Foot and Ankle Surgery 25 (2019) 19–23

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

Infections in primary total ankle replacement: Anterior approach versus lateral transfibular approach

Federico Giuseppe Usuelli[a,*], Cristian Indino[a], Camilla Maccario[a,b], Luigi Manzi[a], Federico Maria Liuni[c], Ettore Vulcano[d,e]

[a] IRCCS Istituto Ortopedico Galeazzi, Milan, Italy
[b] Università degli Studi di Milano, Milan, Italy
[c] Department of Orthopaedics and Traumatology, Santa Maria Hospital, Borgo Val di Taro (PR), Italy
[d] Foot and Ankle Surgery, Limb Lengthening and Reconstruction, Mount Sinai West, New York, USA
[e] Leni & Peter W. May Department of Orthopaedic Surgery, Icahn School of Medicine at Mount Sinai, New York, USA

ARTICLE INFO

Article history:
Received 15 January 2017
Received in revised form 18 July 2017
Accepted 25 July 2017

Keywords:
Arthritis
Periprosthetic joint infections
Ankle arthroplasty

ABSTRACT

Background: Total ankle replacement (TAR) represents an alternative to fusion for the treatment of end-stage ankle osteoarthritis. The aim of the present study was to retrospectively assess the frequency of infections between TARs with anterior and lateral transfibular approach at 12-months follow-up.
Methods: 81 TARs through an anterior approach and 69 TARs through a lateral approach were performed between May 2011 and July 2015. We compared surgical time and tourniquet time, as well as superficial and deep infections frequency during the first 12 postoperative months.
Results: In the anterior approach group, there were 3 (3.7%) deep infections and 4 (4.9%) superficial wound infections. In the lateral approach group, there were 1 (1.4%) deep infection and 2 superficial wound infections (2.9%). There were not statistically significant differences between the groups. There was a significant difference between anterior approach (115 minutes) and lateral approach group (179 minutes) in terms of surgical time ($P < 0.001$).
Conclusions: The frequency of superficial and deep periprosthetic infections during the first postoperative year was not significantly different in the lateral approach group compared to the anterior approach group, despite the significantly longer surgical time in the lateral transfibular approach group.

1. Introduction

End stage ankle osteoarthritis (OA) is a disabling condition that can severely impact patients' quality of life, especially given their younger age and greater activity level compared to their knee/hip OA counterpart [1,2].

Ankle arthrodesis has traditionally been the treatment of choice for patients affected by end-stage ankle arthritis although total ankle replacement (TAR) has gained growing popularity over the last decade [2]. The latest generations of TARs have demonstrated good function as well as lower complications rate compared to earlier implant designs [1,3,4].

The reported frequency of periprosthetic joint infections following TAR ranges from 2% to 8.6% [5–9]. They may result in implant failure, more than one revision surgery, salvage arthrodesis, and below knee amputation [10–14]. Deep periprosthetic joint infection has been classified as a high-grade complication due to the high rate of consequent implant failure: prevention, early diagnosis and treatment of any wound infection are the keys to prevent negative outcomes [10,13,15,16].

The anterior approach may be associated with a risk of wound complications ranging from 2% to 40% [17–19]; superficial and deep peroneal nerve, and anterior tibial artery are also at risk with anterior approach [20].

One of the most recent TARs to be introduced requires implantation through a lateral transfibular approach [20]. Potential advantages of the lateral approach include: low risk of wound complications thanks to a preservation of the blood supply to the skin and a preservation of the distal leg and ankle angiosomes, leading to less vascular disruption [21] (Fig. 1); bone stock preservation thanks to limited bone resections [20]; easier identification of the anatomic center of rotation and the possibility to address coronal plane deformities without substantial release or reconstruction of the deltoid ligament [22].

* Corresponding author at: IRCCS Istituto Ortopedico Galeazzi, Via Riccardo Galeazzi 4, 20161 Milan, Italy.
E-mail address: fusuelli@gmail.com (F.G. Usuelli).

http://dx.doi.org/10.1016/j.fas.2017.07.643
1268-7731/

Fig. 1. Surgical incision for total ankle replacement through lateral transfibular approach.

The purpose of this study is to retrospectively compare the frequency of superficial and deep infections between TARs performed through an anterior approach and TARs performed through a lateral transfibular approach at 12-months follow-up.

2. Materials and methods

The study was approved by the Local Ethics Committee as the protocol TARUS (66/INT/2016). We retrospectively reviewed all patients who underwent a TAR at the authors' institution. This included one-hundred and fifty (150) primary TARs (150 patients) performed between May 2011 and July 2015 with at least 1-year follow up. Only primary TARs were included in this study; patients were excluded if they underwent a revision TAR procedure. Neuropathic arthropathy, neuromuscular disorders, acute infectious arthritis, and avascular necrosis of the talus involving greater than 50% of the bone were considered contra-indications for TAR [23]. A 3-component uncemented implant (Hintegra, Newdeal SA, Lyon, France) was used in 81 TARs (54%) through an anterior approach. A 2-component uncemented implant (Zimmer Trabecular Metal Total Ankle, Zimmer, Warsaw, IN), was implanted in 69 TARs (46%) through a lateral transfibular approach.

The mean age in anterior approach group was 55 years (range, 22–79 years), and 51 years (range, 21–77 years) in lateral approach group. Indications for TAR included posttraumatic OA in 118 patients (79%) and rheumatoid arthritis in 8 patients (5%). The other diagnoses were primary OA (7 patients, 5%), ankle instability-related OA (7 patients, 5%), clubfoot sequelae (5 patients, 3%), septic OA sequelae (3 patients, 2%), and tarsal coalition (2 patient, 1%).

Tourniquet time, operative time, and superficial and deep infections were recorded for each patient up to the 1-year follow-up.

2.1. Surgical technique and management

Each procedure was performed by an orthopedic foot and ankle surgeon (the Senior Author) with extensive TAR experience. All prostheses were implanted using the manufacturer's described technique [24,25]. In the anterior approach group a mobile-bearing three components TAR was implanted. In the lateral approach group a two components fixed-bearing system was implanted through a lateral transfibular approach. The latter required a distal fibula osteotomy fixed with plate and screws at the end of the procedure. At the time of surgery, any additional procedure required to achieve a balanced implant was performed by the surgeon. Antibiotic prophylaxis included 2 g of intravenous cefazolin preoperatively. Patients with a higher risk of developing infections (body mass index of 30 or greater, use of steroids, malignancy, smoking, diabetes, immunosuppression, and surgery time greater than 3 h) also received 1 g intravenous every 8 h for 24 h postoperatively. Patients with poorly controlled diabetes, recent (last 12 months) ankle surgery, previous open fractures, or long hospitalizations in the last 12 months also received 1 g of intravenous vancomycin preoperatively.

All patients were clinically and radiographically evaluated postoperatively at two, six and twelve months.

2.2. Infection evaluation

The diagnosis of superficial or deep infection was made by an interdisciplinary team composed by an orthopedic surgeon (the Senior Author), an infectious diseases specialist and a plastic surgeon. The postoperative management was the same in both groups: all patients were placed into a short leg cast – with an anterior or lateral window to enable wound inspection and wound dressings – for 4 weeks. They were restricted to non-weight bearing for 4 weeks. The wound dressings were performed daily during the hospital stay and, afterward, every two days by a nurse or the general practitioner. On postoperative day 15 the wound was inspected through the window by the Senior Author. If the wound edges were dry, intact and without erythema, the sutures were removed. The patients were allowed to weight bear as tolerated at 4 weeks postoperatively using a walker-boot for further 2 weeks. At 6 weeks, patients started a rehabilitation program, including stretching of the triceps surae, calf strengthening, and proprioception [25].

If the wound showed signs of drainage, erythema, or other signs of delayed healing, the sutures were left in place and the patients were evaluated by the infectious diseases specialist. After further 2 weeks, if the wound failed to heal the patients were evaluated by a plastic surgeon to collaboratively plan the treatment with either local wound care versus operative management.

Superficial wound infections were classified as a dehiscence, eschar, or wound drainage (Fig. 2) according to criteria of the Centers for Disease Control and Prevention for surgical wound infection [26,27]. This states that an infection occurring within 30 days after the surgery must be associated with at least 1 of the following: (1) purulent drainage from the incision; (2) organisms isolated from an aseptically obtained culture from the incisional fluid or tissue; (3) at least 1 of the following signs or symptoms: pain or tenderness, erythema, localized swelling, heat, superficial incision that is deliberately opened by surgeon, unless culture of incision is negative; or (4) a diagnosis of surgical site infection by an attending physician.

The clinical signs of deep infection included pain, erythema, warmth, sinus tract, and/or abscess around the wound. Definitive diagnosis was made with at least one of the following findings: growth of the same organism in at least two cultures of synovial fluid, peri-prosthetic tissue and/or sonicated fluid collected intraoperatively; intraoperative finding of pus in/around the joint; abnormal acute inflammation markers (complete blood count, ESR, CRP); histopathological signs of inflammation (>5 neutrophils/high-power field); a sinus tract directly communicating with the implant. Deep infections were classified according to Fitzgerald's classification: acute postoperative (within three months after the surgery); deep late infections (between three months and two years after the surgery); late hematogenous infections (more than two years after the surgery,

Fig. 2. Superficial infection 2 months after total ankle replacement through lateral approach that was treated with oral antibiotic and fibular hardware removal. It progressed into a deep infection that was treated with removal of the implants and insertion of antibiotic-impregnated cement spacer.

not included in this paper because of the follow-up shorter than two years) [28].

2.3. Statistical analysis

The statistical analysis was performed by a statistical software (Matlab version 2008, MathWorks, Natick, MA, USA). We compared the frequency of superficial and deep infections between the two groups using the Fisher exact test. We compared the operative time between the groups using the ANOVA test and the Kolmogorov–Smirnov test confirmed the normality of the distribution of the data [29,30]. Then, the Fisher–Snedecor F-test was used to verify the equality of variances.

Confidence intervals were defined at 95%. All statistical tests were considered significant with P-value < 0.05.

3. Results

Tourniquet was used in all the primary TARs of the anterior approach group. It was inflated prior to skin incision and deflated immediately after skin closure. The mean operative and tourniquet time was 115 min (range, 65–150 min). In the same group, 20 (25%) patients underwent at least one concurrent surgical procedure at the time of TAR. The 2 most commonly performed procedures were percutaneous Achilles tendon lengthening (7 patients), and subtalar arthrodesis (4 patients) [31].

In the anterior approach group, there were 4 (4.9%) superficial wound infections that consisted of a dehiscence in 3 patients and a wound drainage in 1 patient. They were all treated with oral antibiotic therapy. In one patient the wound dehiscence resulted in prolonged tibialis anterior tendon exposure not-responsive to non-operative therapy that required a tibialis anterior tenotomy: this went to skin healing without any further surgery. Two of the patients with a superficial wound infection developed a deep infection.

Overall, there were 3 (3.7%) deep infections in the anterior approach group (Fig. 3). One patient was successfully treated with culture-specific intravenous antibiotics for 6 weeks and vacuum assisted closure (VAC). However, the other two patients required surgical revision: removal and replacement of the tibial component and polyethylene liner in one patient; debridement, polyethylene exchange, and VAC treatment in the other.

In lateral approach group tourniquet was used in 25 patients (36%) with a mean tourniquet time of 57 min (range, 10–169 min). The tourniquet was only inflated for the accessory procedures. Fibular osteotomy is part of the surgical technique, thus not representing an accessory procedure. The mean operative time was 179 min (range, 105–333 min). The most commonly performed concurrent procedures were subtalar arthrodesis (10 patients) and percutaneous Achilles tendon lengthening (5 patients).

In the lateral approach group, there were 2 superficial infections (2.9%) that consisted of a wound drainage in 1 patient and a dehiscence in the other one (Fig. 2). They were treated with oral antibiotic treatment and fibular hardware removal (2 months after the TAR surgery in both patients). One patient also required skin flap coverage. One of these patients with a superficial infection developed a deep infection.

Overall, there was 1 deep infection (1.4%) in lateral approach group that was treated with removal of the implants and insertion of antibiotic-impregnated cement spacer.

Operative time was statistically different between anterior and lateral approach group, with a longer surgical time for the lateral approach group ($P < 0.001$).

Fig. 3. Deep infection 6 weeks after total ankle replacement through anterior approach that was successfully treated with intravenous antibiotic therapy and vacuum assisted closure (VAC).

Table 1
Isolated pathogens and treatment for deep infections following total ankle replacement.

Patient n.	Group	Type of infection	Pathogen	Treatment
01	Anterior approach	Acute postoperative	*Staphylococcus aureus* and *Stenotrophomonas maltophilia*	Intravenous antibiotic treatment + VAC treatment
02	Anterior approach	Late	*Streptococcus equisimilis*	Debridement + liner exchange + VAC treatment
03	Anterior approach	Late	*Psaeudomonas aeruginosa*	Intravenous antibiotic treatment + revision of tibial component and liner
04	Lateral approach	Late	*Staphylococcus aureus* and *Staphylococcus epidermidis*	Implants removal and antibiotic-impregnated cement spacer

Anterior approach group: patients treated with total ankle replacement through anterior approach. Lateral approach group: patients treated with total ankle replacement through lateral transfibular approach. Acute postoperative infection: infection that occurred within three months after the ankle replacement surgery. Late infection: infection that occurred between three months and two years after the ankle replacement surgery. VAC: vacuum assisted closure.

There was no statistically significant difference between the two groups in terms of superficial infections ($P = 0.687$), and deep infections ($P = 0.625$).

Demographics, infections, pathogens, and treatments of deep infections are summarized in Table 1.

Tourniquet time, number of patients in whom the tourniquet was used, operative time and number of patients in whom accessory procedures were performed are summarized in Table 2.

4. Discussion

In this study, the frequency of superficial and deep infections was retrospectively compared between TARs performed through either an anterior approach or a lateral transfibular approach at 12-months follow-up. Superficial and deep periprosthetic infections frequency during the first postoperative year was not significantly different between the lateral and the anterior approach group, despite the significantly longer operative time in the lateral approach group.

We did not consider septic osteoarthritis sequelae as a contraindication to TAR. Other studies also recommended TAR in patients with ankle OA secondary to a previous infection [32,33]. In our series, patients with a history of septic OA did not develop any infectious complication.

Few level III studies have evaluated infection rate, management, and outcome in TAR registries or single cohorts [14–16]: a retrospective case series reported that the anterior approach is susceptible to wound healing problems and higher infection rates and a systematic review on 7942 TARs reported a superficial wound infection frequency of 2.4% and deep infection frequency of 1.1% [16,34]. In the present study, the superficial wound infection frequency was 4.9% in the anterior approach group and 2.9% in the lateral approach group. Deep infections frequency was 3.7% and 1.4% in anterior and lateral approach group, respectively. Statistical analysis of the data did not reveal any significant difference between the two groups. This data supports the safety of the lateral approach in terms of infections frequency, despite a significantly longer surgery time.

Some authors reported a frequency of wound complications ranging from 20% to 28% following TARs performed through the anterior approach [35,36]. The authors did not distinguish infectious complications from delayed wound healing, which possibly explains the higher complication frequency compared with the superficial wound infections in the present study. They hypothesized that the anterior aspect of the ankle heals slowly and mobilization of the anterior tibial neurovascular bundle, necessitated by the exposure, may contribute to the incidence of complications [35].

In a prospective controlled trial that compared TAR through anterior approach and ankle fusion [37], the wound problems occurrence was 20.9% as site adverse event and 3.2% as major complication while the infections occurrence was 4.4% as site adverse event and 1.3% as major complication: this is somewhat similar to the data in the present study. In the same study, the authors also concluded that the anterior approach is associated with a higher rate of sensory nerve dysfunction, wound problems, and soft tissue edema compared to the lateral approach used in the fusion group of the study [37].

In another series of 100 consecutive TARs implanted through an anterior approach the deep wound infection frequency and the wound complications frequency were comparable to our results (4% and 6% respectively) [38].

In a matched case-control study on 26 periprosthetic ankle infections, the authors reported that poor wound healing and wound drainage led to a 7–15-fold odds of developing periprosthetic joint infection [7]. These findings are consistent with the present study, in which 3 out of 4 periprosthetic joint infections followed a superficial infection.

Tourniquet time and prolonged operative time have also been found responsible for increased risk of a periprosthetic joint infections [6,10,23,39–41]. To the best of our knowledge there is no known operative time threshold that significantly increases the risk of TAR infection. A retrospective review of 6489 total knee replacements found that an operative time greater than 2.5 h was associated with an increased incidence of infection [42]. In the present cohort no difference was found in terms of superficial and periprosthetic infections frequency between the two groups despite a statistically significant difference in operative time. It is possible that the potential impact of the prolonged operative

Table 2
Relation between surgical approach for total ankle replacement and operative variables.

Variable	Anterior approach	Lateral approach
Tourniquet time (min)	115	57
Tourniquet (number of patients)	81 (100%)	25 (36%)
Operative time (min)	115	179
Concurrent surgical procedure (number of patients)	20 (25%)	25 (36%)

Anterior approach: patients treated with total ankle replacement through anterior approach. Lateral approach: patients treated with total ankle replacement through lateral transfibular approach. Data are reported as mean or number of patients (%).

time in lateral approach group was counteracted by the shorter use of tourniquet [7,41].

Guidelines have been proposed for the surgical treatment of hip and knee periprosthetic joint infections, including criteria for retention of the components [43]. However, hip and knee grading are too strict for periprosthetic joint infections of the ankle, due to the different thickness of the surrounding tissues, and correlation between bacterial load and inflammation [15]. A retrospective study on 19 cases of periprosthetic joint infections concluded that only a limited number of patients with infected TAR can expect to undergo successful joint-preserving revision ankle arthroplasty [16]. In accordance with the latter study we believe that early postoperative infections can be managed with retention of the components, while late chronic infections should be treated with surgical revision of the implants.

Limitations of the present study include its retrospective design, the small cohort and the short 1-year follow-up. Moreover, we compared two different implant designs and manufacturers so this could have influenced the results. Despite these limitations, the present study compared the frequency of infection between TARs implanted through two different surgical approaches: the lateral transfibular approaches and the anterior approach. It demonstrates a lower superficial and deep wound infections frequency in the lateral transfibular approach group compared to the anterior approach group. Nonetheless, this difference was not statistically significant. The significantly longer operative time in the lateral approach group did not seem to affect the infections frequency, possibly because of the significantly shorter use of the tourniquet.

In conclusion, TARs performed through a lateral approach appear to be as reliable as TARs done through an anterior approach in terms of the infections frequency within the first postoperative year. Further studies on larger cohorts and longer follow-up are essential to validate the findings from the present study.

Conflict of interest

Dr. Usuelli reports personal fees from Integra, grants and personal fees from Zimmer, outside the submitted work. Dr. Indino, Dr. Maccario, Dr. Manzi, Dr Liuni and Dr. Vulcano have nothing to disclose.

References

[1] Courville XF, Hecht PJ, Tosteson AN. Is total ankle arthroplasty a cost-effective alternative to ankle fusion? Clin Orthop Relat Res 2011;469:1721–7.
[2] Easley ME, Adams Jr. SB, Hembree WC, DeOrio JK. Results of total ankle arthroplasty. J Bone Jt Surg Am 2011;93-A:1455–68.
[3] Gougoulias NE, Khanna A, Maffulli N. History and evolution in total ankle arthroplasty. Br Med Bull 2009;89(1):111–51.
[4] Saltzman CL, Kadoko RG, Suh JS. Treatment of isolated ankle osteoarthritis with arthrodesis or the total ankle replacement: a comparison of early outcomes. Clin Orthop Relat Res 2010;2:1–7.
[5] Henricson A, Knutson K, Lindahl J, Rydholm U. The AES total ankle replacement: a mid-term analysis of 93 cases. Foot Ankle Surg 2010;16:61–4.
[6] Hurowitz EJ, Gould JS, Fleisig GS, Fowler R. Outcome analysis of agility total ankle replacement with prior adjunctive procedures: two to six year followup. Foot Ankle Int 2007;28:308–12.
[7] Kessler B, Sendi P, Graber P, Knupp M, Zwicky L, Hintermann B, et al. Risk factors for periprosthetic ankle joint infection: a case-control study. J Bone Jt Surg Am 2012;94-A:1871–6.
[8] Kitaoka HB, Patzer GL. Clinical results of the Mayo total ankle arthroplasty. J Bone Jt Surg Am 1996;78-A:1658–64.
[9] Lee KB, Cho SG, Hur CI, Yoon TR. Perioperative complications of HINTEGRA total ankle replacement: our initial 50 cases. Foot Ankle Int 2008;29:978–84.
[10] Clement ND, Breusch SJ, Biant LC. Lower limb joint replacement in rheumatoid arthritis. J Orthop Surg Res 2012;7:27.
[11] Ellington JK, Gupta S, Myerson MS. Management of failures of total ankle replacement with the agility total ankle arthroplasty. J Bone Jt Surg Am 2013;95(23):2112–8.
[12] Gadd RJ, Barwick TW, Paling E, Davies MB, Blundell CM. Assessment of a three-grade classification of complications in total ankle replacement. Foot Ankle Int 2014;35(5):434–7.
[13] Glazebrook MA, Arsenault K, Dunbar M. Evidence-based classification of complications in total ankle arthroplasty. Foot Ankle Int 2009;30(10):945–9.
[14] Patton D, Kiewiet N, Brage M. Infected total ankle arthroplasty: risk factors and treatment options. Foot Ankle Int 2015;36(6):626–34.
[15] Kessler B, Knupp M, Graber P, Zwicky L, Hintermann B, Zimmerli W, et al. The treatment and outcome of periprosthetic infection of the ankle: a single cohort-center experience of 34 cases. Bone Jt J 2014;96-B:772–7.
[16] Myerson MS, Shariff R, Zonno AJ. The management of infection following total ankle replacement: demographics and treatment. Foot Ankle Int 2014;35(9):855–62.
[17] Bleazey ST, Brigido SA, Protzman NM. Perioperative complications of a modular stem fixed-bearing total ankle replacement with intramedullary guidance. J Foot Ankle Surg 2013;52(1):36–41.
[18] Myerson MS, Mroczek K. Perioperative complications of total ankle arthroplasty. Foot Ankle Int 2003;24(1):17–21.
[19] Pyevich MT, Saltzman CL, Callaghan JJ, Alvine FG. Total ankle arthroplasty: a unique design. Two to twelve-year follow-up. J Bone Jt Surg Am 1998;80:1410–20.
[20] Tan EW, Maccario C, Talusan PG, Schon LC. Early complications and secondary procedures in transfibular total ankle replacement. Foot Ankle Int 2016;1(1):1–7.
[21] Femino JE, Vaseenon T. The direct lateral approach to the distal tibia and fibula: a single incision technique for distal tibial and pilon fractures. Iowa Orthop J 2009;29:143–8.
[22] Lamothe J, Deland J, Schon LC, Saltzman C, Herbst S, Ellis S. Total ankle replacement through a lateral approach. Tech Foot Ankle 2015;14:69–78.
[23] Usuelli FG, Maccario C, Manzi L, Gross CE. Posterior talar shifting in mobile-bearing total ankle replacement. Foot Ankle Int 2016;37(3):281–7.
[24] Barg A, Knupp M, Henninger HB, Zwicky L, Hintermann B. Total ankle replacement using HINTEGRA, an unconstrained, tricomponent system: surgical technique and pitfalls. Foot Ankle Clin 2012;17:607–35.
[25] Usuelli FG, Indino C, Maccario C, Manzi L, Salini V. Total ankle replacement through a lateral approach: surgical tips. SICOT J 2016;2:38, doi:http://dx.doi.org/10.1051/sicotj/2016029.
[26] Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. Infect Control Hosp Epidemiol 1992;13(10):606–8.
[27] Matsumoto T, Parekh SG. Use of negative pressure wound therapy on closed surgical incision after total ankle arthroplasty. Foot Ankle Int 2015;36(7):787–94.
[28] Fitzgerald Jr. RH, Nolan DR, Ilstrup DM, Van Scoy RE, Washington 2nd JA, Coventry MB. Deep wound sepsis following total hip arthroplasty. J Bone Jt Surg Am 1977;59(7):847–55.
[29] Cohen J. A coefficient of agreement for nominal scales. Educ Psychol Meas 1960;20:37–46.
[30] Hogg RV, Ledolter J. Engineering statistics. New York: MacMillan; 1987.
[31] Usuelli FG, Maccario C, Manzi L, Gross CE. Clinical outcome and fusion rate following simultaneous subtalar fusion and total ankle arthroplasty. Foot Ankle Int 2016;37(7):696–702.
[32] Eichinger S, Forst R, Kindervater M. Indications and alternatives for arthroplasty in young patients. Orthopade 2007;36:311–24.
[33] Espinosa N, Klammer G. Treatment of ankle osteoarthritis: arthrodesis versus total ankle replacement. Eur J Trauma Emerg Surg 2010;36:525–35, doi:http://dx.doi.org/10.1007/s00068-010-0058-1.
[34] Zaidi R, Cro S, Gurusamy K, Siva N, Macgregor A, Henricson A, et al. The outcome of total ankle replacement. Bone Jt J 2013;95-B:1500–7.
[35] Schuberth JM, Patel S, Zarutsky E. Perioperative complications of the agility total ankle replacement in 50 initial, consecutive cases. J Foot Ankle Surg 2006;45(3):139–46.
[36] Whalen JL, Spelsberg SC, Murray P. Wound breakdown after total ankle arthroplasty. Foot Ankle Int 2010;31(4):301–5.
[37] Saltzman CL, Mann RA, Ahrens JE, Amendola A, Anderson RB, Berlet GC, et al. Prospective controlled trial of STAR total ankle replacement versus ankle fusion: initial results. Foot Ankle Int 2009;30(7):579–96.
[38] Noelle S, Egidy CC, Cross MB, Gebauer M, Klauser W. Complication rates after total ankle arthroplasty in one hundred consecutive prostheses. Int Orthop 2013;37(9):1789–94.
[39] Berbari EF, Hanssen AD, Duffy MC, Steckelberg JM, Ilstrup DM, Harmsen WS, et al. Risk factors for prosthetic joint infection: case-control study. Clin Infect Dis 1998;27(5):1247–54.
[40] De Boer AS, Mintjes-de Groot AJ, Severijnen AJ, van den Berg JM, van Pelt W. Risk assessment for surgical-site infections in orthopedic patients. Infect Control Hosp Epidemiol 1999;20(6):402–7.
[41] Willis-Owen CA, Konyves A, Martin DK. Factors affecting the incidence of infection in hip and knee replacement: an analysis of 5277 cases. J Bone Jt Surg Br 2010;92(8):1128–33.
[42] Peersman G, Laskin R, Davis J, Peterson M. Infection in total knee replacement: a retrospective review of 6489 total knee replacements. Clin Orthop 2001;392:15–23.
[43] Zimmerli W, Trampuz A, Ochsner PE. Prosthetic-joint infections. N Engl J Med 2004;351:1645–54.