# Ankle Osteoarthritis

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**Abstract**

Ankle osteoarthritis is a growing problem in health care, with 1 % of the world's adult population being affected. Previous trauma is the most common origin of ankle osteoarthritis. In the current literature, there is no evidence whether sport activities accelerate or prevent the development of ankle degenerative changes. Different surgical approaches have been described for the treatment of ankle osteoarthritis based on osteoarthritis stage. The treatment options range from joint preserving procedures (e.g. open or arthroscopic debridement, joint distraction arthroplasty, and supramalleolar osteotomies) to joint sacrificing procedures (e.g. total ankle replacement and ankle arthrodesis). While numerous studies have addressed clinical and radiographic outcomes in patients who underwent surgery for ankle osteoarthritis, there is scant literature addressing the role of sports participation of patients with ankle osteoarthritis before and after surgical treatment. In general, low impact sports can be recommended postoperatively. However, further prospective clinical studies are needed to identify whether sport activities can be identified as risk factors for treatment failure or for poorer postoperative results.

**Keywords**

Ankle • Ankle osteoarthritis • Sport • Sport activities • Ankle osteoarthritis etiology • Joint-preserving procedure • Joint sacrificing procedures • Supramalleolar osteotomy • Total ankle replacement • Ankle arthrodesis

## Etiology of Ankle Osteoarthritis

Ankle osteoarthritis (OA) is a constantly growing problem in world health care and should not be underestimated [1]. More than 1 % of the entire world's adult population is affected by ankle OA [2]. The mental and physical disability in patients suffering from end-stage ankle OA is at least as severe as that associated with end-stage hip OA [2].

In the current literature there are clinical and epidemiologic studies which address the etiology of ankle OA [1, 3]. Valderrabano et al. [4] evaluated the distribution of etiologies in 390 consecutive patients (406 ankles) with end-stage ankle OA. Posttraumatic ankle OA was observed in the majority (78 %) of patients. Malleolar fractures (type AO 44) were the most common injuries (39 %), followed by ankle ligament lesions (16 %), and tibial plafond fractures (type AO 43, 14 %). Secondary, atraumatic OA was observed in 13 % of patients including patients with rheumatoid arthritis, hemochromatosis, hemophilia, clubfoot etc. Primary OA was the rarest etiology, with 9 % of patients affected. Patients with posttraumatic ankle OA were significantly younger than patients with other ankle OA etiologies [4]. Similar findings

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were found in another epidemiologic study by Saltzman et al. [5]. In this study, 639 consecutive patients with Kellgren grade 3 or 4 ankle OA who presented to the University of Iowa Orthopaedic Foot and Ankle Surgery service between 1991 and 2004 were included. The majority of patients (70 %) had posttraumatic ankle OA, with rotational ankle fractures and recurrent instability being the most common causes, at 37 % and 15 %, respectively. Primary and secondary OA was diagnosed in 22 % and 8 %, respectively [5]. Wang et al. [6] analyzed radiographic hindfoot alignment in 226 consecutive patients with end-stage ankle OA who underwent total ankle replacement (TAR) or ankle arthrodesis. The most common etiology in this cohort was posttraumatic, with 71.2 % of patients reporting previous fractures or recurrent ligament injuries. Primary ankle OA was diagnosed in 5.6 % of patients. Secondary ankle OA was seen in 23.2 %, including OA due to pes planovalgus deformity, rheumatoid arthritis, clubfoot or other congenital foot deformity, postinfectious arthritis, Charcot-Marie-Tooth disease, and haemophilic arthritis [6].

## Sport as Risk Factor for the Development of Ankle Osteoarthritis

In the current literature, there is a controversial discussion whether sport activities play a positive or negative role in the development of ankle OA. Based on the available literature, a causal link between pediatric sports injuries and ankle OA development is possible [7].

In the 1970s, Vincelette et al. [8] compared degenerative changes of the foot and ankle between professional soccer players and controls. Fifty-nine professional football players, with an average age of 23 years (19–27 years), with an average football experience of 9.5 years (2–15 years) were included. The group evaluated 367 radiographs of soccer players and 377 radiographs of control patients. Radiographs were classified as abnormal if they showed signs of OA, periarticular ossifications, dorsal exostosis of the talus, or distal interosseous ligament calcification. Among soccer players, mild findings were found in 10 % and severe findings were found in 90 % of radiographs. In the control group, 22 % had mild findings and 4 % had severe findings regarding radiographic degenerative changes [8].

In 1979, Adams [9] examined 56 soccer players and six coaches (who were former professional players) clinically and radiographically at one football club. All 62 patients showed some signs of ankle pathology. However, the overall incidence of radiographic OA was only 1.6 % [9].

Hellmann et al. [10] performed radiographic analysis of six amateur athletes who had severe atypical degenerative joint disease. One of the patients presented with right ankle pain. The 20-year-old male participated in cross-country motorcycling for several years. Radiographs and computed tomography showed degenerative changes of the subtalar joint in this patient, most likely resulting from extensive sport activities [10].

Kujala et al. [11] investigated the cumulative 21 year incidence of admission to a hospital for OA of the hip, knee, and ankle in former elite athletes and control subjects. In total, 2,049 male athletes who had represented Finland in international events from 1920 to 1965 and 1403 controls were included into this national population based study. The cumulative incidence of admission to a hospital among the former athletes was 3.3 % (95 % CI 2.6–4.1 %), 2.4 % (95 % CI 1.8–3.2 %), and 0.4 % (95 % CI 0.2–0.8 %) for hip, knee, and ankle, respectively. These values were substantially higher than values observed in controls: 1.4 % (0.9–2.2 %), 1.3 % (95 % CI 0.8–2.0 %), and 0 % for hip, knee, and ankle, respectively [11].

The potential influence of long-term, high-intensity physical training on early ankle OA has been investigated in a retrospective study by Knobloch et al. [12]. Twenty-seven track and field long-distance runners and orienteers and nine bobsledders with a mean age of 42 years were compared with a control group of 23 healthy men with a mean age of 35 years. The long-distance runners had a higher prevalence of early ankle OA, however, the multivariate analysis demonstrated that not the sport itself, but rather age and ankle instability were significantly correlated with the development of ankle OA [12].

In their comparative study, Gross and Marti [13] addressed the influence of long-term, professional volleyball playing on the development of early ankle OA. A group of 22 former elite volleyball players with a mean age of 34 ± 6 years who had played for at least three years in the highest league in Switzerland was compared to 19 healthy controls with a mean age of 35 ± 6 years. The majority of players (20 of 22) had lateral ligament lesions, and eight of these required surgery. Radiographic evidence of ankle OA was found in 19 of 22 volleyball players, but only in two of 19 controls. The multiple regression analysis revealed that positive anterior drawer test and subjective instability were statistically significant and independent risk factors for radiographic OA [13].

Zinder et al. [14] evaluated the prevalence of ankle OA following ankle sprains in a cohort of retired professional football players. In total, 2,552 retired professional football players completed a general health questionnaire. Of them, 448 (17.69 %) reported at least one severe ankle sprain in the past. Forty patients developed significant ankle OA. Compared to players without a history of sprains, the injured cohort had a 2.3 times higher prevalence of ankle OA [14].

Kuijt et al. [15] performed a systematic review of the recent literature to investigate the prevalence of knee and/or ankle OA in former elite soccer players. Only four studies were included in the final analysis. The prevalence of degenerative joint disease was found to be between 40 and 80 % for the knee and between 12 and 17 % for the ankle. The prevalence of knee and ankle OA in the former players was substantially higher compared to the general population. However, only the prevalence of OA was measured in this study. Therefore, the authors mentioned the need of further studies based on a health surveillance program to be able to identify players at risk for OA [15].

Recently, Gouttebarge et al. [16] published a systematic review to explore the OA prevalence in former elite athletes from team and individual sports. In total, 15 studies were included in the review. Prevalence of ankle OA was reported only in one study [17]. In this study, by Schmitt et al. [17], which included 40 former elite high jumpers, ankle OA was found in 2.5 %, with a mean age of 41.8 years at time of diagnosis.

In 2015, Iosifidis et al. [18] investigated the prevalence of lower extremity clinical and radiographic OA in a comparative study. The study compared 218 former elite male athletes from various sports (soccer, volleyball, martial arts, track and field, basketball, and skiing) with 181 controls. The prevalence of clinical OA was similar in both groups, with 15.6 % prevalence for former elite athletes and 14.4 % for controls. However, the prevalence of radiographic OA was significantly higher in the former athletes (36.6 %) compared to the controls. Therefore, the radiographic signs of OA may precede the clinical onset of OA. In both groups, several risk factors for OA development were identified: age, body mass index, and occupation [18].

## Ankle Instability as Risk Factor for the Development of Ankle Osteoarthritis

Lateral ankle sprain (LAS) is one of the most common sports injuries in the world. LAS accounts for up to 30 % of all athletic injuries and up to 60 % of injuries in certain sports [19, 20]. It is one of the most common injuries in basketball [21–28], soccer [29–41], football [42–47], and tennis [48–51]. One LAS occurs per 10,000 person-days, and an estimated 2 million acute LAS injuries occur each year in the United States [52]. LAS injuries occur most commonly between 15 and 19 years of age [52], and there is no statistically significant difference in LAS incidence between males and females [52–55]. Ankle injuries, including LAS, are among the most common injuries in children and youth sports, accounting for up to one fourth of all injuries sustained by high-school athletes during the 2005–2006 school year [7, 56]. Swenson et al. [57] analyzed the sports injury data for the 2005 through 2008 academic years from a nationally representative sample of 100 United States high schools. The injuries most often involved the ankle (19 %), knee (14.5 %) and head/face (10.7 %). Notably, the ankle was the most frequently diagnosed site of recurrent injuries at 28.3 % [57].

Up to 40 % of all patients with LAS develop chronic ankle instability (CAI) [58–60]. Different intrinsic and extrinsic factors have been identified as risk factors for development of CAI after LAS: high body mass index, high height, and severity of initial ankle sprain [61, 62]. As mentioned above, CAI from repetitive ankle sprains is an important etiology of ankle OA – up to 20 % of all ankle OA cases and up to 30 % of all patients with posttraumatic ankle OA [4, 5, 63]. Different arthroscopic studies demonstrated a high number of chondral injuries in patients with a prolonged history of ankle instability [64–67].

Several studies have investigated the pathomechanism of ankle instability leading to ankle OA [68–71]. McKinley et al. [71] used an ankle cadaveric model to measure incongruity and instability-associated changes in contact stress directional gradients in the tibiotalar joint. An increase of up to 100 % was observed in unstable specimens [71].

Caputo et al. [69] used magnetic resonance imaging (MRI) and orthogonal fluoroscopy to perform kinematic measurements in nine patients with lateral ankle instability and, in particular, insufficient anterior talofibular ligaments. Several significant changes were observed as compared with the intact contralateral ankles: increase in anterior translation of 0.9 ± 0.5 mm, increase in internal rotation of 5.7° ± 3.6°, and increase in superior translation of 0.2 ± 0.2 mm. These findings [69] may explain the degenerative changes often observed on the medial talus in patients with lateral CAI [65, 72, 73].

Bischof et al. [68] used three-dimensional MRI models and biplanar fluoroscopy to evaluate in vivo cartilage contact strains in patients with isolated lateral ankle instability. In total, seven patients were included in this study. The contralateral healthy side was used as a control to measure the magnitude and location of peak cartilage strain. The unstable ankles demonstrated significantly increased peak strain with 29 ± 8 % vs. 21 ± 5 %. Furthermore, the location of peak strain in the unstable ankles was translated anteriorly by 15.5 ± 7.1 mm and medially by 12.9 ± 4.3 mm. The authors found a correlation between the translation of peak strain and the location of clinically observed degenerative changes of the tibiotalar joint [68].

Recently, Golditz et al. [70] investigated the impact of functional ankle instability on the development of early cartilage damage using quantitative T2-mapping MRI. In total, 36 patients were included, and they were classified into one of three groups: functional ankle instability, ankle sprain “copers” (persons with initial sprains, but without residual instability), and controls (persons without a history of ankle injuries). The authors performed zonal region-of-interest T2-mapping of the deep and superficial layers of the talar and tibial cartilage. Significant to highly significant differences in T2-values in 11 of 12 regions were observed, demonstrating that functional instability causes substantially unbalanced loading in the tibiotalar joint. This, in turn, may result in early degenerative changes of the joint cartilage [70].

Valderrabano et al. [63] investigated the data from 30 patients (33 ankles) with ligamentous end-stage ankle OA. There were 23 male and seven female patients with a mean age of 58.6 years (33–78 years). Ligamentous lesions suffered during sports activities were the most frequent cause for ankle OA (55 %), followed by ankle sprains that occurred during normal daily activities (36 %), and sprains suffered at work (9 %). In 33 % of patients, the ankle injury occurred while playing soccer. In 28 ankles, the initial injury was a lateral ligament injury, in four ankles the medial ligaments were initially injured, and in one ankle a combined medial-lateral ligament injury was diagnosed. The overall mean latency time between the initial injury and development of ligamentous posttraumatic ankle OA was 34.3 years, with a range between 6 and 57 years. The survivorship rate for single ankle sprains was statistically worse than that for chronic recurrent sprains, with the average latency time of 25.7 and 38.0 years, respectively. Also, the survivorship rate for medial sprains was statistically worse than for lateral sprains with 27.5 and 35.0 years until the development of OA, respectively [63].

## Treatment Options for Ankle Osteoarthritis

In the current literature, numerous treatment options have been described for ankle OA. In general, surgical treatments can be divided into joint-preserving and joint-sacrificing procedures (Fig. 33.1). The surgical indications and the choice of treatment for patients with various stages of ankle OA is complex and requires adequate experience in foot and ankle surgery.

## Corrective Osteotomies

As mentioned above, the most common etiology for ankle OA is posttraumatic. Therefore, degenerative changes often develop asymmetrically with a concomitant varus or valgus deformity of the hindfoot [1, 6, 74, 75]. In patients with asymmetric ankle OA, a part of the tibiotalar joint remains preserved and free of degenerative changes. Thus, joint-sacrificing procedures like TAR or ankle arthrodesis may not be the most appropriate treatment options in this patient cohort [76]. In recent decades, realignment surgeries including supramalleolar osteotomies have evolved into valuable treatment options in patients with asymmetric ankle OA [77, 78]. The main indication for supramalleolar osteotomies is asymmetric ankle OA, with concomitant valgus or varus deformity, and a partially (at least 50 %) preserved tibiotalar joint surface [77–81] (Fig. 33.2). Recent literature demonstrates that the short- and mid-term results following realignment surgery are promising, with substantial pain relief and functional improvement observed postoperatively in the majority of patients [77, 78]. However, there is limited literature addressing the effect of corrective osteotomies on patients` ability to participate in sports activities.

Takakura et al. [82] performed valgus opening wedge supramalleolar osteotomies in nine patients with a mean age of 35 years (12–61 years) with posttraumatic varus deformity of the ankle. Osseous union occurred within two months in eight patients and after six months in one patient. At the

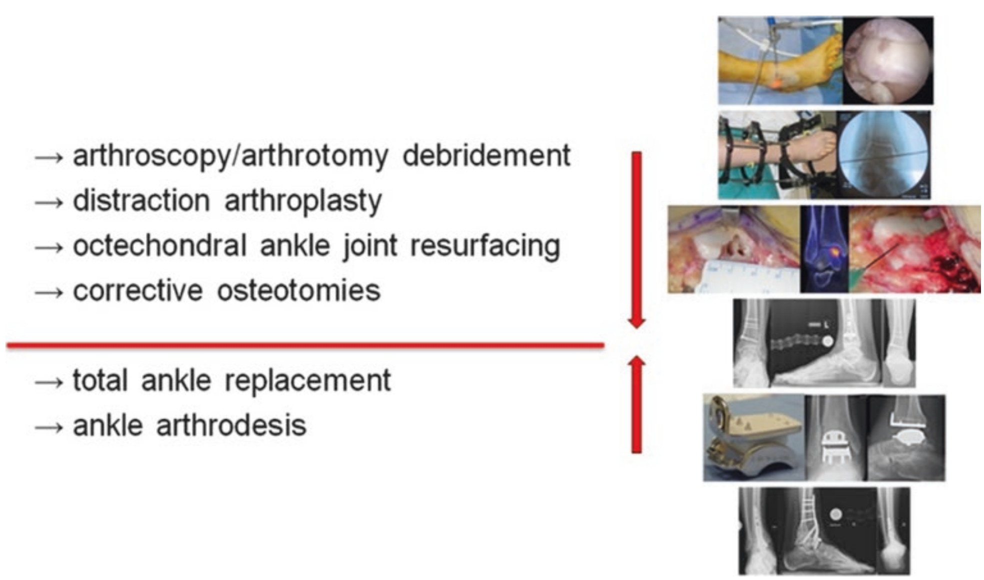


**Fig. 33.1** Stage-adapted treatment options of ankle osteoarthritis including joint-preserving procedures and joint-sacrificing procedures

mean follow-up of 7.3 years, the range of motion of the ankle decreased in six patients and remained the same in three patients. However, none of the patients reported any limitation in daily activities. Moreover, four adolescent patients were able to participate in sports activities at school [82].

Harstall et al. [83] performed supramalleolar lateral closing wedge osteotomies in nine patients between the ages of 21–59 years, with varus ankle OA. The etiology of disease was posttraumatic in eight and childhood osteomyelitis in one. At the mean follow-up of 4.7 years, significant pain relief (American Orthopaedic Foot and Ankle Society (AOFAS) pain subscore change from 16 ± 8.8 preoperatively to 30 ± 7.1 postoperatively) and significant functional improvement (AOFAS hindfoot score change from 48 ± 16.0 preoperatively to 74 ± 11.7 postoperatively) was observed. However, only three patients were able to perform sports activities as desired [83].


**Fig. 33.2** Supramalleolar realignment surgery. (**a**, **b**) An osteochondroma was diagnosed and resected in a 15 year-old female patient by pediatric orthopaedic surgeons. (**c**) Three years later, the patient developed a painful supramalleolar valgus deformity with a medial distal tibial angle [180] of 96°, substantial shortening of the fibula according to Weber´s criteria [221], and valgus position of the heel on the Saltzman hindfoot alignment view [222]. The patient complained of 7/10 pain on a visual analog scale and restriction of sports and daily activities. (**d**) A supramalleolar closing-wedge tibial osteotomy and a corrective lengthening osteotomy of the fibula were performed. At 6-months follow-up, the patient reported substantial pain relief (1–2 on a visual analogue scale)

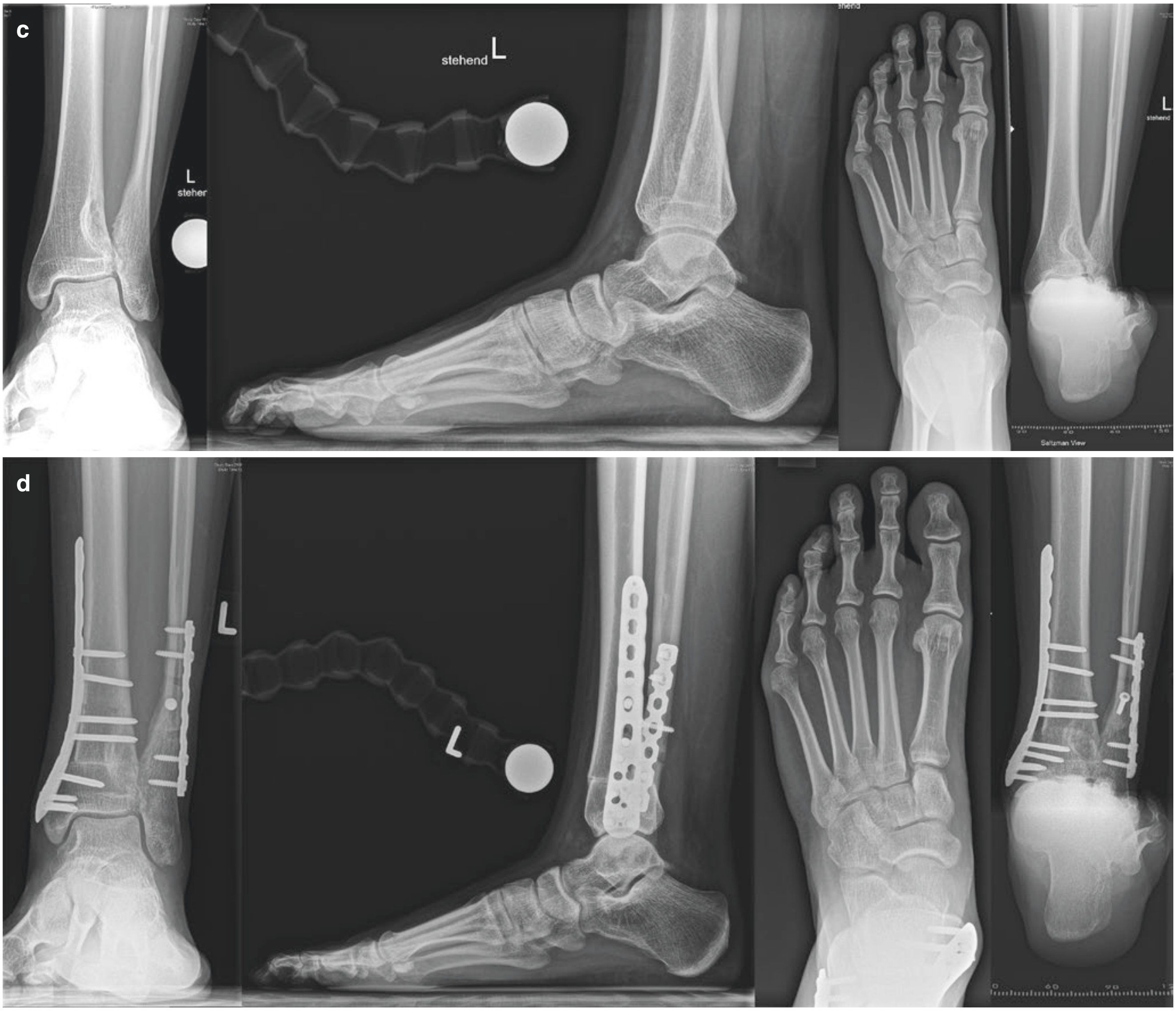


**Fig. 33.2** (continued)

Pagenstert et al. [84] analyzed a prospective case series of 35 consecutive patients with a mean age of 43 years (26–68 years) who underwent realignment surgery due to varus or valgus ankle OA. Significant pain relief (visual analog scale (VAS) change from 7 ± 1.6 preoperatively to 2.7 ± 1.6 postoperatively) and significant functional improvement (AOFAS hindfoot score change from 38.5 ± 17.2 preoperatively to 85.4 ± 12.4 postoperatively) were observed at the final follow-up of a mean of five years. The authors demonstrated that realignment surgery may increase sports activity (Sports Activity Level change from 1.3 ± 1.4 preoperatively to 1.8 ± 1.2 postoperatively, $p = 0.02$, and Ankle Activity Scale change from 25.7 ± 15 preoperatively to 68.1 ± 21 postoperatively, $p = 0.0001$). The types of sports activities that patients performed after realignment surgery were mostly low impact activities, like hiking, biking, swimming or golfing. However, jumping and running were reported as well. The rate of sports inactivity decreased from 43 % before surgery to 20 % at final follow-up. Actually, sports frequency in hours per week showed a weak and statistically insignificant correlation ($r = 0.34$, $p = 0.054$) with the symptom-related Ankle Activity Scale [84].

Hintermann et al. [85] performed a prospective study to analyze the outcome of 48 malunited pronation-external rotation ankle fractures treated by corrective supramalleolar osteotomy. At the mean follow-up of 7.1 years (2–15 years), patients reported significant pain relief (87.2 % of all patients were pain free and 12.8 % reported moderate pain with a mean VAS of 2.1 points) and significant functional improvement (AOFAS hindfoot score from 48 points [36–66] preoperatively to 86 points [64–100] postoperatively).

However, the preoperative and postoperative range of motion of the ankle was comparable at 41.2° (30°–50°) and 40.1° (30°–50°), respectively. In total, 43 patients (89.6 %) returned to their former professional activity, and 34 (70.8 %) returned to their former sport activities. However, 11 patients did not participate in sport prior to their initial injury [85].

Mann et al. [86] published a retrospective study describing the results of opening medial tibial wedge osteotomy (plafond-plasty) as a novel surgical option for treatment of intra-articular varus ankle OA. Nineteen consecutive patients were assessed clinically and radiographically at a mean follow-up of 4.9 years. In total, the varus ankle deformity significantly decreased from 18° preoperatively to 10° postoperatively. The AOFAS hindfoot score improved significantly from 46 points preoperatively to 78 points postoperatively. During the follow-up, four of 19 patients underwent revision surgery: two ankle arthrodeses at seven and 36 months after the index surgery, and two TARs at 30 and 48 months. At the latest follow-up, 12 patients reported participation in moderate sporting activities like biking, golfing, gym exercising, and skiing. Five of 19 patients, were active and were able to walk up to five miles daily. Two patients did not report any activities; both had procedure failure requiring ankle arthrodesis or TAR [86].

## Conclusion

In conclusion, promising short- and midterm results have been reported in patients who underwent supramalleolar realignment surgery. However, there is only one clinical study prospectively comparing the sport activity level in this patient group preoperatively and postoperatively [84]. It still remains unclear whether postoperative functional improvement positively correlates with sport activity level. Further clinical studies are needed to identify the positive and negative predictors for being active in sports and recreational activities.

## Total Ankle Replacement

While total hip replacement and total knee replacement have evolved to well-established treatment options in patients with end-stage degenerative changes, the indication for TAR remains controversial. TAR using current 3rd-generation prosthesis designs provides substantial postoperative pain relief and good functional outcome, including preserved range of motion [87–91]. However, the overall survivorship can be expected to be approximately 90 % at 5 years after initial implantation [92]. The failure rate of TAR is still substantially higher than that of total hip or knee replacement. Labek et al. [93] performed a systematic review, including national registries and clinical studies, demonstrating that the revision rate after TAR was 3.29 per 100 observed component years. This is significantly higher than after total knee replacement (1.26 revisions), medial unicompartmental replacement (1.53 revisions), or total hip replacement (1.29 revisions). The most common reasons for revision surgery after TAR were aseptic loosening (38 %), persisting pain syndrome (12 %), and septic loosening (9.8 %) [94].

Based on our experience with TAR [87, 88, 95–127], the ideal candidate for TAR is middle-aged or older, is reasonably mobile, has no significant comorbidities, participates in low impact physical activities (e.g. hiking, swimming, biking, golfing), is not obese or overweight, has good bone stock, and has no concomitant instabilities/deformities [88, 105] (Fig. 33.3). In our clinic, we still consider the need for high impact physical activities (e.g. contact sports, jumping) as a contraindication for TAR [88, 105]. However, there is limited evidence whether (1) the patients who underwent TAR are able to return to sport activities postoperatively and (2) postoperative sport activities can be identified as risk factors for TAR failure.

The clinical study by Pipino and Calderale [128] is the first clinical study mentioning sport activities in patients who underwent TAR. In this study from the year 1983, the 1st generation PC ankle prosthesis was used in 15 patients. The authors stated that one of 15 patients had started practicing sports after TAR [128].

The study by Valderrabano et al. [126] was the first study specifically analyzing participation in sports after TAR. In total, 147 patients (152 TARs) with a mean age of 59.6 years (28–86 years) were included in this prospective study. At the mean follow-up of 2.8 years (2–4 years) a significant functional improvement was observed in AOFAS hindfoot score (from 36 preoperatively to 84 postoperatively) and range of motion (from 21° (0°–45°) preoperatively to 35° (10°–55°) postoperatively). A special sports frequency score was developed to assess sports activity (Table 33.1). TAR resulted in significant increase of sports participation (36 % preoperatively to 56 % postoperatively). Sports-active patients had a significantly higher AOFAS hindfoot score than patients who did not participate in sports. The most commonly reported sports activities were hiking, biking, swimming, aerobics, downhill skiing, and golfing [126].

Naal et al. [129] analyzed the preoperative and postoperative participation in sports and recreational activities of 101 patients with a mean age of 59.4 years (24–85 years), at a mean of 3.7 years after TAR. The preoperative and postoperative percentage of sports-active patients was 62.4 % and 66.3 %, respectively. The patients were active in 3.0 ± 1.8 different sports and recreational activities preoperatively, and in 3.0 ± 1.6 activities postoperatively. The sports frequency remained the same, with 2.0 ± 1.6 sessions per week before


**Fig. 33.3** Total ankle replacement. (**a**) A 45-year old male patient with posttraumatic ligamentous ankle osteoarthritis. (**b**) At 1-year follow-up, the patient was pain free without any restrictions in sports or daily activities including cycling, golf, hiking, skiing, and tennis

**Table 33.1** Valderrabano's sports frequency score [126]

| Score | Definition |
|---|---|
| 0 (none) | no sports activity |
| 1 (moderate) | moderate level of sports activity in leisure time, <1 h/week |
| 2 (normal) | normal level of sports activity in leisure time, 1–5 h/week |
| 3 (high) | high level of sports activity in leisure time, > 5 h/week |
| 4 (elite) | professional level of sports activity, elite athlete |

TAR and 2.3 ± 1.7 sessions after TAR. However, 65 % of patients stated that the surgery substantially improved their sports ability. The University of California at Los Angeles activity scale improved significantly from 45.5 ± 16.6 to 84.3 ± 13.3. Neither sports participation nor activity levels were identified as risk factors for development of periprosthetic radiolucencies [129].

Bonnin et al. [130] evaluated function and return to sports after TAR in 140 patients who underwent TAR with the Salto total ankle prosthesis (noncemented, mobile bearing prosthesis) due to OA (100 patients) or rheumatoid arthritis (40 patients). At the mean follow-up of 4.5 years, the Foot Function Index scores were 13.7 ± 17 for "activity limitations", 31.7 ± 23 for "disability", and 16.9 ± 19 for "pain". The Foot and Ankle Ability Measurement scores were 74.9 ± 18 for activities of daily living and 48.9 ± 28 for sports activities. In the OA subgroup, 38 bicycled, 21 performed recreational gymnastics, 58 swam, 50 gardened, 27 danced, and 43 hiked. Seven patients played tennis, nine cross-country ski, 17 downhill skied, and six regularly ran more than 500 m. Most often, patients limited their sports activity for reasons independent of their ankle. Of the patients who had regular or intense sports activity, four mentioned substantial pain in their ankle during sports. In conclusion, the authors demonstrated that TAR may improve quality of life, and that return to recreational activities was generally possible. However, the return to high impact sport was rarely possible [130].

A prospective study has been performed by Barg et al. [99] to evaluate the mid-term outcome in eight haemophilia patients treated with TAR (10 TAR). At the mean follow-up of 5.6 years, significant pain relief and functional improvement was observed. Preoperatively, only one patient was able to participate in sport activities. However, at the latest follow-up, five patients had a normal level of sport activity and one patient had a moderate level [99]. Considering the unique hemophilic etiology of OA in this cohort, the postoperative increase in sport activities may have an especially positive effect, as it has been demonstrated that exercise may help reduce further joint destruction in haemophilia patients [131]. Another prospective study by Barg et al. [112] evaluated the feasibility of TAR in 18 patients with von Willebrand disease. Similar to patients with haemophilia, significant pain relief and functional improvement was observed at the mean follow-up of 7.5 years. Preoperatively, seven patients were moderately active in sports. At the latest follow-up, the postoperative sports activity level was moderate and normal in ten and seven patients, respectively [112]. The same group has evaluated the clinical and radiographic outcome in 16 patients with hereditary hemochromatosis who underwent TAR (21 procedures) [100]. At latest follow-up of 5.3 years in this prospective study, four of 19 patients had a normal level of sport activity and four of 19 patients had a moderate level. For comparison, preoperatively only two of 19 patients had a normal level of sport activity and two of 19 had a moderate level [100]. A similar increase in sport activity was observed in another clinical study addressing the outcome of TAR in 16 patients (19 ankles) with gouty arthritis [107]. Preoperatively, only one patient reported a moderate level of sport activity. Postoperatively, at a mean follow-up of 5.1 years, 13 patients reported participating in a moderate level of sport activity [107].

The outcome in 26 patients with simultaneous bilateral TAR has been analyzed by Barg et al. [102]. Significant pain relief and improvement in functional outcome and quality of life were observed at the mean follow-up of five years in this prospective study. Also, sport activity was assessed preoperatively and postoperatively using Valderrabano's score [126]. Preoperatively, five patients had a normal level of sport activity and three patients had a moderate level. At latest postoperative follow-up, eight patients had a normal level of sport activity, six patients had a moderate level, and one patient had a high level. One patient in the cohort had a reduced level of sport activity postoperatively (from normal to moderate) [102].

The component stability, weight change, and functional outcome was analyzed in 118 consecutive obese patients in the International Federation of Foot & Ankle Societies 2011 Award paper [104]. Preoperatively, 23 patients (19.5 %) reported a moderate level, 15 patients (12.7 %) a normal level, and one patient (0.8 %) a high level of sport activity. At the mean follow-up of 5.6 years (2.4–10.5 years), 61 patients (22.9 %) reported a moderate level, 29 patients (24.6 %) a normal level, and one patient (0.8 %) a high level of sport activity. A significant weight loss after one and two years of 1.6 ± 3.2 kg, and 2.1 ± 3.6 kg, respectively. Using a 5 % weight loss criterion, 14 patients (11.9 %) lost weight at one-year follow-up. Significant weight loss could be predicted by male gender, but not by age or, surprisingly, postoperative sport activity level [104].

Schuh et al. [132] compared the participation in sports and recreational activities in 21 patients with ankle arthrodesis and 20 patients with TAR. At the mean follow-up of 2.9 years of this prospective study, 86 % and 76 % of all patients were active in sports in the arthrodesis and TAR groups, respectively. Also, clinical and functional outcomes were comparable [132].

Criswell et al. [133] analyzed survival, overall reoperation rate, and functional outcome in 64 patients (65 ankles) who underwent TAR using the Agility prosthesis. Sixteen of the 41 patients (39 %) needed revision of at least one prosthesis component. At the median follow-up of 8 years (0.5–11 years), the average Foot and Ankle Ability Measure subscale scores for sports and daily living activities were 33 and 57 points, respectively. Thirty-three patients reported moderate to extreme difficulty with running, jumping, low impact activities, and the ability to participate in sports [133].

Dalat et al. [134] retrospectively evaluated two continuous series of 59 ankle arthroplasties and 46 ankle arthrodeses performed between 1997 and 2009. The mean follow-up was 4.4 and 4.8 years in TAR and ankle arthrodesis groups, respectively. The mean overall sports level was relatively low in both groups. However, patients who underwent TAR had significantly higher Foot Ankle Ability Measure sports scores with 49.5 ± 24.4 points vs. 29.8 ± 26.2 points. The most common sports in both patient cohorts were non-contact sports including cycling, swimming, and hiking [134].

Nodzo et al. [135] performed a retrospective study including 74 consecutive patients (75 ankles), with a mean age of 60.6 years (41–82 years), who underwent TAR using the Salto prosthesis. At the mean follow-up of 3.6 years, average dorsiflexion and plantarflexion significantly improved from 4.3° ± 3.3° to 8.7° ± 5.6° and from 24° ± 11° to 29° ± 7°, respectively. The subscales of the validated Foot and Ankle Outcome Score for sport activity and activity of daily living also improved significantly from 20 ± 12 to 55 ± 35 and from 50 ± 16 to 83 ± 22, respectively. Positive correlations between high patient satisfaction and the pain, activities of daily living, and quality of life scores were identified [135].

Braito et al. [136] analyzed clinical and radiographic outcomes in 84 patients who underwent HINTEGRA TAR at a mean follow-up of four years. The sports subscale of the Foot and Ankle Outcome Score improved significantly from 17.2 ± 15.4 points preoperatively to 45.8 ± 24.2 points postoperatively [136].

Recently, Kerkhoff et al. [137] analyzed short-term results in 67 patients who underwent primary TAR using the three-component Mobility prosthesis. The percentage of sports active patients was the same before and after surgery at 73 %. Six patients stopped their sports activities after surgery and six patients resumed some sports activities following TAR. The most common sports following TAR were cycling, hiking, and swimming. Although 73 % of all patients were sport active, 91 % were unable to run a short distance [137].

## Conclusion

In the last 25 years, TAR has progressed remarkably as a treatment option in patients with end-stage ankle OA [87, 88]. A prospective controlled trial comparing TAR with ankle arthrodesis demonstrated the superiority of TAR in postoperative pain relief and functional outcome [138]. However, the overall survivorship of TAR is still lower than total hip or knee replacement [93], with aseptic loosening being the most common reason for TAR failure [94]. In the current literature, it remains controversial whether patients with TAR have improved ability to participate in sport activities [126, 129, 130]. Also, the question of whether the patients with TAR are more sports-active than demographically comparable patients who underwent ankle arthrodesis cannot be answered definitively by the current literature. There is only one comparative study addressing participation in sports and recreational activities in patients who underwent either ankle arthrodesis or TAR, and it demonstrated no significant differences between groups [132]. However, both groups were small, with only 41 patients in total, and the mean follow-up was relatively short at 2.9 years [132]. Thus, the results of this study must be interpreted with caution.

In the current literature, there are no evidence-based findings that high level sport activity is associated with increased failure rate of TAR. Therefore, such activity should not be considered a contraindication for TAR. However, we recommend against performing TAR in patients with high demands or unrealistic expectations for physical activities [88, 105]. This is the most common recommendation in the literature, as it is supported by numerous studies [139–151]. However, we do not support suggestions that patients with any sports activities should be excluded from TAR, as stated by Giannini et al. [152].

## Ankle Arthrodesis

For decades, ankle arthrodesis has been considered the "gold-standard" treatment in patients with end-stage ankle OA, independent of the underlying etiology [153, 154]. Ankle arthrodesis was first described in the nineteenth century [155]. Since then almost 50 different surgical techniques have been described in the literature with good mid-term results: substantial pain relief and acceptable functional outcome [154, 156, 157] (Fig. 33.4). However, many clinical reports have described short-term and long-term problems following ankle arthrodesis in association with daily activities, including climbing stairs, getting out of a chair, walking on uneven surfaces, and running [158–161]. Another major long-term complication following ankle arthrodesis is development of degenerative changes in the adjacent joints, as reported by several authors [157, 160, 162–166]. The development of subsequent OA in adjacent joints may lead to additional fusion surgeries [157, 167]. OA development in adjacent joints can be partially explained by alterations in gait resulting in compensatory motion and overload in the neighboring joints [168]. There are numerous clinical studies investigating gait analysis in patients who underwent ankle arthrodesis. Hahn et al. [169] performed a comparative gait analysis of ankle arthrodesis and TAR. Substantial pain relief and functional improvement was demonstrated one year after both procedures. However, TAR resulted in more natural ankle joint function with increased range of motion [169]. A similar comparative study has been performed by Piriou et al. [170]. Three groups of 12 patients were analyzed: patients with ankle arthrodesis, patients with TAR, and controls. Clinically important differences were demonstrated, but neither TAR nor fusion restored normal movement or walking speed. Patients with ankle arthrodesis showed a faster gait with a longer step length, while patients with TAR had greater ankle range of motion, symmetrical timing of gait, and restored ground reaction force pattern [170]. Recently, Jastifer et al. [171] prospectively compared the performance of TAR and ankle arthrodesis on uneven surfaces, stairs, and inclines. Both groups demonstrated improved performance at one-year follow-up compared to preoperatively. However, TAR patients had higher functional scores than the ankle arthrodesis patients [171].

Regarding the possible development of subsequent OA in adjacent joints and alterations in gait after fusion, it remains unclear whether the patients with ankle arthrodesis are able to regain the ability to participate in sport. Also, there is no data on what effect sport activities may have on long-term outcome.

Mazur et al. [160] analyzed functional outcome and gait in 13 patients with ankle arthrodesis. This was a long-term study with a mean follow-up of 8.3 years. All but one patient were sports active at the latest follow-up, reporting activities

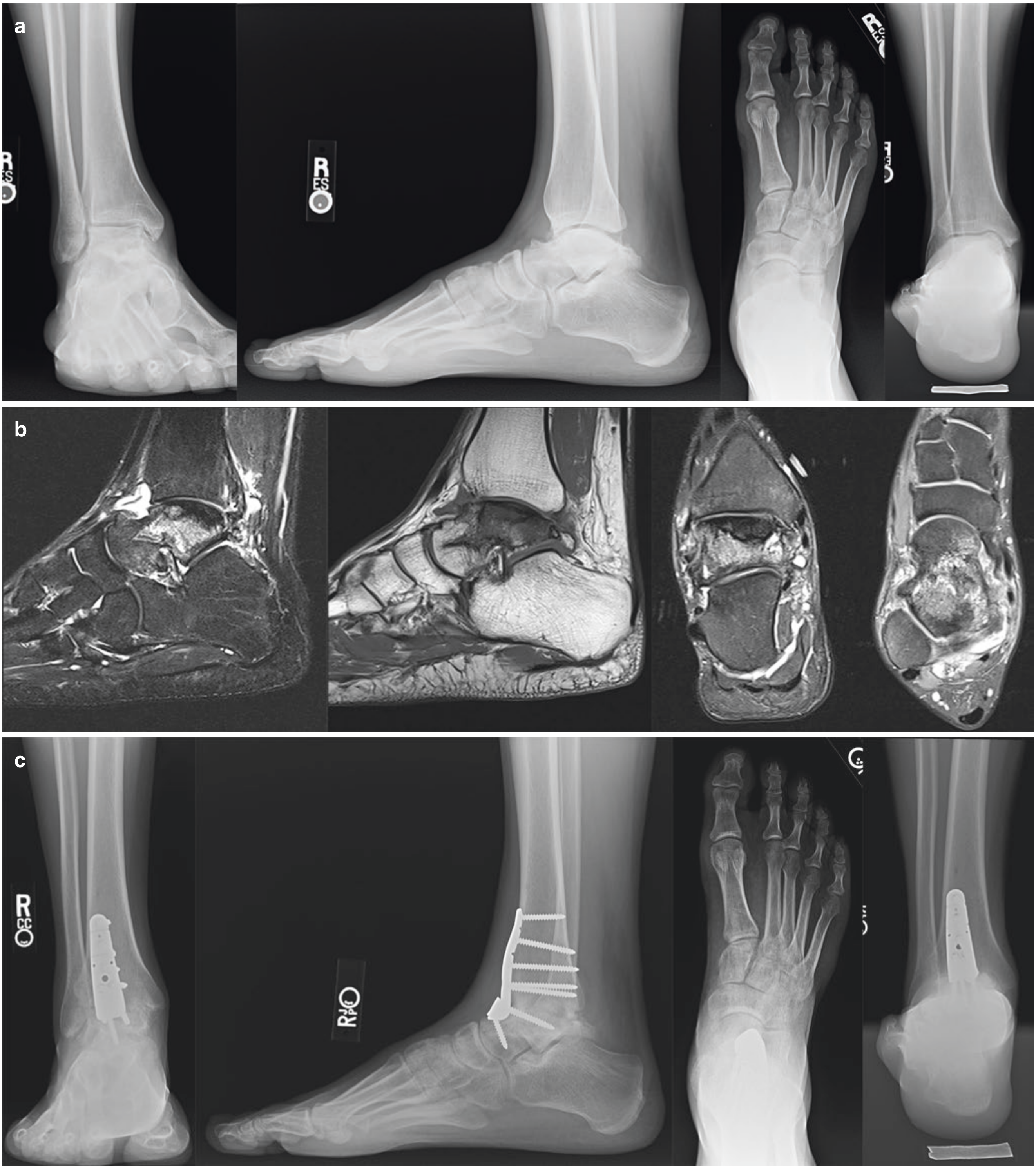


**Fig. 33.4** Ankle arthrodesis. (**a**) A 29-year old male with ankle osteoarthritis and significant pain due to avascular necrosis of the talus. (**b**) Magnetic resonance imaging demonstrates avascular necrosis of the talus with more than 50 % involvement. (**c**) At 1-year follow-up after arthrodesis, the patient had no pain and was able to regain his participation in sport and recreational activities including bowling, cycling, diving, fishing, golf, hiking, ice hockey, and skiing

like hunting, hockey, baseball, golf, swimming, bowling, skiing, and jogging. Ten of 13 patients were able to return to the recreational sports activities they performed before they developed ankle symptoms [160].

Lynch et al. [159] reported their long-term results in 39 patients with a mean age of 50 years who underwent ankle arthrodesis. At the latest follow-up of a mean of seven years, none of the patients were involved in high impact sports, and running activities were difficult for all but four younger patients who could run limited distances. Three of these four patients were able to participate in ice skating and ice hockey without any restrictions [159].

Thermann et al. [172] reported their results of 225 ankle arthrodeses performed between 1975 and 1995 using external fixation (44 patients) or screw fixation (225 patients). In total, 68 % of all patients were able to participate in sports activities (swimming and biking). Younger patients were also active in playing badminton and soccer, climbing (at a low level), and bodybuilding [172].

Vertullo and Nunley [173] used questionnaires sent to members of the American Orthopaedic Foot and Ankle Society and to trainers of professional basketball and American football teams and asked respondents for guidelines for sports participation after an ankle arthrodesis. The most recommended sport activities were golf, skiing, and tennis with 94 %, 77 %, and 38 % of respondents suggesting them. The authors stated that all high-impact sports should be avoided to minimize the development of adjacent joint OA and stress fractures [173].

Goebel et al. [174] performed a short-term prospective study including 29 patients who underwent tibiotalocalcaneal arthrodesis using a retrograde femur nail. At the mean follow-up of 2.1 years, complete osseous union was achieved in 90 % of patients. At the latest follow-up one fourth of all patients were sports active, whereas none of the patients were able to participate in their chosen sports before surgery [174].

Akra et al. [175] reported their results of 25 patients (26 ankles) treated with ankle arthrodesis using a transfibular approach over a five-year period. In this patient cohort, all patients who were involved in recreational sporting activities were able to return to their usual sports. However, the authors did not mention the percentage of sports active patients in their study [175].

## Conclusion

Ankle arthrodesis can be used as a safe surgical procedure for numerous indications in patients with end-stage ankle OA [153, 154, 156]. On one hand, it may provide acceptable mid-term results [154]. But, on the other hand, it may be associated with long-term complications including development of painful OA in the adjacent joints [163]. Similar to TAR, there is limited literature addressing patients' participation in sports postoperatively. In general, younger patients with ankle arthrodesis are able to participate in sports. However, there are no studies revealing positive or negative effects of sport activities on long-term clinical outcome and OA status in the neighboring joints. Nevertheless, in the current literature there is consensus that high impact sport activities should be avoided in patients who underwent ankle arthrodesis.

## Sports Activities in Patients Treated for Ankle Osteoarthritis

The most common etiology for end-stage ankle OA is posttraumatic [4, 5]. Therefore, it is not surprising that almost half of all patients with posttraumatic ankle OA present with a concomitant hindfoot deformity [6, 74, 75]. A direct correlation between the degree of hindfoot malalignment and degenerative process in the ankle joint has been described in the literature [176, 177]. Patients with substantial varus or valgus hindfoot deformity may develop asymmetric ankle OA [1]. Patients with posttraumatic asymmetric ankle OA are a challenging patient cohort, as they are often young and active. Furthermore, the complex underlying biomechanics of their concomitant deformities needs to be recognized and addressed [178]. The treatment of asymmetric ankle OA is also challenging because a substantial portion of the tibiotalar joint surface is usually preserved, and so joint-sacrificing procedures like TAR or ankle arthrodesis may not be the most appropriate treatment [77]. In the recently published review articles, realignment hindfoot surgeries have been shown to have promising short-term and mid-term results, with substantial pain relief and functional improvement [77, 78].

What can be said about sports participation in this specific patient group, who underwent hindfoot realignment, TAR, or ankle arthrodesis surgery? The literature addressing this specific topic is rare, indeed. As such, our recommendations are based on our experience with these surgical procedures over the last two decades [76–78, 80, 81, 84, 85, 178–193] (Table 33.2).

The next discussion point is represented by patients with complete end-stage ankle OA. Due to improved designs and overall survivorship of newer generation TAR systems, ankle arthrodesis should not be considered as the only "gold-standard" treatment option in patients with end-stage ankle OA. However, ankle arthrodesis still remains a proven procedure with good mid-term results, including substantial pain relief [153, 154, 156, 194–196] and acceptable functional outcome [166, 197]. Considering the survivorship of TAR, which is still lower than knee or hip replacement [93], young patients with end-stage ankle OA are better treated by ankle arthrodesis. In a previous study, we analyzed TAR survivorship in 684 patients and determined that age ≤70 years is a statistically significant and independent risk factor for TAR failure with an odds ratio of 3.85 (95 % CI 1.47–10.00) [111]. Literature addressing outcomes following TAR n younger

**Table 33.2** Our recommendations regarding sports activities (in alphabetic order) in patients who underwent realignment surgery, total ankle replacement, or ankle arthrodesis due to ankle osteoarthritis

| Sports activities | | Realignment surgery | Total ankle replacement | Ankle arthrodesis |
|---|---|---|---|---|
|  | Aerobics | Recommended | Recommended | Recommended |
|  | Athletic sports | Possible | Not recommended | Not recommended |
|  | Badminton | Recommended | Possible | Possible |
|  | Basketball | Possible | Not recommended | Not recommended |
|  | Beach volleyball | Possible | Not recommended | Not recommended |
|  | Bowling | Recommended | Recommended | Recommended |
|  | Chess | Recommended | Recommended | Recommended |
|  | Cross-country skiing | Recommended | Possible | Not recommended |
|  | Cycling | Recommended | Recommended | Recommended |
|  | Dancing | Recommended | Recommended | Recommended |
|  | Diving | Possible | Possible | Possible |
|  | Fishing | Recommended | Recommended | Recommended |
|  | Golf | Recommended | Recommended | Recommended |
|  | Gymnastics | Recommended | Possible | Possible |
|  | Handball | Possible | Not recommended | Not recommended |
|  | Hang gliding | Possible | Possible | Possible |
|  | Hiking, hillwalking | Recommended | Recommended | Recommended |
|  | Horseback riding | Possible | Not recommended | Possible |
|  | Hurdle race | Not recommended | Not recommended | Not recommended |
|  | Ice hockey | Possible | Not recommended | Possible |

(continued)

**Table 33.2** (continued)

| Sports activities | | Realignment surgery | Total ankle replacement | Ankle arthrodesis |
|---|---|---|---|---|
| | Ice skating | Possible | Not recommended | Possible |
| | Jogging | Possible | Not recommended | Not recommended |
| | Martial arts | Not recommended | Not recommended | Not recommended |
| | Mountain biking | Possible | Not recommended | Possible |
| | Muscle exercises | Recommended | Recommended | Recommended |
| | Nordic walking | Recommended | Recommended | Recommended |
| | Oarsmanship | Recommended | Possible | Possible |
| | Paragliding | Possible | Not recommended | Possible |
| | Rugby, American football | Not recommended | Not recommended | Not recommended |
| | Sailing | Recommended | Possible | Possible |
| | Skiing | Recommend | Possible | Possible |
| | Sledding | Possible | Not recommended | Possible |
| | Soccer | Not recommended | Not recommended | Not recommended |
| | Swimming | Recommended | Recommended | Recommended |
| | Table tennis | Possible | Possible | Possible |
| | Tennis | Possible | Possible | Possible |
| | Volleyball | Possible | Not recommended | Not recommended |
| | Water aerobics | Recommended | Recommended | Recommended |
| | Water skiing | Possible | Not recommended | Possible |
| | Weightlifting | Not recommended | Not recommended | Not recommended |
| | Windsurfing | Possible | Not recommended | Possible |

patients is rare. Kofoed and Lundberg-Jensen [145] compared survivorship and functional outcome of TAR between two groups consisting of 30 patients younger than 50 years and 70 patients aged 70 years or older. The postoperative results were comparable in both groups. However, the mean follow-up in both groups was six years with a wide range between one and 15 years [145]. The results of studies with short follow-up should be interpreted carefully. For example, several studies demonstrated encouraging results following TAR using the STAR prosthesis. These studies showed high prosthesis survivorship: 95 % at six years [198], 93.9 % at five years [199], and 96.0 % at five years [200]. However, a long-term TAR study by Brunner et al. [113] with a mean follow-up of 12.4 years (10.8–14.9 years) revealed the probability of implant survival was 70.7 % and 45.6 % at 10 and 14 years, respectively. The recent systematic literature reviews by Gougoulias et al. [92] and Zaidi et al. [91] demonstrated a five-year survivorship of 90 % and 10-year survivorship of 89 %, respectively. Based on results reported in the current literature, a 30 year old patient treated by TAR will most likely have revision surgery due to failure. A salvage procedure of failed TAR – conversion to ankle arthrodesis [201–205] or revision TAR [115, 120, 206, 207] – is a technically demanding procedure and may have worse results than the comparable primary procedure.

Biomechanical cadaver studies demonstrated that TAR may change the natural ankle joint kinematics and biomechanics. However, these changes are less than those observed in fused ankles [208–210]. Still, as mentioned before, patients with high to elite sports activities or unrealistic expectations should not be considered for TAR. Why might excessive sport activities have a negative influence on TAR? First, excessive sport activities and consecutive overload may dramatically change the joint contact pressures. Espinosa et al. [211] analyzed the influence of misalignment of total ankle components on joint contact pressures using finite element models. Two prosthesis types were compared in this in-vitro study: the highly congruent mobile-bearing design of the Mobility TAR and the less congruent two-component Agility TAR. It has been demonstrated, that the congruent mobile-bearing design resulted in more evenly distributed and lower-magnitude joint contact pressure. However, both designs were highly vulnerable to increased contact pressure induced by malalignment of prosthesis components [211]. It can be speculated that excessive sport activities may substantially worsen this problem. Another problem which may occur in excessively sports-active patients may be related to increased polyethylene insert wear or failure. It has been demonstrated that TAR generates wear particles similar to knee prostheses [212]. Increased polyethylene wear may cause periprosthetic osteolysis as a foreign-body reaction resulting in TAR failure, similar to failures observed in total hip replacement. Harris et al. [213] published a case report describing large wear debris cysts in a 65-year-old man who underwent TAR, and required revision surgery. Another complication is fracture of the mobile bearing, which may occur in up to 14 % of patients who undergo TAR using a three-component prosthesis design [87, 113, 214]. Sport activities at high level may increase the rate of this type of complication, although this is only speculation. Finally, periprosthetic fractures may be a specific problem in sports-active patients who undergo TAR. In the current literature, there are only few reports on this complication. The literature consists primarily of case reports [215–217] or short annotations within large TAR studies [218]. Recently, Manegold et al. [219] established a concise classification system of periprosthetic fractures in TAR and described their treatment algorithm based on data from 503 ankle replacements. In total, 21 patients (4.2 %) were identified with a periprosthetic fracture. Eleven and ten patients had intraoperative and postoperative fractures, respectively. The postoperative fractures included two traumatic cases and eight stress fractures. The authors did not mention how traumatic periprosthetic fractures occurred. However, high-energy sports, including contact sports, may be responsible for this difficult to treat complication [219].

Can all these problems be easily avoided by choosing ankle arthrodesis as a treatment option for end-stage ankle OA? Problems unique to TAR, like component loosening or failure of polyethylene inserts will not occur in patients who undergo ankle arthrodesis. However, other long-term problems in this patient cohort can occur. In a cadaveric study by Jung et al. [220] it was demonstrated that the tibiotalar joint arthrodesis significantly affected joint pressure distribution in the adjacent tarsal joints. This may explain the high incidence of OA in the adjacent joints following ankle arthrodesis [163, 165]. Further clinical studies need to be performed whether sports activities may accelerate the degenerative changes of the adjacent joints in patients who underwent ankle arthrodesis.

Based on our experience in foot and ankle surgery, we developed guidelines regarding sport activities in patients who underwent surgical treatments due to ankle OA (Table 33.2). We do believe that sports activities are part of an appropriate postoperative rehabilitation process in these patients. We encourage the patients to stay sports active or to regain their previous recreational activities. However, as Paracelsus stated in the sixteenth century, *Dosis sola facit venenum*. “The dose makes the poison": that means that even healthy sporting activities can be harmful it taken to excess. Every patient should keep in mind that he or she had ankle surgery in the past which may substantially lower the limits of their personal physical capacity. These limits should be respected, and not exceeded, in order to ensure good long-term results.

## Evidence

- Bonnin MP, Laurent JR, Casillas M. Ankle function and sports activity after total ankle arthroplasty. Foot Ankle Int 2009;30:933–44. Level of Evidence: III, Retrospective Case Control Study. *This study included 140 patients who underwent Salto total ankle replacement. Surgery improved their quality of life and return to recreational activities was generally possible, but return to impact sport was rarely possible* [130].
- Iosifidis MI, Tsarouhas A, Fylaktou A. Lower limb clinical and radiographic osteoarthritis in former elite male athletes. Knee Surg Sports Traumatol Arthrosc 2015;23:2528–35. Level of Evidence: III, Case–control Prognostic Study. *This case–control study included 218 former elite male athletes and 181 male controls. It showed that former elite athletes may not be at increased risk of developing clinical osteoarthritis. However, radiographic osteoarthritis signs had a significantly higher incidence in the athletes group* [18].
- Naal FD, Impellizzeri FM, Loibl M, Huber M, Rippstein PF. Habitual physical activity and sports participation after total ankle arthroplasty. Am J Sports Med 2009; 37:95–102. Level of Evidence: IV, Case Series. *The preoperative and postoperative percentage of sports-active patients was constant with two-thirds of the 101 patients included in this study. No association between sports participation, increased physical activity, or the appearance of periprosthetic radiolucencies was found at a mean follow-up of 3.7 years after TAR* [129].
- Pagenstert G, Leumann A, Hintermann B, Valderrabano V. Sports and recreation activity of varus and valgus ankle osteoarthritis before and after realignment surgery. Foot Ankle Int 2008;29:985–93. Level of Evidence: II, Prospective Comparative Study. *This study demonstrated that hindfoot realignment surgery in patients with varus or valgus deformity substantially increased sports activity postoperatively. Improved ankle pain and function correlated with ability to perform activity without symptoms* [84].
- Saltzman CL, Mann RA, Ahrens JE, Amendola A, Anderson AB, Berlet GC, Brodsky JW, Chou LB, Clanton TO, Deland JT, DeOrio JK, Horton GA, Lee TH, Mann JA, Nunley JA, Thordarson DB, Walling AK, Wapner KL, Coughlin MJ. Prospective controlled trial of STAR total ankle replacement versus ankle fusion: Initial results. Foot Ankle Int 2002; 23:68–74. Level of Evidence: II, Prospective Controlled Comparative Surgical Trial. *The only available prospective controlled trial addressing the safety and efficacy of total ankle replacement versus ankle fusion to treat end-stage ankle osteoarthritis. At 2-years follow-up, patients treated with total ankle replacement had better function and equivalent pain relief as patients treated with fusion* [138].
- Schuh R, Hofstaetter J, Krismer M, Bevoni R, Windhager R, Trnka HJ. Total ankle arthroplasty versus ankle arthrodesis. Comparison of sports, recreational activities and functional outcome. Int Orthop 2012; 36:1207–14. Level of Evidence: II, Prospective Comparative Study. *This study included 21 patients with ankle arthrodesis and 20 patients with total ankle replacement. It revealed no significant difference between groups concerning activity levels, participation in sports activities, or functional scores* [132].
- Valderrabano V, Horisberger M, Russell I, Dougall H, Hintermann B. Etiology of ankle osteoarthritis. Clin Orthop Relat Res 2009; 467:1800–6. Level of Evidence: IV, Prognostic Study. *In this study, the distribution of etiologies leading to ankle arthritis in 406 ankles was analyzed. Ankle osteoarthritis developed secondary to trauma in 79%. The traumas were mostly malleolar fractures, ligament lesions, and tibial plafond fractures* [4].
- Valderrabano V, Pagenstert G, Horisberger M, Knupp M, Hintermann B. Sports and recreation activity of ankle arthritis patients before and after total ankle replacement. Am J Sports Med 2006; 34:993–9. Level of Evidence: IV, Case Series. This is *the first clinical study addressing participation in sports after total ankle replacement. There was a significant increase in sports activity after total ankle replacement, with sports-active patients having better functional outcome than patients who did not participate in sports activities* [126].

## Summary

- Ankle OA is a debilitating disease and a growing problem in health care worldwide.
- Unlike the hip and knee, the ankle is most commonly affected by posttraumatic OA following fractures or ligament injuries.
- In the current literature, there is a controversial discussion whether sport activities play a positive or negative role in the development of ankle OA.
- In patients with ankle OA, numerous treatment options have been described, including joint-preserving and joint-sacrificing procedures.

- There is limited literature addressing participation in sports in patients who underwent surgical procedures due to ankle OA. In general, low impact sports can be recommended postoperatively. Further clinical studies are needed to define the role of sport in postoperative rehabilitation and to determine whether excessive sports activity is a risk factor for failure or worse outcomes.

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