JB&JS OPEN ACCESS

Total Ankle Arthroplasty for Rheumatoid Arthritis in Japanese Patients

A Retrospective Study of Intermediate to Long-Term Follow-up

Makoto Hirao, MD, PhD, Jun Hashimoto, MD, PhD, Hideki Tsuboi, MD, PhD, Kosuke Ebina, MD, PhD, Akihide Nampei, MD, PhD, Takaaki Noguchi, MD, PhD, Shigeyoshi Tsuji, MD, PhD, Norihiro Nishimoto, MD, PhD, and Hideki Yoshikawa, MD, PhD

Investigation performed at Osaka University Graduate School of Medicine and National Hospital Organization, Osaka Minami Medical Center, Osaka, Japan

Background: Outcomes after total ankle arthroplasty (TAA) combined with additive techniques (augmentation of bone strength, control of soft-tissue balance, adjustment of the loading axis) for the treatment of rheumatoid arthritis were evaluated after intermediate to long-term follow-up. The influences of biologic treatment on the outcomes after TAA were also evaluated.

Methods: We performed a retrospective observational study involving 50 ankles (44 patients) that underwent TAA for the treatment of rheumatoid arthritis. The mean duration of follow-up was 7.1 years. Clinical outcomes were evaluated with use of the Japanese Society for Surgery of the Foot (JSSF) scale score and a postoperative self-administered foot-evaluation questionnaire (SAFE-Q). Radiographic findings were evaluated as well. These parameters also were compared between patients managed with and without biologic treatment.

Results: This procedure significantly improved the clinical scores of the JSSF rheumatoid arthritis foot and ankle scale ($p < 0.0001$). Forty-eight of the 50 ankles had no revision TAA surgery. Subsidence of the talar component was seen in 8 ankles (6 in the biologic treatment group and 2 in the non-biologic treatment group); 2 of these ankles (both in the biologic treatment group) underwent revision TAA. The social functioning score of the SAFE-Q scale at the time of the latest follow-up was significantly higher in the biologic treatment group ($p = 0.0079$). The dosage of prednisolone ($p = 0.0003$), rate of usage of prednisolone ($p = 0.0001$), and disease-activity score ($p < 0.01$) at the time of the latest follow-up were all significantly lower in the biologic treatment group.

Conclusions: TAA is recommended for the treatment of rheumatoid arthritis if disease control, augmentation of bone strength, control of soft-tissue balance, and adjustment of the loading axis are taken into account. The prevention of talar component subsidence remains a challenge in patients with the combination of subtalar fusion, rheumatoid arthritis, and higher social activity levels.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

In recent years, tight control of disease activity in patients with rheumatoid arthritis has been possible with use of biologic treatment and/or methotrexate. However, we often see patients who require surgical intervention for the treatment of progressive ankle joint destruction. Since 2003, we have been performing total ankle arthroplasty (TAA) rather than arthrodesis in order to maintain mobility of the ankle joint. Prosthesis edge-loading after TAA has been described as a frequent complication in ankles with a preoperative hindfoot deformity[1-3]. Deformities of the ankle joint associated with destruction of the hindfoot should be corrected prior to TAA. We also frequently observe periarticular osteopenia induced by joint inflammation. The technique of implantation of the prostheses and modifications for such issues is required in order to obtain sufficient fixation of the prostheses in patients with rheumatoid arthritis. We have been performing TAA with augmentation of bone strength with use of hydroxyapatite[4], soft-tissue balancing by means of malleolar osteotomy[5], and preoperative planning for

Disclosure: There was no external funding source for this study. The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSOA/A27).

adjustment of the loading axis of the ankle joint by checking the alignment of the entire lower extremity[6]. In the present study, we evaluated (1) the outcome of TAA combined with such techniques for the treatment of rheumatoid arthritis and (2) the influence of biologic treatment on the outcomes of TAA.

Materials and Methods

We performed a retrospective observational study of 55 consecutive ankles in patients with rheumatoid arthritis who received a mobile-bearing ankle prosthesis (FINE Total Ankle System; Teijin-Nakashima Medical) from January 2003 to February 2014. The mean duration of postoperative observation (and standard deviation) was 7.1 ± 3.3 years (range, 3 to 14 years). Five ankles (including 4 in patients who died and 1 in a patient who was lost to follow-up) were excluded from the study. Clinical and radiographic outcomes were evaluated for the remaining 50 ankles. All patients had rheumatoid arthritis with severe pain and gait

TABLE I Demographic Characteristics*

Age† *(yr)*	63.9 ± 8.7 (47 to 79)
Duration of disease† *(yr)*	19.3 ± 9.9
Duration of follow-up† *(yr)*	7.1 ± 3.3 (3 to 14)
Female:male ratio *(no. of patients)*	36:8
Height† *(cm)*	152.2 ± 8.4 (134 to 179)
Weight† *(kg)*	50.3 ± 9.8 (32.5 to 78.4)
BMI† *(kg/m²)*	21.7 ± 3.4 (15 to 28.2)
Steinbrocker classification[30]	
Stage *(no. of ankles)*	III (12), IV (38)
Functional class *(no. of ankles)*	I (3), II (23), III (22), IV (2)
DAS28-CRP score† *(points)*	
Preop.	2.86 ± 0.76
Latest follow-up	2.52 ± 0.74‡
Prednisolone dosage† *(mg/day)*	
Preop.	1.88 ± 2.6
Latest follow-up	1.67 ± 2.6
Prednisolone usage	
Preop.	48% (24 of 50)
Latest follow-up	40% (20 of 50)
Methotrexate usage	70% (35 of 50)
Biologics usage	
Preop.	46% (23 of 50)
Latest follow-up	52% (26 of 50)
Biologics used *(no. of ankles)*	Tocilizumab (14), infliximab (2), etanercept (1), adalimumab (2), golimumab (2), abatacept (5)
Previous surgery *(no. of ankles)*	Total (42 of 50), HHR (2), THA (14), TEA (13), TKA (33), TAA on contralateral side (6), cervical spine (4), lumbar spine (1), hindfoot (13), forefoot (8), wrist and hand (7)
Augmentation of tibia with hydroxyapatite	94% (47 of 50)
Concomitant malleolar osteotomy	40% (20 of 50)
Subtalar-talonavicular fusion *(no. of ankles)*	Ankylosing (16 [2 of 16, calcaneal osteotomy]), prior to TAA (13), simultaneous (9), none (12)
Lower limb surgery after TAA *(no. of ankles)*	Total (30 of 50), THA (2), TKA (7), TAA on contralateral side (8), hindfoot (2), forefoot (20)

*BMI = body mass index, HHR = humeral head replacement, THA = total hip arthroplasty, TEA = total elbow arthroplasty, TKA = total knee arthroplasty, TAA: total ankle arthroplasty. †The values are given as the mean and the standard deviation, with or without the range in parentheses. ‡Significantly different from preoperative score (p = 0.03).

disorder. The radiographic grade of ankle joint destruction was assessed with use of the method described by Larsen et al.[7]. All ankles were classified as grade 4 (complete loss of joint space) or grade 5 (periarticular bone loss). The patient characteristics are shown in Table I. At the time of surgery, 27 ankles were in patients who were not receiving biologic treatment. Of these 27 ankles, 3 were in patients who had been converted to biologic treatment within 1 year after TAA and had been observed for at least 3 years. Thus, in the present study, the non-biologic group included 24 ankles and the biologic group included 26 ankles at the time of the latest follow-up. This research was performed in compliance with the Helsinki Declaration and was approved by the Institutional Ethics Review Board of the Osaka University Hospital (approval number 14219) and the National Hospital Organization, Osaka Minami Medical Center (approval number 28-12). Informed consent was obtained from all patients.

Preoperative Planning

Preoperative planning was performed with use of the hip-to-calcaneus radiograph[6] (Fig. 1, panel A). First, the preoperative calcaneal tip and loading axis were identified. Second, the ideal loading axis was drawn (to make the axis pass the center of the distal plafond of the tibia). Finally, the angle created by the ideal loading axis and the line connecting the center of the plafond and the calcaneal tip was defined as the angle that totally corrected for the adjustment of the weight-bearing line in the ankle joint (Fig. 1, panel B, angle A). Next, the correction angle for tibial osteotomy was calculated. The angle between the distal tibial plafond and the perpendicular line to the long axis of the tibia was defined as the correction angle as the tibial osteotomy should be perpendicular to the long axis of the tibia (Fig. 1, panel C, angle B). Consequently, the angle that was calculated by subtracting angle B from angle A was defined as the angle that must be corrected by means of talar osteotomy. The concept of correction by means of talar osteotomy is based on the concept of the "talar sculpturing technique."[8]

Surgical Technique and Postoperative Procedure

Subtalar and/or Talonavicular Joint Arthrodesis Prior to TAA

In the 13 feet with hindfoot valgus deformity (as indicated by a tibiocalcaneal angle of >10°), correction and arthrodesis of the subtalar and/or talonavicular joint was performed prior to

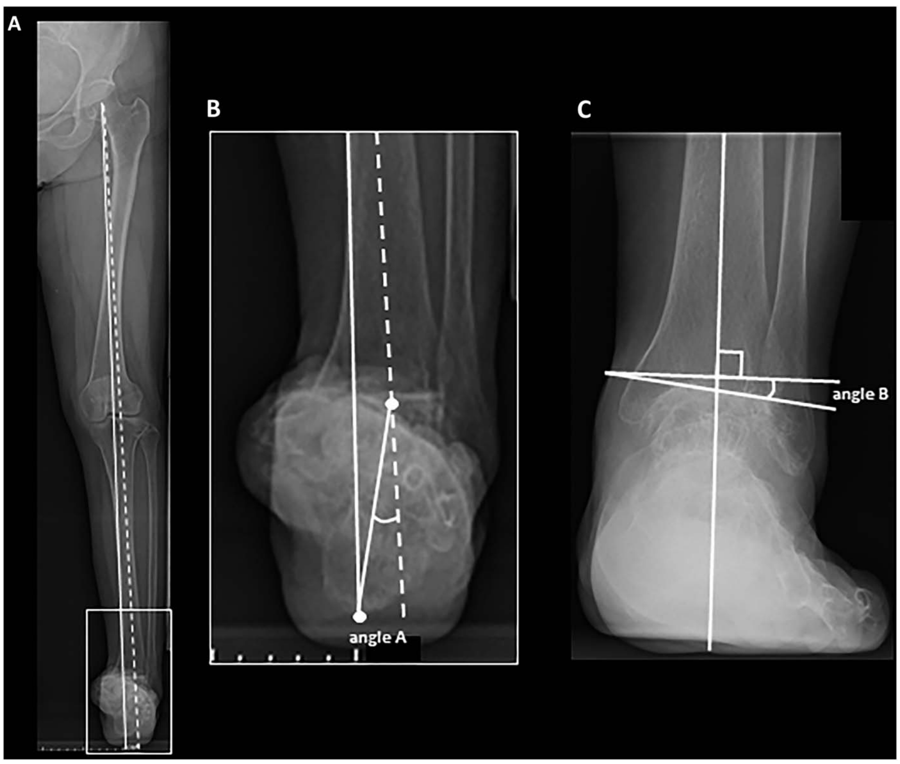

Fig. 1

Panels A through C: Preoperative radiographs used for TAA planning. **Panel A:** Hip-to-calcaneus radiograph. The solid line shows the preoperative calcaneal tip and loading axis. The dashed line shows the ideal loading axis, which passes through the center of the distal plafond of the tibia. **Panel B:** Enlarged radiograph of the ankle area as shown in Panel A. Angle A (created by the lines connecting the center of the plafond and the calcaneal tip and the ideal loading axis) is defined as the angle that must be totally corrected for the adjustment of the weight-bearing line in the ankle joint. **Panel C:** Anteroposterior weight-bearing radiograph of the ankle in the standing position. Angle B (the angle between the distal tibial plafond and the perpendicular line to the long axis of the tibia) is defined as the correction angle to be achieved through tibial osteotomy.

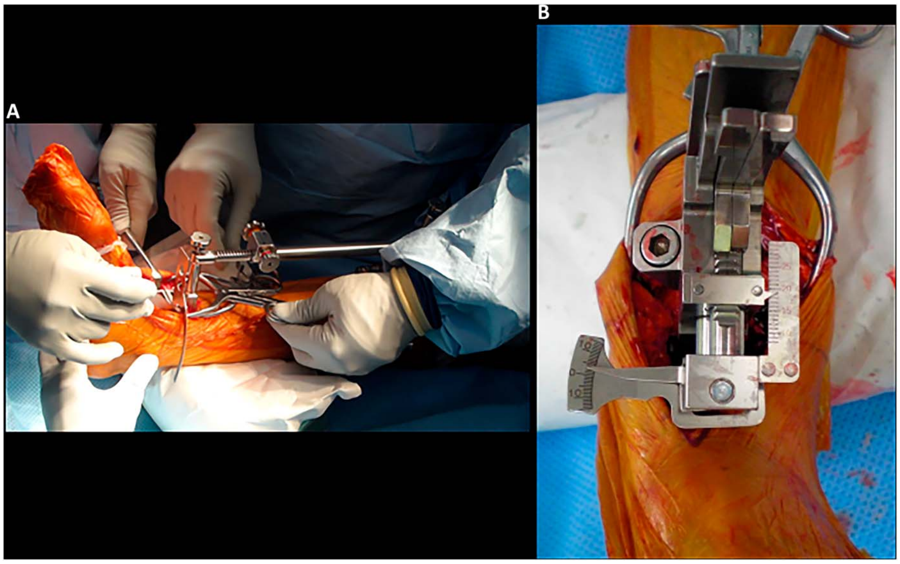

Fig. 2

Panels A and B: Intraoperative photographs showing devices used during the procedure. **Panel A:** The osteotomy guide for the tibia is similar to the tibial cutting guide that is used during total knee arthroplasty. This rigid guide is set up along the long axis of the tibial bone and is fixed with 2-mm Kirschner wires. The varus-valgus direction is adjustable in the coronal plane, and the inclination angle is adjustable in the sagittal plane. Alignment is checked with use of fluoroscopy. **Panel B:** The balancer is used after tibial and talar osteotomy. The space is spread to 18 mm (scale shown on the right side) because the minimum size of the spacer block in this prosthetic system is 17 mm. In this case, the gap of soft-tissue balance between the medial and lateral sides was 3° (scale shown on the left side) and a medial malleolar osteotomy was performed.

TAA. After the approach to the subtalar and/or talonavicular joint was performed, decortication and drilling was done. After correction of the valgus deformity, the osseous defect was filled with autologous bone, allograft bone, and/or hydroxyapatite and then the site was fixed with screws and staples. Postoperatively, the ankle was immobilized in a below-the-knee cast for 6 weeks and the patient remained non-weight-bearing for 8 weeks.

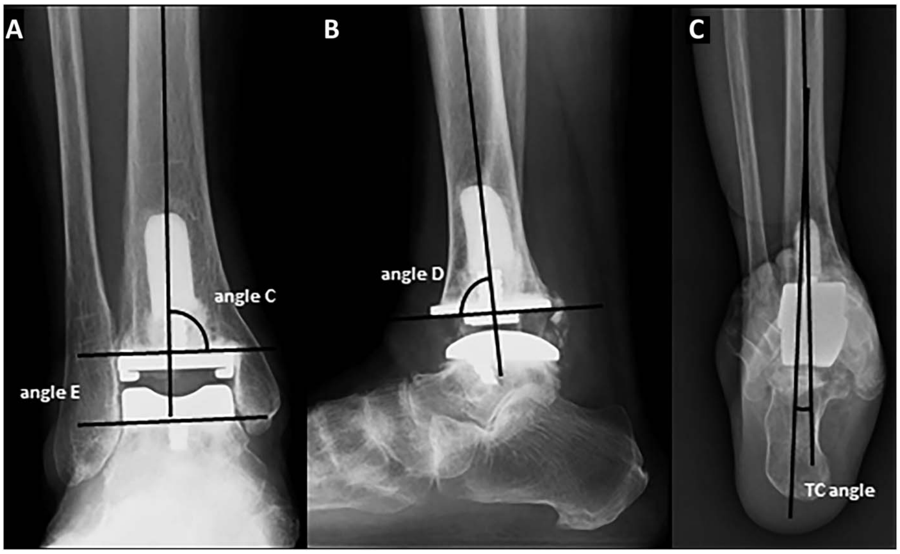

Fig. 3

Panels A through C: Postoperative radiographic parameters. **Panels A and B:** The postoperative angular position of the tibial component is defined as the angle between the base plate of the tibial component and the long axis of the tibia on both anteroposterior (angle C) and lateral (angle D) radiographs. The postoperative tilting angle between the tibial and talar components is defined as the angle between the base plates of the tibial and talar components (angle E). **Panel C:** The tibiocalcaneal angle (TC angle) is measured on the subtalar view.

TABLE II JSSF Rheumatoid Arthritis (RA) Foot and Ankle Scale Scores*

JSSF RA Foot and Ankle Scale Score	Preop.	Latest Follow-up	P Value
General pain (30 points)	7.45 ± 5.7	28.9 ± 3.1	<0.0001
Deformity (25 points)	11.5 ± 4.1	16.9 ± 4.1	<0.0001
Motion (15 points)	3.35 ± 2.2	7.3 ± 3.3	<0.0001
Walking ability (20 points)	5.44 ± 2.8	15.4 ± 5.0	<0.0001
Activities of daily living (10 points)	1.33 ± 1.0	3.3 ± 1.7	<0.0001

*The values are given as the mean and the standard deviation.

TABLE III Self-Administered Foot Evaluation Questionnaire (SAFE-Q) at Time of Latest Follow-up*

SAFE-Q Score	Score at Latest Follow-up
Pain and pain-related (100 points)	77.3 ± 15.9
Physical functioning and daily living (100 points)	51.3 ± 19.5
Social functioning (100 points)	51.7 ± 30.3
Shoe-related (100 points)	55.2 ± 25.7
General health and well-being (100 points)	65.9 ± 26.1

*The values are given as the mean and the standard deviation.

TAA

TAA was performed through an anterior approach. The tibial bone cut was performed to make the surface perpendicular to the long axis of the tibial bone. After the osteotomy guide had been set up (Fig. 2, panel A), the plane of the bone cut was checked with use of fluoroscopy. The talar cut was performed with correction according to the preoperative plan described above. The correction angle was produced by the difference between the amounts of talar bone removed medially and laterally. Subsequently, a malleolar lengthening osteotomy[5] was added with transplantation of autologous bone chips when the balance between the medial and lateral soft tissues was not acceptable. Briefly, soft-tissue balance

TABLE IV JSSF Rheumatoid Arthritis (RA) Foot and Ankle Scale and SAFE-Q Scale Scores for Non-Biologic and Biologic Treatment Groups

Clinical Outcomes Scales	Non-Biologic Treatment Group (N = 24)	Biologic Treatment Group (N = 26)	P Value*
JSSF RA Foot and Ankle Scale score			
Preop.			
General pain (30 points)	7.14 ± 5.61	7.69 ± 5.87	NS
Deformity (25 points)	10.6 ± 3.61	12.2 ± 4.44	NS
Motion (15 points)	3.38 ± 2.77	3.32 ± 1.63	NS
Walking ability (20 points)	6.19 ± 3.12	4.80 ± 2.27	NS
Activities of daily living (10 points)	1.38 ± 1.20	1.28 ± 0.84	NS
Latest follow-up			
General pain (30 points)	29.0 ± 3.01	28.5 ± 3.26	NS
Deformity (25 points)	16.4 ± 4.30	17.4 ± 4.04	NS
Motion (15 points)	6.95 ± 4.08	7.60 ± 2.47	NS
Walking ability (20 points)	14.3 ± 17.7	16.4 ± 4.90	NS
Activities of daily living (10 points)	3.14 ± 1.80	3.44 ± 1.56	NS
SAFE-Q Scale score at latest follow-up			
Pain and pain-related (100 points)	75.9 ± 17.7	78.4 ± 14.6	NS
Physical functioning and daily living (100 points)	49.1 ± 19.5	53.0 ± 19.8	NS
Social functioning (100 points)	38.7 ± 29.6	62.7 ± 27.0	0.0079
Shoe-related (100 points)	55.9 ± 26.0	54.6 ± 26.0	NS
General health and well-being (100 points)	66.3 ± 25.1	65.6 ± 27.4	NS

*NS = not significant.

TABLE V Comparison of Non-Biologic and Biologic Treatment Groups

	Non-Biologic Treatment Group (N = 24)	Biologic Treatment Group (N = 26)	P Value*
Age† *(yr)*	65.0 ± 7.2	63.0 ± 9.9	NS
Duration of disease† *(yr)*	18.4 ± 9.2	20.1 ± 10.6	NS
Duration of follow-up† *(yr)*	6.9 ± 2.9 (3 to 14)	7.2 ± 3.8 (3 to 14)	NS
Female:male ratio *(no. of ankles)*	21:3	21:5	NS
Height† *(cm)*	151.2 ± 7.8 (134 to 165)	153.0 ± 8.8 (144 to 179)	NS
Weight† *(kg)*	47.9 ± 8.8 (32.5 to 69.1)	52.5 ± 10.1 (36 to 78.4)	NS
BMI† *(kg/m²)*	21.0 ± 3.9 (15 to 28.2)	22.3 ± 2.8 (17 to 27.1)	NS
Steinbrocker classification[30]			
Stage *(no. of ankles)*	III (7), IV (17)	III (5), IV (21)	NS
Functional class *(no. of ankles)*	I (1), II (12), III (10), IV (1)	I (1), II (11), III (12), IV (2)	NS
Prednisolone			
Dosage† *(mg/day)*	3.0 ± 2.9	0.5 ± 1.4	0.0003
Rate of usage	71% (17 of 24)	12% (3 of 26)	0.0001
DAS28-CRP score†			
Preop.	3.0 ± 0.9	2.72 ± 0.63	NS
Latest follow-up	2.83 ± 0.72	2.24 ± 0.66	<0.01
Methotrexate usage	83% (20 of 24)	58% (15 of 26)	NS
Angle C at latest follow-up† *(deg)*	88.7 ± 2.1	89.6 ± 1.3	NS
Angle D at latest follow-up† *(deg)*	85.4 ± 2.3	85.9 ± 2.6	NS
Angle E at latest follow-up† *(deg)*	−0.01 ± 0.5	0.1 ± 1.1	NS
Tibiocalcaneal angle† *(deg)*			
Preop.	2.6 ± 8.7	5.6 ± 7.5	NS
Latest follow-up	3.2 ± 4.0	4.4 ± 3.1	NS
Talar component sinking	8% (2 of 24)	23% (6 of 26)	NS†
Focal radiolucent area	13% (3 of 24)	19% (5 of 26)	NS†
Surgery in lower limb in history *(no. of ankles)*			
Forefoot	3	5	—
Hindfoot	6	7	—
Total hip arthroplasty	9	5	—
Total knee arthroplasty	19	14	—
Surgery in lower limb after TAA *(no. of ankles)*			
Forefoot	8	12	—
Hindfoot	0	2	—
Total hip arthroplasty	1	1	—
Total knee arthroplasty	2	5	—
TAA on contralateral side	3	3	—
Revision TAA required	0% (0 of 24)	8% (2 of 26)	NS†
Additional calcaneal osteotomy	0% (0 of 24)	8% (2 of 26)	NS†

*NS = not significant. †Evaluation performed with use of chi-square analysis.

was evaluated with use of the balancer with a 17 to 18-mm spread space (Fig. 2, panel B) as the minimum size of the spacer block of this prosthetic system was 17 mm. If the balance gap measured >2°, a malleolar osteotomy was done. Twenty of the 50 ankles were balanced with the osteotomy, with preservation of the periosteum. No internal fixation at the osteotomy site was added. When fracture at the malleolus occurred during surgery (7 ankles), no internal fixation was used. In 47 ankles, hydroxyapatite augmentation for the distal part of the tibia was performed as described in our

TABLE VI Postoperative Issues and Radiographic Findings After TAA

Delayed wound-healing	10% (5 of 50)
Deep or periprosthetic infection	0% (0 of 50)
Cellulitis around ankle joint	2% (1 of 50)
Deep-vein thrombosis	0% (0 of 50)
Revision TAA required	4% (2 of 50)
Additional calcaneal osteotomy	4% (2 of 50)
Intraoperative malleolar fracture	14% (7 of 50)
Delayed union at site of malleolar osteotomy	15% (3 of 20)
Nonunion at site of osteotomy	0% (0 of 20)
Migration of tibial component	0% (0 of 50)
Sinking of talar component	16% (8 of 50)
Focal radiolucent area	16% (8 of 50)

previous report[4]. After preparation was completed, the prostheses were implanted and fixed with cement. The thickest possible polyethylene liner was then introduced between these components with use of manual joint distraction. Routine wound closure with careful suturing of the extensor retinaculum completed the procedure. Achilles tendon lengthening was not performed.

The ankle was immobilized postoperatively in a below-the-knee cast for 2 weeks with non-weight-bearing. Immobilization was prolonged to 6 weeks when subtalar and/or talonavicular joint arthrodesis had been performed at the time of TAA (thereby increasing the duration of non-weight-bearing to 8 weeks). The duration of casting was not changed if malleolar lengthening osteotomy was added. When full-weight-bearing was resumed, the patient wore an ankle brace to avoid an ankle sprain[9].

Evaluations of Clinical Outcomes

Preoperative and postoperative scores were evaluated according to the Japanese Society for Surgery of the Foot (JSSF) rheumatoid arthritis foot-ankle scale[10,11]. A postoperative self-administered foot-evaluation questionnaire (SAFE-Q)[12] also was administered at the time of the latest follow-up. Control of rheumatoid arthritis was assessed with use of the Disease Activity Score 28-joint count C-reactive protein (DAS28-CRP) score[13].

TABLE VII Radiographic Angles

	Preop.*	Latest Follow-up*	P Value
Angle C *(deg)*	—	89.2 ± 1.8	—
Angle D *(deg)*	—	85.7 ± 2.4	—
Angle E *(deg)*	—	−0.07 ± 0.9	—
Tibiocalcaneal angle *(deg)*	4.5 ± 8.5	3.6 ± 3.5	0.003†

*The values are given as the mean and the standard deviation. †Significant difference (p = 0.003). Statistical analysis was performed with use of the difference from 2°.

Evaluation of Radiographic Parameters

Radiographic evaluation was performed with use of standard anteroposterior and lateral radiographs of the leg, including the ankle joint. Weight-bearing radiographs were made preoperatively and at each follow-up evaluation. The postoperative angular position of the tibial component was defined as the angle between the base plate of the tibial component and the long axis of the tibia on both anteroposterior radiographs (Fig. 3, panel A, angle C) and lateral radiographs (Fig. 3, panel B, angle D). The postoperative tilting angle between the tibial and talar components (the index of prosthesis edge-loading in the standing position) was defined as the angle between the base plate of the tibial and talar components (Fig. 3, panel A, angle E)[9]. The tibiocalcaneal angle was measured with subtalar radiographs (Fig. 3, panel C, TC angle) with use of the modified Cobey method[14] to evaluate hindfoot alignment before and after surgery. The radiographs were assessed for prosthetic subsidence or migration (>2 mm) and radiolucent areas.

Statistical Analysis

All data are expressed as the mean and the standard deviation (SD). Differences between the groups were assessed by the Wilcoxon rank-sum test and the chi-square test with use of JMP 13 statistical analysis software (SAS Institute). A p value of <0.05 was considered significant.

Results

Clinical Outcomes

On the JSSF rheumatoid arthritis foot and ankle scale scores, all of the indices (general pain, deformity, motion, walking ability, activities of daily living) were significantly improved after TAA (Table II). The SAFE-Q assessment at the time of the latest follow-up showed relatively good results for pain and pain-related (77.3 ± 15.9) and general health and well-being (65.9 ± 25.1) scores. The mean physical functioning and daily living, social functioning, and shoe and shoe-related scores were lower (51.3, 51.7, and 55.2, respectively) (Table III). The scores for each index of the JSSF rheumatoid arthritis foot and ankle scale and SAFE-Q score showed no significant difference between the biologic treatment and non-biologic treatment groups at the time of final follow-up, except for SAFE-Q social functioning score (non-biologic group, 38.7 ± 29.6; biologic group, 62.7 ± 27.0) (Table IV). Prednisolone dosage (non-biologic group, 3.0 ± 2.9 mg/day; biologic group, 0.5 ± 1.4 mg/day), usage (non-biologic group, 71%; biologic group, 12%), and disease activity (DAS28-CRP score) (non-biologic group, 2.83 ± 0.72; biologic group, 2.24 ± 0.66) were significantly decreased in the biologic group at the

TABLE VIII Relationships Between Revision TAA and Talar Component Sinking and Between Subtalar Joint Fusion and Talar Component Sinking

	Talar Component Sinking			Subtalar Joint Fusion		
	Yes	No	P Value	Yes	No	P Value
Revision TAA required	25% (2 of 8)	0% (0 of 42)	<0.001*	—	—	—
Talar component sinking	—	—	—	21% (8 of 38)	0% (0 of 12)	NS (0.08)*

*Chi-square analysis. NS = not significant.

time of the latest follow-up (Table V). No deep infection was observed in either group. Delayed wound-healing was seen in 5 ankles (10%). Of the 50 ankles, 48 (96%) did not require revision surgery (Table VI).

Radiographic Outcomes

Migration of the tibial component was not seen. Subsidence of the talar component was seen in 8 ankles (Table VI). Additional calcaneal osteotomy (medial offset) was performed in 2 ankles because of the residual valgus tilt between the tibial and talar components (Table VI). The mean angle C was 89.2° ± 1.8°, the mean angle D was 85.7° ± 2.4°, and the mean angle E was −0.07° ± 0.9°. The tibiocalcaneal angle was significantly improved after TAA (preoperative, 4.5° ± 8.5°; latest follow-up, 3.6° ± 3.5°) (Table VII). There was no difference in these angles between the biologic and non-biologic

Fig. 4

Panels A, B, and C: Anteroposterior (top) and subtalar (bottom) weight-bearing radiographs of a representative ankle that underwent subtalar-talonavicular joint arthrodesis prior to TAA. **Panel A (top and bottom):** Preoperative radiographs showing hindfoot valgus deformity and ankle joint destruction. The tibiocalcaneal angle was 24°. **Panel B (top and bottom):** Eight months after hindfoot-correction surgery, alignment was improved and the tibiocalcaneal angle had decreased to 5°. **Panel C (top and bottom):** Radiographs made 1 month after TAA for the treatment of residual ankle pain. Hydroxyapatite was also implanted into the distal part of the tibia.

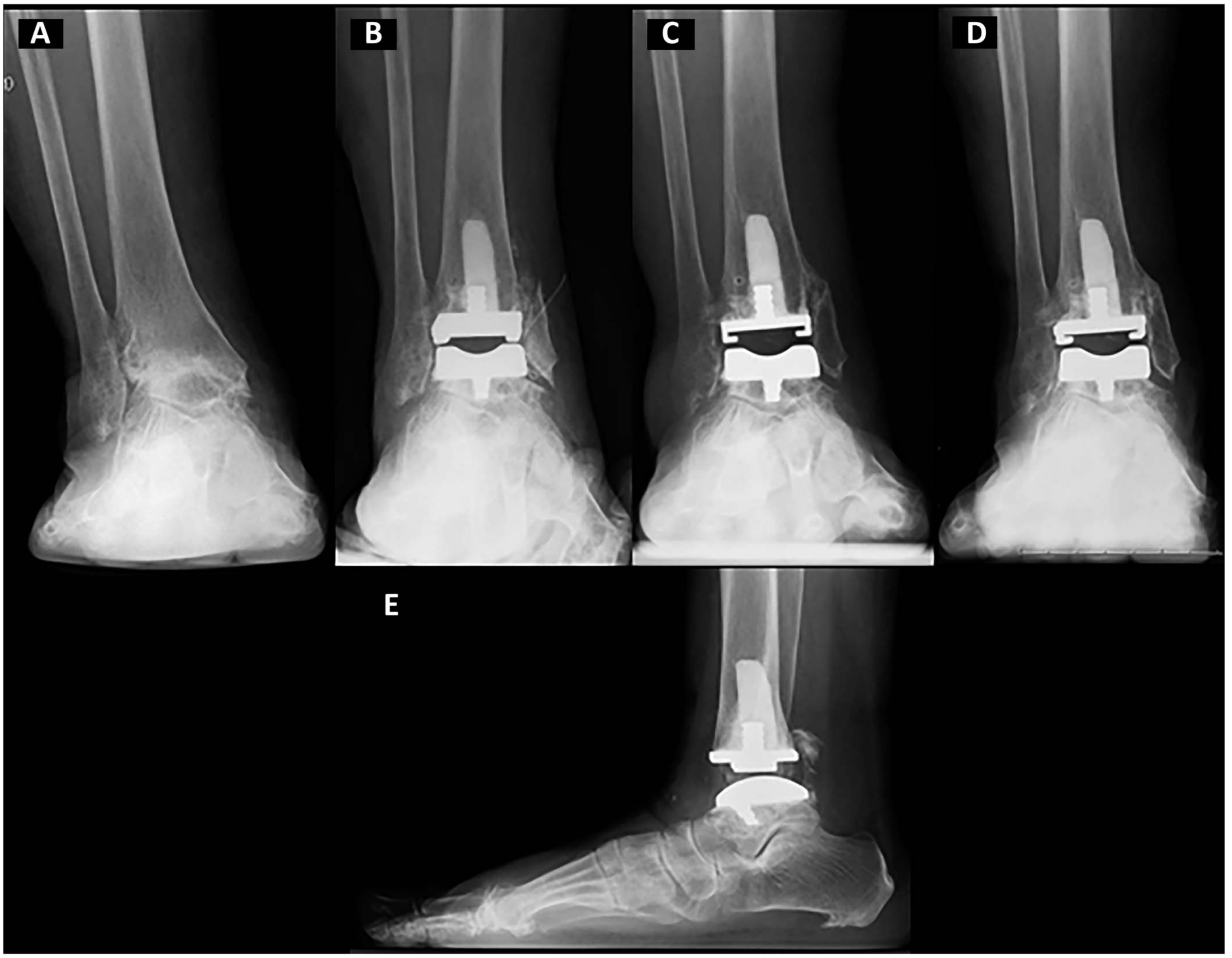

Fig. 5

Panels A through E: Radiographs of a representative ankle that underwent TAA with concomitant medial malleolar osteotomy. Hydroxyapatite was also implanted into the distal part of the tibia. **Panel A:** Preoperative weight-bearing anteroposterior radiograph of the ankle in the standing position. **Panel B:** Radiograph made immediately after TAA. Autologous bone chips were transplanted to the site of the opening-wedge osteotomy. **Panel C:** Radiograph made 1 year after TAA. Bone formation has progressed, and osseous fusion is almost completed at the osteotomy site. **Panel D:** Radiograph made 5 years after TAA. Osseous fusion has accelerated, and bone sclerosis is also observed. No implant loosening is seen. **Panel E:** Lateral radiograph of the ankle, made 5 years after TAA. No implant loosening is observed.

groups (Table V). Three ankles showed delayed osseous union (>3 months) at the malleolar osteotomy site. No patient reported pain during walking, and osseous union was complete in all cases (Table VI). Intraoperative malleolar fracture occurred in 7 feet (Table VI); however, osseous union was complete in all cases and no pain was reported. Talar component subsidence tended to be observed more frequently in the biologic group than in the non-biologic group (23% [6 of 26] compared with 8% [2 of 24]), although the difference was not significant (Table V). The rate of revision TAA surgery was higher in the biologic group than in the non-biologic group (8% [2 of 26] compared with 0% [0 of 24]), although this difference also was not significant (Table V). The rate of revision TAA surgery was higher in the group of ankles with subsidence than in the group without subsidence (25% [2 of 8]) compared with 0% [0 of 42]) (Table VIII). Ankles with subtalar fusion had a higher rate of talar component sinking (21% [8 of 38]) than those that did not have subtalar fusion (0% [0 of 12]) (Table VIII).

Discussion

Ankle arthrodesis and/or simultaneous arthrodesis surgery of both the ankle and the subtalar joint with use of an intramedullary nail, plate, and screws has been recommended for the treatment of severe ankle destruction in patients with rheumatoid arthritis[15,16]. However, these

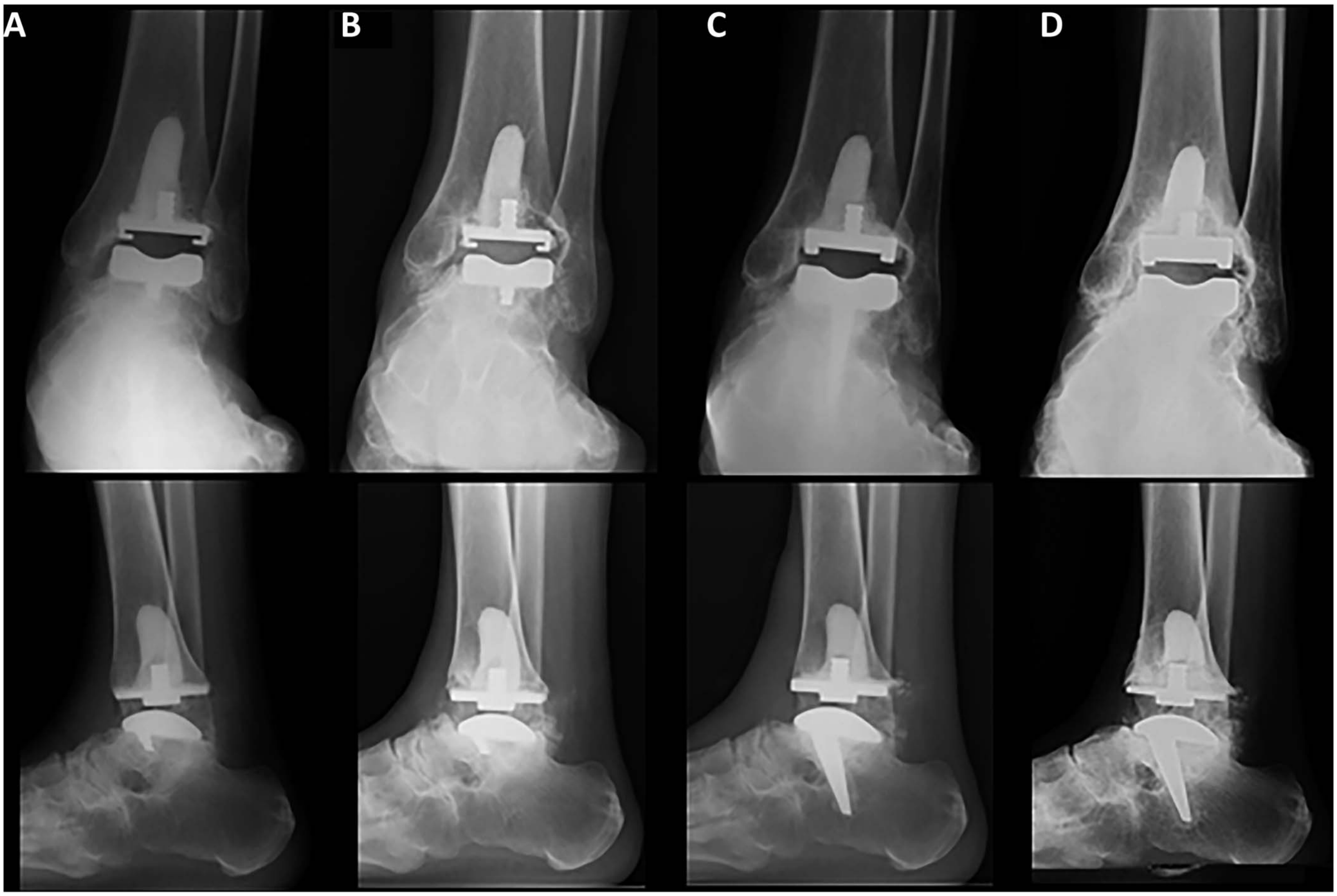

Fig. 6

Panels A through D: Anteroposterior (top row) and lateral (bottom row) standing radiographs of a representative ankle that underwent revision TAA after subsidence of the talar component. Ankylosis of the subtalar joint was seen. **Panel A (top and bottom):** One month after primary TAA, coverage of talar component was not completely achieved, especially as seen on the lateral radiograph. **Panel B (top and bottom):** Two years after primary TAA, sinking of the talar component and a radiolucent area around tibial component were seen. **Panel C (top and bottom):** Radiographs made one month after revision TAA with use of a larger talar component with a long stem. **Panel D (top and bottom):** Radiographs made 8 years after revision TAA, showing no sinking of the talar component.

procedures restrict hindfoot mobility, causing inconvenience when the patient climbs stairs and steps. In addition, hindfoot immobility is known to cause excessive forefoot loading[17], so there is concern that forefoot deformity induced by metatarsophalangeal (MTP) joint inflammation in association with rheumatoid arthritis could be accelerated. Furthermore, ankle arthrodesis requires a long period of immobilization and non-weight-bearing (normally >8 weeks). TAA has potential advantages compared with arthrodesis, notwithstanding concerns regarding the durability of the prostheses. As the ankle joint has a relatively small surface contact area of about 350 mm^2[2,18] and the surface is highly loaded during walking, by up to 5 times body weight[19], edge loading of the prosthesis is likely to occur if hindfoot deformity remains[1-3]. As excessive edge loading can lead to prosthesis breakage and loosening, adjusting the loading axis to avoid edge loading is important. Therefore, correction of hindfoot alignment was completed first, and then TAA was performed (Fig. 4). The adjustment of hindfoot alignment contributed to good compatibility (angle E) between the tibial and talar components (Table VII).

Soft-tissue imbalance between the medial and lateral ligaments also causes edge loading of the ankle prosthesis[20]. Malleolar osteotomy was used to achieve soft-tissue balance[5] (Fig. 5). We previously reported high rates of migration of the tibial component (13 of 21 ankles) after TAA for the treatment of rheumatoid arthritis[21]. Subsequently, a procedure for the implantation of hydroxyapatite bone in the tibia was established[4]. In the present study, no migration of the tibial component was seen (Table VI). However, talar component subsidence was seen in 8 of the 50 ankles. In all 8 cases, the subtalar joint was fused. Of these 8 ankles, 2 (25%) required revision surgery because of residual pain (Table VIII). Furthermore, the rate of talar component sinking was higher in ankles in which the subtalar joint was fused than those in which it was preserved (21% [8 of 38] compared with 0% [0 of 12]) (Table VIII). It is possible that the blood supply to the talar dome is decreased after subtalar joint fusion. The tarsal canal artery from the medial posterior tibial artery, and the deltoid branch of the posterior tibial artery[22], provide the blood supply to the talar dome. These 2 major arteries passing in the sinus tarsi and subtalar space might be disrupted after subtalar joint ankylosis or arthrodesis. Thus, there might be relatively more intense fragility in the talar dome than in a fused and sclerotic subtalar joint. In 1 patient, the size of the talar component was too small. A sufficiently sized talar component with a long stem was selected for revision TAA. Eight years after revision surgery, no talar component sinking had been seen (Fig. 6). Thus, although sufficient size selection for implants is important, the use of a long-stem talar component also might be useful for ankles with ankylosis of the subtalar joint.

With such progress in the additive techniques for TAA, disease control with use of biologics and/or methotrexate also was considered to be important for outcomes after TAA in patients with rheumatoid arthritis. Although there were no preoperative data for the SAFE-Q assessment because the SAFE-Q system was introduced in 2014, the score of the social functioning index of SAFE-Q at the time of the latest follow-up was significantly higher in the biologic treatment group than in the non-biologic treatment group (Table IV). Talar component subsidence was more frequently observed in the biologic treatment group (Table V). Both the dosage and the usage of prednisolone were significantly decreased in the biologic treatment group (Table V). Withdrawal from steroids may reduce osteoporosis and bone fragility[23], and it also has been reported that the reduction of steroid administration contributes to improving the serum level of bone-formation markers[24]. On the other hand, the inhibition of cytokines also seems to improve bone mineral metabolism. Some studies have shown that anti-tumor necrosis factor (TNF)-α therapy prevented bone loss in patients with rheumatoid arthritis[25], that downregulation of bone formation by interleukin-6 (IL-6) was restored with anti-IL-6 receptor therapy[26], and that abatacept directly suppressed osteoclast formation[27]. Taken together, these findings suggest that biologic treatment theoretically would have an advantage for prosthesis durability from the perspective of the strength of bone mineral structure because it is also known that bone mineral content and microstructure at the knee joint have an influence on outcomes after total knee arthroplasty[28] and bone loss around prostheses after total knee arthroplasty is also 1 of the factors inducing prosthesis loosening[29]. In spite of these theoretically attractive advantages of biologics for the bone supporting the prosthesis, subsidence of the talar component and revision TAA surgery tended to be observed more frequently in the biologic treatment group (Table V). This phenomenon might be due to the higher social activity in the biologic treatment group (Table IV). To tolerate higher activity, some modifications for the fixation of talar component are needed, especially in ankles treated with subtalar fusion.

In conclusion, TAA is recommended for the treatment of rheumatoid arthritis if disease control, augmentation of bone strength, control of soft-tissue balance, and adjustment of the loading axis are taken into account. The prevention of talar component subsidence remains a challenge in patients with the combination of subtalar fusion, rheumatoid arthritis, and higher social activity. ■

Note: The authors thank all of the physical therapists, especially Naotaka Tasaki and Kohei Kushimoto, medical assistants, staff, and rheumatologists in Osaka Minami Medical Center and Osaka University Hospital for their excellent therapy and support. The authors also thank Teijin-Nakashima Medical for the kind technical support.

Makoto Hirao, MD, PhD[1]
Jun Hashimoto, MD, PhD[2]
Hideki Tsuboi, MD, PhD[3]
Kosuke Ebina, MD, PhD[1]
Akihide Nampei, MD, PhD[2]
Takaaki Noguchi, MD, PhD[2]
Shigeyoshi Tsuji, MD, PhD[2]
Norihiro Nishimoto, MD, PhD[4,5]
Hideki Yoshikawa, MD, PhD[1]

[1]Department of Orthopaedics, Osaka University Graduate School of Medicine, Osaka, Japan

[2]Department of Orthopaedics/Rheumatology, National Hospital Organization, Osaka Minami Medical Center, Osaka, Japan

[3]Department of Orthopaedics, Osaka Rosai Hospital, Osaka, Japan

[4]Osaka Rheumatology Clinic, Osaka, Japan

[5]Department of Molecular Regulation for Intractable Diseases Institute of Medical Science, Tokyo Medical University, Tokyo, Japan

E-mail address for M. Hirao: makohira777@gmail.com

ORCID iD for M. Hirao: 0000-0002-1408-7851

References

1. Wood PLR, Deakin S. Total ankle replacement. The results in 200 ankles. J Bone Joint Surg Br. 2003 Apr;85(3):334-41.

2. Haskell A, Mann RA. Ankle arthroplasty with preoperative coronal plane deformity: short-term results. Clin Orthop Relat Res. 2004Jul;(424):98-103.

3. Doets HC, Brand R, Nelissen RG. Total ankle arthroplasty in inflammatory joint disease with use of two mobile-bearing designs. J Bone Joint Surg Am. 2006 Jun; 88(6):1272-84.

4. Shi K, Hayashida K, Hashimoto J, Sugamoto K, Kawai H, Yoshikawa H. Hydroxyapatite augmentation for bone atrophy in total ankle replacement in rheumatoid arthritis. J Foot Ankle Surg. 2006 Sep-Oct;45(5):316-21.

5. Doets HC, van der Plaat LW, Klein JP. Medial malleolar osteotomy for the correction of varus deformity during total ankle arthroplasty: results in 15 ankles. Foot Ankle Int. 2008 Feb;29(2):171-7.

6. Haraguchi N, Ota K, Tsunoda N, Seike K, Kanetake Y, Tsutaya A. Weight-bearing-line analysis in supramalleolar osteotomy for varus-type osteoarthritis of the ankle. J Bone Joint Surg Am. 2015 Feb 18;97(4):333-9.

7. Larsen A, Dale K, Eek M. Radiographic evaluation of rheumatoid arthritis and related conditions by standard reference films. Acta Radiol Diagn (Stockh). 1977 Jul;18(4):481-91.

8. Kofoed H. Scandinavian total ankle replacement (STAR). Clin Orthop Relat Res. 2004 Jul;(424):73-9.

9. Hirao M, Oka K, Ikemoto S, Nakao R, Tsuboi H, Nampei A, Akita S, Shi K, Ebina K, Murase T, Sugamoto K, Yoshikawa H, Hashimoto J. Use of a custom-made surgical guide in total ankle arthroplasty in rheumatoid arthritis cases. Tech Orthop. 2014;29:103-12.

10. Niki H, Aoki H, Inokuchi S, Ozeki S, Kinoshita M, Kura H, Tanaka Y, Noguchi M, Nomura S, Hatori M, Tatsunami S. Development and reliability of a standard rating system for outcome measurement of foot and ankle disorders I: development of standard rating system. J Orthop Sci. 2005 Sep;10(5):457-65.

11. Niki H, Aoki H, Inokuchi S, Ozeki S, Kinoshita M, Kura H, Tanaka Y, Noguchi M, Nomura S, Hatori M, Tatsunami S. Development and reliability of a standard rating system for outcome measurement of foot and ankle disorders II: interclinician and intraclinician reliability and validity of the newly established standard rating scales and Japanese Orthopaedic Association rating scale. J Orthop Sci. 2005 Sep;10(5):466-74.

12. Niki H, Tatsunami S, Haraguchi N, Aoki T, Okuda R, Suda Y, Takao M, Tanaka Y. Validity and reliability of a self-administered foot evaluation questionnaire (SAFE-Q). J Orthop Sci. 2013 Mar;18(2):298-320. Epub 2013 Jan 9.

13. Inoue E, Yamanaka H, Hara M, Tomatsu T, Kamatani N. Comparison of Disease Activity Score (DAS)28- erythrocyte sedimentation rate and DAS28- C-reactive protein threshold values. Ann Rheum Dis. 2007 Mar;66(3):407-9. Epub 2006 Aug 22.

14. Cobey JC. Posterior roentgenogram of the foot. Clin Orthop Relat Res. 1976 Jul-Aug;(118):202-7.

15. Niinimäki TT, Klemola TM, Leppilahti JI. Tibiotalocalcaneal arthrodesis with a compressive retrograde intramedullary nail: a report of 34 consecutive patients. Foot Ankle Int. 2007 Apr;28(4):431-4.

16. Myerson MS, Alvarez RG, Lam PW. Tibiocalcaneal arthrodesis for the management of severe ankle and hindfoot deformities. Foot Ankle Int. 2000 Aug;21(8):643-50.

17. Armstrong DG, Stacpoole-Shea S, Nguyen H, Harkless LB. Lengthening of the Achilles tendon in diabetic patients who are at high risk for ulceration of the foot. J Bone Joint Surg Am. 1999 Apr;81(4):535-8.

18. Thomas RH, Daniels TR. Ankle arthritis [Review]. J Bone Joint Surg Am. 2003 May;85-A(5):923-36.

19. Stauffer RN, Chao EY, Brewster RC. Force and motion analysis of the normal, diseased, and prosthetic ankle joint. Clin Orthop Relat Res. 1977;(127):189-96.

20. Bonnin M, Judet T, Colombier JA, Buscayret F, Graveleau N, Piriou P. Midterm results of the Salto total ankle prosthesis. Clin Orthop Relat Res. 2004 Jul;(424):6-18.

21. Nishikawa M, Tomita T, Fujii M, Watanabe T, Hashimoto J, Sugamoto K, Ochi T, Yoshikawa H. Total ankle replacement in rheumatoid arthritis. Int Orthop. 2004 Apr;28(2):123-6. Epub 2003 Oct 7.

22. Mulfinger GL, Trueta J. The blood supply of the talus. J Bone Joint Surg Br. 1970 Feb;52(1):160-7.

23. Canalis E, Mazziotti G, Giustina A, Bilezikian JP. Glucocorticoid-induced osteoporosis: pathophysiology and therapy. Osteoporos Int. 2007 Oct;18(10):1319-28. Epub 2007 Jun 14.

24. Tada M, Inui K, Sugioka Y, Mamoto K, Okano T, Koike T, Nakamura H. Reducing glucocorticoid dosage improves serum osteocalcin in patients with rheumatoid arthritis-results from the TOMORROW study. Osteoporos Int. 2016 Feb;27(2):729-35. Epub 2015 Aug 21.

25. Marotte H, Miossec P. Prevention of bone mineral density loss in patients with rheumatoid arthritis treated with anti-TNFalpha therapy. Biologics. 2008 Dec;2(4):663-9.

26. Kaneshiro S, Ebina K, Shi K, Higuchi C, Hirao M, Okamoto M, Koizumi K, Morimoto T, Yoshikawa H, Hashimoto J. IL-6 negatively regulates osteoblast differentiation through the SHP2/MEK2 and SHP2/Akt2 pathways in vitro. J Bone Miner Metab. 2014Jul;32(4):378-92.

27. Axmann R, Herman S, Zaiss M, Franz S, Polzer K, Zwerina J, Herrmann M, Smolen J, Schett G. CTLA-4 directly inhibits osteoclast formation. Ann Rheum Dis. 2008 Nov;67(11):1603-9. Epub 2008 Jan 18.

28. Huang CC, Jiang CC, Hsieh CH, Tsai CJ, Chiang H. Local bone quality affects the outcome of prosthetic total knee arthroplasty. J Orthop Res. 2016 Feb;34(2):240-8. Epub 2015 Aug 11.

29. van Loon CJ, de Waal Malefijt MC, Buma P, Verdonschot N, Veth RP. Femoral bone loss in total knee arthroplasty. A review. Acta Orthop Belg. 1999 Jun;65(2):154-63.

30. Steinbrocker O, Traeger CH, Batterman RC. Therapeutic criteria in rheumatoid arthritis. J Am Med Assoc. 1949 Jun25;140(8):659-62.