inflammatory disease, infection, avascular necrosis, or idiopathic degeneration.[5]

The post-traumatic nature of ankle OA frequently results in asymmetric cartilage loss, coronal or sagittal plane deformity, and compromised bone stock, all of which influence treatment selection and outcomes.

INCIDENCE AND PREVALENCE

Ankle OA is substantially less prevalent than OA of the hip or knee, accounting for approximately 1–4% of all cases of lower extremity OA;[6] however, it represents a distinct clinical entity, frequently developing one to two decades earlier than OA in other major joints, thus disproportionately affecting younger and more active patients during their working years.[1]

The prevalence and clinical impact of ankle OA are expected to increase over time due to several factors, including improved survival after ankle fractures, increased participation in high-impact activities, rising obesity rates, and greater patient expectations for mobility and function. Additionally, advances in surgical reconstruction, particularly total ankle arthroplasty, have increased recognition and referral of patients with end-stage ankle OA, further highlighting the clinical relevance of this condition.

RISK FACTORS

Multiple patient- and disease-related factors influence the development of ankle OA and outcomes following treatment. These include, but are not limited to, age, body mass index, diabetes mellitus, peripheral neuropathy, tobacco use, vascular disease, coronal plane deformity, bone loss, and bone quality.

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Methods

Prognostic summaries of evidence (PSEs) are produced for prognostic PICO questions included in AAOS Clinical Practice Guidelines (CPGs), full CPG methodology can be found here: https://www.aaos.org/globalassets/quality-and-practice-resources/methodology/cpg-methodology-september-2023.pdf. CPGs rely on the clinician work group to determine the scope of the guideline and all PICO questions therein. AAOS CPG methods have been updated to remove prognostic recommendations from the formal CPG document as they do not fit the criteria for an actionable recommendation. PSEs are compiled from searches that result from the a priori workgroup defined prognostic PICO question(s) to support shared decision making and patient-clinician communication. PSEs do not recommend for or against any interventions, but rather provide a summary of the current available evidence. As such, PSEs do not undergo a formal review period nor public comment. PSEs are published as a companion to the parent CPG.

Risk Factors

Age

Chronological age alone is not a contraindication to either total ankle arthroplasty (TAA) or ankle arthrodesis (AA). Across cohorts, older adults achieve meaningful improvements in pain and function after both procedures. However, advanced age is consistently associated with higher rates of medical complications, readmissions, and short-term mortality.

For total ankle arthroplasty (TAA) specifically, several series suggest a pattern wherein younger age is associated with higher revision risk over time (likely activity/implant demand related), while older age carries more medical (not mechanical) risk. In AA, the risk of nonunion appears to be driven more by biologic and modifiable factors (e.g., smoking, diabetes, infection history, bone biology) than by age itself; age may contribute indirectly through comorbidity burden and frailty.

A body of predominantly low-quality, retrospective cohort literature evaluates age as a prognostic factor after TAA and AA.[7–25] Heterogeneity exists in age cutpoints (e.g., ≥65, ≥70, ≥75), implant designs, fixation methods, follow-up duration, and outcome definitions.

- **Functional Outcomes:** Older and younger patients both achieve large, clinically significant improvements in pain and function following TAA and AA. Older cohorts start and end at slightly lower absolute scores but show similar magnitude of improvement.
- **Complications:** With advancing age, medical (not mechanical) complications increase—cardiac, pulmonary, thromboembolic, and delirium—but surgical complication and infection rates remain comparable.
- **Revision and Survivorship (TAA):** Large registry and institutional datasets (Henricson et al, 2015; Dagneaux et al, 2022; Anastasio et al, 2024; Consul et al, 2022) consistently show younger age predicts higher revision risk, likely reflecting greater activity exposure.[7,8,14,15]
- **Fusion (AA):** Studies (Chalayon et al, 2015; Fragomen et al, 2012; Myers et al, 2012) show no independent association between age and nonunion; comorbidities such as diabetes and smoking are stronger predictors.[23–25]

Clinical Implications

- Shared decision-making: Counsel older patients that meaningful symptom relief is expected, but with higher medical risk; counsel younger TAA patients about higher long-term likelihood of revision.
- Risk optimization: Focus preoperative efforts on frailty assessment, cardiopulmonary optimization, glycemic control, nutrition, anemia management, VTE risk stratification, and medication review—measures that often track with age.
- Procedure selection: Age should be one factor among many (deformity, bone quality, activity level, expectations). Neither TAA nor AA is contraindicated solely by age; patient goals and risk tolerance should guide choice.

Limitations

- Predominantly retrospective designs with selection bias (e.g., surgeons may avoid TAA in very young/high-demand patients).
- Inconsistent age thresholds, variable follow-up, and non-standardized outcome reporting.
- Confounding by comorbidities, bone quality, deformity, and implant era/design limits causal inference about age alone.

Future Research

- Prospective, risk-adjusted studies incorporating frailty indices and biologic age (not just chronological age).

- Competing-risk survivorship analyses for TAA across age strata with modern implants/techniques.
- Standardized definitions of medical vs surgical complications and clinically important improvement across age groups.
- Interventional trials of prehabilitation/geriatric co-management to mitigate age-related medical complications after TAA and AA.

BMI

Severe obesity (BMI ≥40 kg/m²) represents a clear threshold where complication rates, nonunion risk, and implant failure increase substantially after total ankle arthroplasty or ankle arthrodesis. Moderate obesity (BMI 30-35 kg/m²) appears to have minimal impact on short-term complications but may affect long-term implant survival. Obese patients achieve meaningful functional improvement comparable to non-obese patients but start from and end at lower absolute functional levels.

Forty-eight low-quality studies investigated the role of body mass index (BMI) on outcomes in patients undergoing total ankle arthroplasty (TAA) or ankle arthrodesis.[7–9,12,17,19,20,23–63] The evidence demonstrates considerable heterogeneity with the impact of obesity depending on severity of obesity, specific outcome measured, and potentially the type of procedure performed.

BMI and Complications

Several large studies found no significant association between BMI and overall complication rates in the short-term. Bakaes et al, 2024, Bouchard et al, 2015, Gross et al, 2016, and Kim et al, 2023 (n=1,093 TAAs, largest single-institution study) all demonstrated that obesity was not associated with increased complication rates.[27,30,35,42] However, severe obesity (Class III, BMI ≥40) represents a critical threshold. Kuttner et al, 2025 (n=527 ankle arthrodeses) found obesity class III patients had elevated risk including nonunion (OR 3.96, P=.002), revision (OR 3.69, P=.03), superficial infection (OR 9.36, P=.002), and readmission (OR 10.90, P=.01).[47] Kamalapathy et al, 2021 found morbid obesity (BMI >40) was associated with increased acute kidney injury (OR 1.94, P<.001).[40]

BMI and Implant Survival

Large registry studies show conflicting evidence. Hermus et al, 2022 (Dutch registry, n=836) found BMI was a significant risk factor for early implant failure (HR 1.09).[37] Jennison et al, 2023 (UK registry) confirmed BMI (HR 1.03, 95% CI 1.01-1.06) was associated with increased TAA failure risk.[20] Suh et al, 2021 (Korean registry, n=2,914) demonstrated severe obesity (BMI ≥30) increased failure risk (aHR 1.632).[59] Long-term studies show more pronounced effects: Schipper et al, 2016 (8.2-year follow-up) found obese patients had significantly greater probability of implant failure (adjusted OR 2.8, P=.04), with obese patients with osteoarthritis showing decreased 5-year survivorship (adjusted HR 3.73, P=.04) compared to obese patients with inflammatory or post-traumatic arthritis.[54]

BMI and Functional Outcomes

Obese patients consistently present with worse preoperative functional status (Bouchard et al, 2015, Gross et al, 2016, Kim et al, 2023).[30,35,42] Despite worse baseline function, obese patients achieve similar magnitude of improvement as non-obese patients. Kim et al, 2023 concluded "there was no differential improvement in PROs across BMI classes," meaning the rate of improvement was similar, but obese patients ended at lower absolute functional levels due to worse starting points.[42]

Clinical Implications

Patients with severe obesity (BMI ≥40) undergoing TAA or ankle arthrodesis should be counseled about increased risks of complications, nonunion, and implant failure. The negative impact of obesity on implant survival may be more apparent with longer follow-up (5-10+ years). Obesity combined with primary osteoarthritis may represent a particularly high-risk scenario.

BMI is a modifiable risk factor, and preoperative weight optimization should be considered for patients with BMI ≥35-40. Enhanced surveillance may be warranted for obese patients, especially Class II-III. Obese patients can achieve meaningful functional improvement but should be counseled that their absolute functional outcomes will likely be lower than non-obese patients, though the magnitude of improvement is similar.

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BMI should be considered in shared decision-making regarding surgical candidacy, procedure selection (TAA vs. arthrodesis), and patient counseling about expected outcomes and complication risks, particularly for patients with BMI ≥35 kg/m².

Limitations

All 48 included studies are low quality, predominantly retrospective cohort studies. Potential confounding exists as obesity often clusters with other risk factors (diabetes, vascular disease). Selection bias may occur as surgeons may be less likely to offer TAA to severely obese patients. Studies demonstrate heterogeneity in outcome measures, follow-up durations, and obesity definitions.

Future Research

Prospective studies examining BMI as a risk factor with standardized outcome measures and adequate follow-up (≥5 years) are needed. Research should identify BMI thresholds for shared decision-making, investigate preoperative weight loss interventions, include stratification by obesity class, examine interactions between BMI and other risk factors, evaluate long-term outcomes (10+ years), compare TAA vs. ankle arthrodesis stratified by BMI, investigate biological mechanisms, and conduct economic analyses of TAA in obese populations.

Diabetes

Several conflicting low-quality studies investigated the role of diabetes mellitus on outcomes after total ankle replacement (TAA) or ankle arthrodesis (AA)[12,23,25,33,34,36,39,44,46,48,58–61,64–69] (Althoff et al, 2018 Chalayon et al, 2015, Choi et al, 2014, Conti et al, 2019, Cunningham et al, 2018, Gross et al, 2015, Heida et al, 2018, Helbing et al, 2024, Jones et al, 2018, Ko et al, 2024, Kostuj et al, 2024, Kwon et al, 2023, Lee et al, 2023, Myers et al, 2012, Partan et al, 2022, Qureshi et al, 2024, Suda et al, 2016, Suh et al, 2021, Thevandran et al, 2015, Woods et al, 2023).

Some of these showed no significant negative outcomes associated with TAA or AA in patients with diabetes (Chalayon et al, 2015, Conti et al, 2019, Cunningham et al, 2018, Gross et al, 2015, Heida et al, 2018, Jones et al, 2018, Ko et al, 2024, Suh et al, 2021, Woods et al, 2023[23,33,34,36,39,44,59,61,66]), while others demonstrated poor patient reported outcomes like delayed wound healing, early onset osteolysis, readmission, nonunion rates (for patients undergoing AA), and the need for revision surgery (Choi et al, 2014, Helbing et al, 2024, Kostuj et al, 2024, Kwon et al, 2023, Myers et al, 2012, Partan et al, 2022, Suda et al, 2016, Thevandran et al, 2015, Althoff et al, 2018, Qureshi et al, 2024[12,25,46,48,58,60,64,65,67,69]).

Clinical Implications
There are no undue risks or harm when performing total ankle replacement or ankle arthrodesis on patients who have diabetes, however patients should be counseled about possible poorer patient reported outcomes for example, delayed wound healing, early onset osteolysis, increased readmission risk, increased nonunion rates (for patients undergoing AA), and the need for revision surgery in patients with diabetes compared to patients without diabetes.

Future Research
Future randomized controlled research should determine if adequate control of diabetes will improve patient reported outcomes and decrease complication rates after Total Ankle Replacement or Ankle Arthrodesis.

Tobacco

Twenty-two low-quality studies investigated the effect of tobacco use on outcomes for patients undergoing total ankle arthroplasty or arthrodesis[8,12,24,25,28,36,38,41,44,48,51,58–61,70–76]

Clinical Implications
The harms of smoking or using tobacco are well-known. There is absolutely no benefit to using tobacco in any form and should be discouraged for any patient undergoing total ankle arthroplasty or arthrodesis. As situations allow, tobacco cessation should be pursued.

Cost Effectiveness/Resource Utilization
Many studies reveal that tobacco usage increases costs on many levels (hospital stay, infection, delayed/non-union, opioid usage, etc.). Those patients that use tobacco and undergo TAA (or A) expend more resources.

Future Research
It is important to find better ways to help people stop/quit smoking.

Neuropathy

Neuropathy and Charcot arthropathy are contraindications for ankle arthroplasty. Low-quality evidence suggests that neuropathy, particularly Charcot neuroarthropathy and peripheral neuropathy, is associated with increased complications following total ankle arthroplasty or ankle arthrodesis. Patients with neuropathy demonstrate higher rates of nonunion and infection, though postoperative pain improvement appears similar to patients without neuropathy.

Evidence Discussion

Three low-quality retrospective studies investigated neuropathy as a risk factor for outcomes after ankle surgery.[24,25,70] Fragomen et al, 2012 (n=101 complex Ilizarov ankle fusions) found that in non-smoking patients with Charcot neuroarthropathy, the non-union rate was significantly worse than non-smokers without Charcot.[24] The authors now recommend tibiotalocalcaneal fusion for all patients with advanced neuropathy and ankle arthritis rather than isolated tibiotalar fusion.

Myers et al, 2012 (n=148 ankle/hindfoot arthrodeses) demonstrated that peripheral neuropathy was the strongest predictor of postoperative complications.[25] Patients with peripheral neuropathy had 21-fold increased risk of infection and 2.6-fold increased risk of any complication. Peripheral neuropathy had the strongest association with postoperative infection among all variables studied.

Vesely et al, 2024 (n=154 tibiotalocalcaneal arthrodeses) found no statistically significant difference in preoperative pain (p=0.061), postoperative pain (p=0.49), or change in pain (p=0.49) between patients with and without Charcot deformity.[70] Average pain decreased from 7.1 to 3.0 regardless of Charcot status, suggesting that while neuropathy increases surgical complications, it does not preclude meaningful pain improvement.

Clinical Implications

Patients with neuropathy undergoing ankle surgery face substantially elevated complication risks, particularly infection and non-union. The 21-fold increased infection risk in neuropathic patients (Myers et al, 2012) represents one of the strongest risk factors identified in the ankle surgery literature.[25] Surgeons should counsel neuropathic patients extensively about these risks and consider extended external fixation times, enhanced postoperative surveillance, and potentially more aggressive surgical approaches such as tibiotalocalcaneal rather than isolated tibiotalar fusion.

Despite elevated complication risks, neuropathic patients can achieve similar pain relief to non-neuropathic patients, supporting limb salvage attempts rather than primary amputation. However, patient selection is critical.

Limitations

All three studies are low quality retrospective analyses. Myers et al, 2012 matched diabetic and non-diabetic patients but did not match for neuropathy specifically, and 85% of diabetic patients had neuropathy, confounding the independent effect of neuropathy versus diabetes.[25] Fragomen et al, 2012 had small numbers of Charcot patients (n=19) limiting statistical power.[24] Vesely et al, 2024 did not specify neuropathy diagnosis methods or severity.[70] No studies examined neuropathy subtypes, severity grading, or duration of neuropathy. The interaction between neuropathy and other risk factors (diabetes, smoking, vascular disease) is incompletely characterized.

Cost Effectiveness/Resource Utilization

Neuropathy screening is inexpensive and should be routine. However, elevated complication rates in neuropathic patients substantially increase healthcare costs through longer external fixation, higher reoperation rates for infection and non-union, need for conversion to more extensive procedures, below-knee amputation in failures, and prolonged wound care.

Feasibility
Neuropathy assessment is highly feasible using monofilament testing during routine preoperative examination. However, managing neuropathic patients requires extended external fixation capability, enhanced postoperative surveillance infrastructure, education for wound monitoring, and potentially multidisciplinary care. Some practices may lack resources for optimal neuropathic patient management, warranting referral to specialized centers.

Future Research
Critical research priorities include: investigation of whether neuropathy type (diabetic, alcohol-related, idiopathic) differentially affects outcomes; studies examining protective strategies such as extended external fixation times, prophylactic antibiotics, negative pressure wound therapy, or staged procedures; cost-effectiveness analyses of different surgical approaches (internal fixation vs external fixation, isolated tibiotalar vs tibiotalocalcaneal fusion) stratified by neuropathy severity.

Vascular Disease

The relationship between vascular disease and outcomes following total ankle replacement (TAR) is incompletely defined, but available evidence suggests an association with increased postoperative complications.[24,25,28,33,34,52,60,76] The most direct evidence comes from Conti et al, 2019, who demonstrated that patients with peripheral vascular disease (PVD) undergoing TAR experienced significantly higher rates of postoperative complications, including infection, wound complications, and reoperation, compared with patients without PVD.[33] This study highlights compromised vascular status as an independent risk factor in the TAR population.

Additional TAR-focused studies provide indirect contextual evidence. Barg et al, 2011 identified patient-level risk factors for symptomatic deep vein thrombosis after TAR, underscoring the relevance of vascular pathology to perioperative outcomes even in the setting of routine thromboprophylaxis.[28] Cunningham et al, 2018 reported that common patient risk factors did not significantly affect short-term readmissions or emergency department visits after TAR; however, vascular disease was not a primary variable of interest, and the study focused on short-term utilization rather than surgical complications.[34] Large population-based analyses, such as that by Randsborg et al, 2022, demonstrate meaningful revision rates after TAR, though comorbidity-specific risk stratification, including vascular disease, remains limited.[52]

Because vascular disease is often under-represented in TAR cohorts, evidence from related foot and ankle surgery literature provides biologic plausibility. Studies examining arthrodesis and complex reconstruction (Fragomen et al, 2012; Myers et al, 2012; Thevendran et al, 2015) consistently demonstrate higher rates of nonunion, infection, and complications in patients with systemic comorbidities associated with impaired perfusion, including diabetes and vascular disease.[24,25,60] Collectively, these findings support the hypothesis that compromised vascular status negatively influences outcomes following TAR.

The current evidence base consists primarily of retrospective cohort studies and database analyses with limited TAR-specific vascular stratification. No prospective or randomized studies directly evaluate vascular disease as an isolated risk factor for TAR outcomes.

Successful total ankle replacement relies on adequate soft-tissue healing, osseointegration, and resistance to infection—all processes dependent on sufficient vascular perfusion. Peripheral vascular disease compromises microcirculatory blood flow, impairs oxygen delivery, and disrupts inflammatory and reparative pathways necessary for wound healing and bone-implant integration. Conti et al, 2019 provide direct clinical evidence that patients with PVD experience higher complication rates following TAR, likely reflecting these biologic mechanisms.[33] Additional support comes from foot and ankle reconstruction literature demonstrating increased nonunion and complication rates in populations with impaired vascular or metabolic status (Myers et al, 2012; Thevendran et al, 2015)[25,60]. Although some TAR studies show acceptable short-term outcomes across heterogeneous patient populations, the cumulative evidence suggests that vascular disease increases susceptibility to wound breakdown, infection, thrombotic events, and potential implant failure.

Clinical Implications

Patients with known peripheral vascular disease should be considered higher risk candidates for total ankle replacement. Preoperative vascular assessment, including history, physical examination, and selective noninvasive testing, should be strongly considered. Optimization of modifiable risk factors, careful patient selection, and thorough counseling regarding elevated complication risk are essential. In patients with significant vascular compromise, alternative treatments such as ankle arthrodesis or nonoperative management may offer more predictable outcomes.

Limitations

The existing literature is limited by retrospective study designs, inconsistent definitions of vascular disease, and under-representation of patients with advanced PVD in TAR cohorts. Many studies focus on short-term outcomes or aggregate comorbidity indices, limiting the ability to isolate vascular disease as an independent risk factor. Extrapolation from non-TAR foot and ankle procedures introduces biologic plausibility but reduces specificity.

Future Research

Prospective studies with standardized vascular assessment are needed to better define thresholds of vascular disease that meaningfully impact TAR outcomes. Risk-adjusted registry data, incorporation of objective perfusion metrics, and comparative studies evaluating TAR versus arthrodesis in patients with vascular disease would significantly strengthen the evidence base and guide surgical decision-making.

Bone Quality

The available evidence is insufficient to determine whether bone quality affects outcomes after total ankle arthroplasty or ankle arthrodesis.

Two low-quality studies were identified, but neither measured bone quality using validated methods (DEXA, BMD, CT Hounsfield units).[23,52] Chalayon et al, 2015 (n=215 ankle arthrodeses, 91% union rate) identified previous subtalar fusion and varus alignment as nonunion risk factors but did not assess bone quality and excluded complicated cases most likely to have bone quality issues.[23] Randsborg et al, 2022 (n=2,945) reported 2-year revision rates of 5.6% (TAR) vs 7.6% (AA) but provided no bone quality data in this claims-based study.[52]

Despite absent evidence, bone quality is theoretically important: for TAA, poor bone quality may increase subsidence and periprosthetic fracture risk; for ankle arthrodesis, it may increase nonunion risk. Current practice relies on subjective assessments (intraoperative findings, radiographic surrogates like cortical thickness, clinical risk factors) - none validated for ankle surgery outcomes.

Cost Effectiveness/Resource Utilization
DEXA scans ($100-300) typically measure spine/hip/forearm, not ankle. Specialized ankle imaging lacks standardization. Cost-effectiveness of bone quality screening cannot be determined without evidence. Preoperative optimization (vitamin D, teriparatide $3,000-4,000/month) lacks proven ankle-specific benefit.

Feasibility
Multiple barriers explain evidence absence: DEXA does not routinely measure ankle, regional ankle BMD is technically difficult, CT-based assessments not standardized, and bone quality assessment requires preoperative planning not routinely performed. Retrospective studies lack preoperative imaging; database studies lack bone quality coding.

Future Research
Critical priorities: validated ankle-specific BMD protocols; standardized CT measurements; large prospective cohorts with preoperative bone quality assessment and ≥5-year follow-up; bone quality threshold identification; intervention trials of preoperative optimization and intraoperative augmentation; comparative studies by bone quality; economic analyses of screening; and registry enhancement for bone quality capture.

Bone Loss

Bone loss, including periprosthetic osteolysis, cystic change, and poor bone density, is associated with inferior implant survival and higher revision risk after total ankle arthroplasty (TAA). The relationship between bone loss and outcomes after ankle arthrodesis (AA) is less clearly defined, but severe subchondral deficiency can compromise fixation and may increase nonunion risk. Periprosthetic osteolysis is a recognized late mechanical failure mechanism in TAA; however, the presence of mild or radiographically stable osteolysis does not always correlate with pain or functional decline.

Four low-quality studies met inclusion criteria for this prognostic factor.[23,45,50,77]

<u>Total Ankle Arthroplasty (TAA)</u>
Koivu et al, 2017 (n = 130)[45]
Reported medium- to long-term outcomes for the Ankle Evolutive System TAA, demonstrating inferior survival (79.3%) attributed primarily to peri-implant osteolysis. Osteolysis was the predominant radiographic finding preceding revision, suggesting it is a major mechanical failure pathway over time.

Lee G.W. et al, 2021 (n = 92)[77]
Compared preoperative bone density (quantified by HU) in patients who did and did not develop periprosthetic osteolysis following TAA. Lower baseline bone density correlated with increased risk of osteolysis and component subsidence. Authors concluded poor bone quality predisposes to periprosthetic bone loss and mechanical instability.

Lee G.W. et al, 2022 (n = 250)[50]
In a large single-center cohort, periprosthetic osteolysis was the most significant predictor of revision (adjusted HR 5.68; $p < 0.01$). Revisions were primarily for loosening and talar subsidence. Functional outcomes (AOFAS, VAS Pain) improved post-TAA regardless of radiographic osteolysis, but progressive or cystic lesions correlated with worsening alignment and impending mechanical failure.

<u>Ankle Arthrodesis (AA)</u>
Chalayon et al, 2015 (n = 117)[23]
Identified osteopenia and bone quality as secondary variables affecting open ankle arthrodesis outcomes. While not an independent statistical predictor in multivariate modeling, poor host bone stock was associated with delayed union and need for bone graft augmentation.

Clinical Implications
Bone loss, whether preexisting or progressive, represents a key mechanical and biological risk factor in ankle reconstructive surgery.

- In TAA, periprosthetic osteolysis is the primary radiographic marker of mechanical failure, and preoperative low bone density increases this risk.
- In AA, bone deficiency complicates fixation, particularly in revision or infection settings, though modern techniques and grafting can mitigate risk.

Clinical recommendations:

- Evaluate preoperative bone density (Dorr/CT HU or DEXA when indicated).
- Address large cysts or osteolysis with bone grafting or augments during implantation.
- Consider early revision or bone grafting for progressive osteolysis.
- Counsel patients with osteopenia or cystic defects regarding increased risk of loosening, nonunion, and reoperation.

Limitations

- All included studies are retrospective and single-center with variable implant designs and definitions of "osteolysis."

- Heterogeneity exists in imaging modalities (plain film vs CT) and follow-up duration.
- Bone quality often interacts with other risk factors (age, sex, BMI, activity, implant design), limiting isolated assessment.

Future Research

- Prospective multicenter studies quantifying bone mineral density and periprosthetic bone remodeling using standardized CT metrics.
- Long-term registry analyses correlating osteolysis size/progression with clinical outcomes and revision.
- Comparative studies of bone-augmenting strategies (e.g., porous metal augments, custom stems, biologics) for severe talar/tibial bone loss.
- Investigation of systemic bone health optimization (vitamin D, osteoporosis therapy) on ankle arthrodesis and TAA survival.

Deformity

Twelve low quality articles investigated the affect of ankle deformity on patient outcomes in total ankle arthroplasty.[15,17,44,45,78–85]

a) Dagneaux et al, 2022 4,748 French TAA patients, mix of implants, "concomitant osteotomies or fusions" associated with earlier revision, but so were other factors.[15]
b) Haytmanek et al, 2015 - 89 STARs, patients with > 10-degree deformity had higher secondary surgery rate and metal component revision rate (14% vs 10%), does not appear SS.[78]
c) Henricson et al, 2007 - 186 TAAs, 4.2-year follow-up, mix of implants, revision rate 31% in varus ankles, 17% in neutral and valgus. Study also reported a lot of residual ankle varus or valgus beyond 5 degrees.[79]
d) Joo et al, 2017 - 105 TAAs, neutral vs moderate vs severe varus - no difference in AOFAS, VAS, ROM, complication rate, though less SS improvement in the SF-36 in the severe varus group.[80]
e) Ko et al, 2024 - 214 ankles 2-year follow-up, all greater than 5 degrees deformity. No increased failure rate with severity of deformity.[44]
f) Koivu et al, 2017 - 130 AES ankles - Post-op varus > 10-degrees associated with increased failures.[45]
g) Lee et al, 2019 - 148 HINTEGRAs, 74-month follow-up compared 41 ankles with severe deformity 20-35 degrees, to lesser deformity (5-15). No SS difference in AOS, AOFAS, SF 36, VAS or ankle ROM or complication rate or mean implant survival. Were more coronal plane outliers post op in the severe group.[81]
h) Lee et al, 2018 - 144 HINTEGRAs, 89-month follow-up, compared neutral (5 varus to 5 valgus, to varus and valgus ankles. No difference in PROMs, but more concomitant procedures in varus group, lower survival in valgus group (81% vs 97 varus and 90 neutral).[82]
i) Richter et al, 2021 - 935 HINTEGRA, mean 8.8-year follow-up, ankle with major deformity (7 degrees varus or 5 valgus), hazard ratio from 1.9-2.5.[83]
j) Schenk et al, 2011 - Less revisions for severe varus (greater than 15 degrees) 11% vs patients with less varus (16%) or neutral (16%) but no report of SS.[84]
k) Yang et al, 2019 - 210 HINTEGRAs, 6.4-year follow-up, no association with preop coronal plane deformity and failure rates.[17]
l) Zafar et al, 2020- 322 HINTEGRAs, unclear follow-up. Lots of failures (75% 5-year survival, 68% at 10 years). Cox model showed 5-yearr risk of revision with increasing post op tibial varus and less risk of revision with preop talar varus.[85]

One low quality article investigated the effect of ankle deformity on patient outcomes in total ankle arthrodesis.[86]

Dannawai et al, 2011 - Arthroscopic ankle fusion with deformity over 15 degrees associated with SS slower time to union but no difference in union rate or G/E results.[86]

References

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