

Outcomes of resection and joint-preserving arthroplasty for forefoot deformities in patients with rheumatoid arthritis

Abstract

Background: We investigated the clinical outcomes of resection and joint-preserving arthroplasty for forefoot deformities in patients with rheumatoid arthritis.

Methods: Sixteen feet of 14 women (average age, 67.1 years; range, 53-82) underwent resection arthroplasty of the metatarsal head (resection group), and 18 feet of 15 women (average age, 61.3 years; range, 40-73) underwent a metatarsophalangeal joint-preserving procedure with shortening oblique osteotomy of the lesser toe (joint-preservation group).

The mean disease duration in the resection and joint-preservation groups was 23.6 and 19.1 years, and the average follow-up period was 37.3 and 33.5 months, respectively. The classification of Larsen was used to assess the severity of destruction of the MTP joint.

Preoperative and postoperative clinical evaluation included Japanese Society for Surgery of the Foot (JSSF) score and postoperative complications.

Results: The number of preoperative radiographic destruction of the MTP joints (Larsen grade II, III, IV and V) was 0, 29, 39, 12 and 13, 67, 9, 1 joints in the resection and joint-preservation groups, respectively. The mean JSSF score improved significantly from 61.3 to 83.9 points in the resection group ($P < .001$) and from 62.2 to 90.8 points in the joint-

preservation group ($P < .001$). In the resection group, recurrence of callosities and claw toe deformity were observed in 6 and 3 feet, respectively. In the joint-preserving group, recurrence of callosities and hammer toe deformity were observed in each one foot.

Conclusion: The resection arthroplasty and joint-preserving procedure showed satisfactory short-term clinical outcomes. However, whether both procedures can maintain the good clinical results without the recurrence of forefoot deformity should await longer careful follow-up of the current set of patients.

Level of Evidence: A retrospective level IV review of RA forefoot surgery outcomes.

Keywords: Rheumatoid arthritis, Forefoot deformities, Resection arthroplasty, Joint-preserving arthroplasty

Introduction

Foot problems appear to be common throughout the course of rheumatoid arthritis (RA), frequently causing pain during weightbearing activities such as standing, walking, and running.¹⁰ The typical rheumatoid forefoot deformity is characterized by hallux valgus and subluxation or dislocation of the lesser toes at the metatarsophalangeal (MTP)

joints³⁸. Patients with RA may undergo joint surgery to improve physical function and quality of life, in part based on the increased expectation levels of these patients.²⁵

Increasing number of RA patient required foot arthroplasties have been reported in a Japanese cohort study.²⁹ Conventionally, resection arthroplasty was widely performed to treat forefoot deformities associated with RA.^{4,8,15,24,27,40} However, this procedure sacrifices the function of the MTP joint. The clinically beneficial effects of disease-modifying antirheumatic drugs (DMARDs), including methotrexate and/or biologic DMARDs (b-DMARDs), have contributed to the increase in the number of patients who achieve clinical remission¹². Advanced disease control for RA involves prevention of joint destruction and joint remodeling even in joints damaged by RA.¹⁸ For the rheumatoid forefoot surgery, other alternative surgical procedures those can preserve the MTP joint have become reasonable for patients with mild to moderate disease. Several joint-preserving procedures have been reported to be good clinical results.^{11,13,14,33,34,36,42} We recently performed correction osteotomies of the first metatarsal and shortening oblique osteotomy (SOO) of the lesser metatarsal to preserve joint function as an alternative to joint-sacrificing surgeries.³⁴

In the current study, we investigated the clinical and radiographic outcomes of resection and joint-preserving arthroplasty for forefoot deformities in patients with RA.

Patients and Methods

This retrospective study was approved by the ethics committee of our institute (approval number: 2194), and informed consent was obtained from all patients. Thirty-four feet of 29 women with RA underwent surgery for treatment of forefoot deformities in our institute from July 2010 to December 2014. All patients met the American Rheumatism Association 1987 revised criteria for RA.¹ The joint-sacrificing procedure (arthrodesis or resection arthroplasty) has been indicated for all rheumatoid forefoot deformities in our institute until 2011, then the joint-preserving procedure has been started to indicate for painful plantar callosities, deformity of the forefoot with subluxation or dislocation of one or more MTP joints and mild (Larsen grade I or II) or moderate (Larsen grade III) destruction of the MTP joints from 2012. At present, resection arthroplasty of the metatarsal head still tends to be indicated for relatively older patients (over 65 years-old) with severe dislocation of the MTP joints, destruction of the metatarsal head, and with poor disease control due to comorbidity. Sixteen feet of 14 women (average age, 67.1 years; range, 53–82) underwent resection arthroplasty of the metatarsal head (resection group), and 18 feet of 15 women (average age, 61.3 years; range, 40–73) underwent an MTP joint-preserving procedure with correction osteotomy of the first metatarsal bone

for big toe and SOO for the lesser toe (joint-preservation group). The SOO of the lesser metatarsal was done for 2nd, 3rd, 4th, and 5th lesser metatarsal in 14, 16, 11, and 9 feet, respectively. The minimum follow-up period was 24 months. We have already reported outcomes of joint-preserving procedure with a shorter follow-up periods (minimum 6-months' follow-up) in 17 patients included in this study.³⁴ Two patients underwent resection arthroplasty on one foot and joint-preserving arthroplasty on the contralateral foot. In these two patients, same evaluations were used for disease activity and clinical score relating to ADL in both feet. On the other hand, clinical score excluding ADL and radiographic outcomes were assessed in each foot separately. The average disease duration in the resection and joint-preservation groups was 23.6 (range, 10–54) years and 19.1 (range, 4–47) years, respectively, and the average follow-up period was 37.3 (range, 24–71) months and 33.2 (range, 24–61) months, respectively. Twenty-four patients had been treated with conventional synthetic DMARDs (cs-DMARDs) preoperatively [methotrexate, n = 18; salazosulfapyridine, n = 6; bucillamine, n = 3; prednisolone, n = 17; tacrolimus, n = 6; shiosol, n = 1], and 7 patients had been treated with b-DMARDs preoperatively (infliximab, n = 1; etanercept, n = 6). One patient was not taking any medication at the time of surgery. In one patient, cs-DMARDs was switched to b-DMARDs postoperatively and all patients except this patient had been treated with same

medications between pre- and postoperatively. The mean Disease Activity Score 28 (DAS28)-CRP⁴¹ in the resection and joint-preservation groups was 2.69 (range, 1.27–4.12) and 2.71 (range, 1.45–3.76), respectively, and the mean modified Health Assessment Questionnaire (mHAQ)³⁵ score was 0.56 (range, 0–1.25) and 0.36 (range, 0–1.25), respectively (Table 1).

Assessment

Clinical assessment

Preoperative and postoperative clinical evaluation included assessment of Japanese Society of Surgery of the Foot (JSSF) score using the standard rating system for the RA foot and ankle scale for pain (0–30 points), deformity (0–25 points), range of motion (ROM) (0–15 points), walking ability (0–20 points), and activities of daily living (ADL) (0–10 points).^{31,32} The presence of symptomatic plantar callosities and residual toe deformities were examined postoperatively.

Radiographic assessment

The classification of Larsen²¹ was used to assess the severity of destruction of the MTP joint. Grade I or grade II indicated mild destruction, grade III moderate destruction and

grade IV or grade V severe destruction. Preoperative and postoperative radiographic assessments included measurement of the hallux valgus angle (HVA), intermetatarsal angle of the first and second metatarsals (M1M2A), and intermetatarsal angle of the first and fifth metatarsals (M1M5A) on anteroposterior weightbearing radiographs using Miller's method.³⁰

Operative technique

The resection arthroplasty was performed using the method described by Hoffmann,¹⁵ which involves resection of the second to fifth metatarsal heads. For the big toe, a medial MTP joint capsule is opened with Y-shaped incision, and the flap is reflected distally. After the resection of metatarsal head, the capsule was closed with advance the Y-shaped incision into V-shaped reefing to the metatarsal shaft using drill hole, while holding the phalangeal bones at corrected position. (Figure 1). We did not use longitudinally positioned Kirschner wires (K-wire) that extended percutaneously from the toe tip, across the resection cleft of the metatarsal head, and into the shaft of the corresponding metatarsal. The manipulation of PIP joint was done in all feet. The extensor plication and dermadesis at PIP joints were performed in 6 toes of 2 feet. In 7 toes of three feet, Z-lengthening of the extensor digitorum longus (EDL) tendon was performed with release of

the extensor digitorum brevis (EDB) tendon.

In the joint-preservation group, we modified the SOO procedure for correcting lesser toe deformities described by Hanyu et al (Figure 2).¹¹ The metatarsal bone was fixed with a screw instead of a longitudinal K-wire from the distal phalanx to the metatarsal shaft (Figure 3).³⁴ In the big toe, hallux valgus deformities were corrected using the modified Mann method (Figure 2B). A modified Mann method was applied in combination with elevation of the abductor hallucis tendon, which was dislocated to the plantar side of the big toe toward the tibial side of the metatarsal bone, and removal of the inflamed connective tissue caused by bunions. Proximal osteotomy of the metatarsal bone was performed for shortening and varus correction.⁵ Locking plates were used for fixation of the osteotomy site. For the big toe, a modified Mann method with plate (DARCO[®], Wright Medical Technology, Memphis, TN, USA) fixation was performed in seven feet. For the lesser toe, cortex screws (Modular Hand System, DePuy Synthes, Switzerland) were used in 16 cases and cannulated cancellous screws (DARTFIRE[®], Wright Medical Technology, Memphis, TN, USA) were used in 2 cases to fix the osteotomy site according to our previously described procedure.³⁴ The manipulation of PIP joint was done in all feet. The extensor plication and dermadesis at PIP joints were performed in 9 toes of 5 feet. In 39 toes of twelve feet, Z-lengthening of the EDL tendon was performed with

release of the EDB tendon.

Postoperative management

In the resection group, a bulky compressive bandage was applied with the toe held in plantarflexion for 10 to 14 days. Patients were allowed to bear full weight and begin passive and active ROM exercises on the day after surgery. After removal of the bandage, the patients wore an arch support (custom-made orthosis to support the longitudinal arch) for 2 months. In the joint-preservation group, a bulky compression bandage was applied with the toe held in plantarflexion for 7 to 10 days. Passive and active ROM exercises were started at 5 to 7 days. Heel gait was permitted at 7 days if possible, and partial weightbearing with an arch support was permitted at 2 weeks. Full weightbearing with an arch support was permitted 3 weeks after surgery. The patients wore an arch support for 2 months.³⁴

Statistical analysis

Statistical analyses were performed using R for Windows (www.r-project.org). Values were compared using the Mann–Whitney U test, Wilcoxon signed-rank test, and Fisher’s exact test. A *P* value of <.05 was considered statistically significant.

Results

The number of preoperative radiographic destruction of the MTP joint (Larsen grade II, III, IV and V) was 0, 29, 39, 51, 12 and 13, 67, 9, 1 joints in the resection and joint-preservation groups, respectively. The mean JSSF score improved significantly from 61.3 (range, 45.0–84.0) to 83.9 (range, 52.0–99.0) points in the resection group ($P < .001$). In the joint-preservation group, the mean JSSF score improved significantly from 62.2 (range, 46.0–81.0) to 90.8 (range, 70.0–98.0) points ($P < .001$). (Table 2). In the sub-analysis of ADL in the resection group, standing on the toe was easy in six feet, difficult in seven feet, and impossible in three feet. In the joint-preservation group, standing on toe was easy in 13 feet and difficult 5 feet. No patients in this group were unable to stand on the toe. In the resection group, preoperative and postoperative radiographic evaluation showed that the HVA, M1M2A, and M1M5A improved significantly from 43.5 (range, 25.0–59.0) to 20.1 (range, 5.0–36.0) ($P < .001$), 11.1 (range, 0.0–19.0) to 9.3 (range, 1.0–18.0) ($P = .020$), and 32.6 (range, 23.0–45.0) to 28.5 (range, 21.0–36.0) ($P = .040$), respectively. In the joint-preservation group, preoperative and postoperative radiographic evaluation showed that the HVA, M1M2A, and M1M5A also improved significantly from 30.3 (range, 4.0–56.0) to 23.7 (range, 4.0–44.0) ($P = .020$), 11.8 (range, 6.0–21.0) to 10.1

(range, 4.0–20.0) ($P = .007$), and 34.2 (range, 24.0–46.0) to 30.8 (range, 19.0–45.0) ($P = .017$), respectively (Table 2). In the resection group, recurrence of callosities and claw toe deformity were observed in 6 and 3 feet, respectively. In the joint-preserving group, recurrence of callosities and hammer toe deformity were observed in each one foot.

Postoperative infection occurred in each one foot in the resection and joint-preservation groups. (Table3).

In five feet with recurrence of hallux valgus (HVA of more than 30 degrees), severe hallux valgus (HVA of greater than or equal to 47 degrees) was observed preoperatively despite the fact that the RA disease activity of these patients had reached remission at the final follow-up. Recurrence of claw toe deformity occurred in three feet in the resection group at the final follow-up, and these feet had mid-hindfoot deformities including bony ankyloses. Bone union was achieved in all cases in the joint-preservation group.

Discussion

Various modifications of resection arthroplasty have been performed with good clinical results in patients with RA.^{4,8,15,24,27,40} In our study, resection arthroplasty of the big and lesser metatarsal heads with the treatment of medial soft tissue for big toe (modified Lelièvre procedure) showed good clinical results. However, resection arthroplasty has

some disadvantages: the metatarsal head with destruction may be allowed with resection of other head even when one or two MTP joints show radiographically normal, and there is a risk of painful callosities with bony proliferations of the metatarsal stump during longer follow-up^{4,17,23}. In addition, one study showed that during the long-term follow-up, hallux valgus recurred in more than 50% of patients who underwent resection arthroplasty,⁶ and another study showed that the recurrence of hallux valgus and toe deformity may cause patient dissatisfaction.²⁶ Arthrodesis of the first MTP joint provides a low recurrence of the hallux valgus deformity but has been also reported some disadvantages, including more degeneration of the interphalangeal joint^{2,39}, excessive pressure on the first toe², and relatively high complication and reoperation rates¹⁶. Therefore, we indicated the arthrodesis for severe hallux valgus, and these patients have not been included in the current study. On the other hand, various modifications of joint-preserving procedures have also been performed with good clinical results.^{3,11,13,14,33,34,36,42} Joint-preserving procedures for the correction of RA-associated forefoot deformities has some advantages: It contributes to reconstruction of the transverse metatarsal arch, corrects the metatarsus latus, and preserves the joint function (especially of the fulcrum of the flexor tendon).³⁴ Fukushi et al. reported that joint-preserving procedures for rheumatoid forefoot deformities resulted in better clinical

outcomes than resection arthroplasty with regard to the function of the hallux and the alignment of the lesser toes.⁹ However, the joint-preserving procedure also has some disadvantages: the recurrence of hallux valgus deformity³⁶, the forefoot stiffness^{22,33}, and severe destruction of the metatarsal head is not a good indication for a joint-preserving procedure.^{9,33,42} The SOO method described by Hanyu et al. involved temporary fixation of the osteotomy sites by 1.2-mm K-wires from the distal phalanx to the metatarsal shaft. The K-wires are removed 3 weeks postoperatively.¹¹ Using a similar postoperative protocol, Hirao et al. showed an MTP joint ROM limitation of less than 70 degrees and indicated that decreased ROM in the MTP joints should be factor that decreases the postoperative functional score.¹⁴ In patients with inactive RA, decreased ROM of the MTP joints is associated with decreased walking velocity and stride length.²⁰ However, screw fixation has several advantages over K-wire fixation. Our procedure does not involve fixation of the MTP joint and is not invasive for phalangeal bones. Early postoperative ROM exercises for the MTP joint can be started, thus contributing to improved postoperative ROM and function of the feet. Because the shortening of the metatarsal bone was almost performed by sliding up of the distal fragment at the osteotomy site, the amount of shortening was less than that in previous reports.³⁴ Increasing the amount of shortening contributes to imbalance between the flexor tendon

and extensor tendon. Therefore, to minimize the amount of shortening of the metatarsal bone, we released the extensor digitorum brevis tendon and performed Z-lengthening of the extensor digitorum longus tendon, soft tissue release, and synovectomy at the MTP joints. More patients in the joint-preservation than resection group found it easy to stand on the toe. One study showed that disease activity often persisted in the foot and foot joints even when patients were judged to be in remission based on the 28-joint score.⁷ In the both groups, we performed capsule synovectomy within the MTP joint and restarted the b-DMARD after the operative wound had healed. However, the disease activity was well controlled in both groups, severe hallux valgus (HVA of greater than or equal to 47 degrees) was observed in cases of recurrence. Some reports of patients without RA who underwent proximal metatarsal osteotomy for hallux valgus have suggested that a severe preoperative HVA can be a risk factor for recurrence of hallux valgus.³⁷ As in all feet with recurrence of hallux valgus, severe hallux valgus was observed preoperatively, arthrodesis of the MTP joint should be indicated for severe hallux valgus with an HVA of more than 50 degrees. Bony ankyloses in the mid-hindfoot can reportedly cause recurrence of dislocation of the lesser toe MTP joint.¹⁴ Bony ankyloses were found in the mid-hindfoot in three feet with recurrence of claw toe deformity. Yano et al. reported delayed union in 16.5% of patients who underwent SOO.⁴³ In our procedure, the

osteotomy site was secured with a single screw. The fixation force at the osteotomy site would not be lost before bone union.

There are some limitations in the current study. First, the number of the patient is too small to compare the clinical and radiographical outcomes of two procedures, because both procedures showed good clinical outcomes in the current study. Second, the indications for resection and joint-preserving procedures were not randomly divided. The indications were dependent upon the patients' age, control of disease activity, level of ADL, and destruction of the MTP joints. In the present study, the number of radiographic destruction of the MTP joints higher than Larsen grade IV was 51 and 10 toes in the resection and joint-preservation groups, respectively. We performed resection arthroplasty in 29 toes with moderate destruction of the MTP joint and joint-preserving procedure in ten toes with severe destruction of the MTP joint. Therefore, this study has some degree of selection bias. Arthrodesis of the big toe MTP joint was indicated for severe hallux valgus (HVA of more than 50 degrees). Patients with arthrodesis of the big toe MTP joint were excluded to investigate the clinical scores of resection arthroplasty and joint-preserving procedures. In addition, this study included both patients who underwent bilateral surgery and those who underwent unilateral surgery. Seven and four patients in the resection and joint-preservation groups underwent toe arthroplasty on the

contralateral foot during the follow-up, respectively. Subjective evaluations of patients were recently shown to be important tools for assessment of the postoperative outcomes of RA. Thus, studies involving subjective evaluation should be performed.

Conclusion

The resection arthroplasty and joint-preserving procedure showed satisfactory short-term clinical outcomes. However, whether both procedures can maintain the good clinical results without the recurrence of forefoot deformity should await longer careful follow-up of the current set of patients.

References

- 1) Arnett FC, Edworthy SM, Bloch DA, et al. The American Rheumatism Association 1987 revised criteria for the classification of rheumatoid arthritis. *Arthritis Rheum.* 1987;31(3):315-324.
- 2) Beauchamp CG, Kirby T, Rudge SR, Worthington BS, Nelson J. Fusion of the first metatarsophalangeal joint in forefoot arthroplasty. *Clin Orthop Relat Res.* 1984;190:249–253.
- 3) Bhavikatti M, Sewell MD, Al-Hadithy N, Awan S, Bawarish MA. Joint preserving

surgery for rheumatoid forefoot deformities improves pain and corrects deformity at midterm follow-up. *Foot (Edinb)*. 2012;22(2):81-84.

doi:10.1016/j.foot.2011.12.002.

- 4) Clayton ML. Surgery of the forefoot in rheumatoid arthritis. *Clin Orthop*. 1960;16:136-140.
- 5) Coughlin MJ, Mann RA. Surgery of Foot and Ankle. 7th ed. St. Louis: Mosby; 1999.
- 6) Coughlin MJ. Rheumatoid forefoot reconstruction. A long-term follow-up study. *J Bone Joint Surg Am*. 2000;82(3):322-341.
- 7) Felson DT, Smolen JS, Wells G, et al. American College of Rheumatology/European League against Rheumatism provisional definition of remission in rheumatoid arthritis for clinical trials. *Arthritis Rheum*. 2011;63(3):573-586. doi:10.1002/art.30129.
- 8) Fowler AW. A method of forefoot reconstruction. *J Bone Joint Surg Br*. 1959; 41-B:507-513.
- 9) Fukushi, J, Nakashima, Y, Okazaki, K, et al. Outcome of Joint-Preserving Arthroplasty for Rheumatoid Forefoot Deformities. *Foot Ankle Int*. 2016;37(3):262-8. doi:10.1177/1071100715609981.
- 10) Grondal L, Tengstrand B, Nordmark B, Wretenberg P, Stark A. The foot: still the

most important reason for walking incapacity in rheumatoid arthritis: distribution of symptomatic joints in 1,000 RA patients. *Acta Orthop*. 2008;79(2):257-261. doi: 10.1080/17453670710015067.

11) Hanyu T, Yamazaki H, Murasawa A, Tohyama C. Arthroplasty for rheumatoid forefoot deformities by a shortning oblique osteotomy. *Clin Orthop Relat Res*. 1997;338:131-138.

12) Haugeberg G, Boyesen P, Helvetian K, Proven A. Clinical and radiographic outcomes in patients diagnosed with early rheumatoid arthritis in the first years of the biologic treatment era: a 10-year prospective observational study. *J Rheumatol*. 2015;42(12):2279-2287. doi:10.3899/jrheum.150384.

13) Helal B. Metatarsal osteotomy for metatarsalgia. *J Bone Joint Surg Br*. 1975;57(2):187-192.

14) Hirao M, Ebina K, Tsuboi H, et al. Outcomes of modified metatarsal shortening offset osteotomy for forefoot deformity in patients with rheumatoid arthritis: Short to mid-term follow-up. *Mod Rheumatol*. 2017. [Epub ahead of print]. doi: 10.1080/14397595.2016.1276512.

15) Hoffmann P. An operation for severe grades of contracted or clawed toes. *Am J Orthop Surg*. 1911;9:441-449.

- 16) Hughes J, Grace D, Clark P, Klenerman L. Metatarsal head excision for rheumatoid arthritis: 4-year follow-up of 68 feet with and without hallux fusion. *Acta Orthop Scand*. 1991;62:63-66.
- 17) Hulse N, Thomas AM. Metatarsal head resection in the rheumatoid foot: 5-year follow-up with and without resection of the first metatarsal head. *J Foot Ankle Surg*. 2006;45(2):107-112. doi:10.1053/j.jfas.2005.12.005.
- 18) Ikari K, Momohara S. Images in clinical medicine. Bone changes in rheumatoid arthritis. *N Engl J Med*. 2005;353(15):e13. doi:10.1056/NEJMicm050315.
- 19) Jaakkola, J. I, Mann, R. A. A review of rheumatoid arthritis affecting the foot and ankle. *Foot Ankle Int*. 2004;25(12):866-874.
- 20) Laroche D, Pozzo T, Ornetti P, Tavernier C, Maillefert JF. Effects of loss of metatarsophalangeal joint mobility on gait in rheumatoid arthritis patients. *Rheumatology (Oxford)*. 2006;45(4):435-440. doi:10.1093/rheumatology/kei168.
- 21) Larsen A, Dale, K. Eek, M.. Radiographic evaluation of rheumatoid arthritis and related conditions by standard reference films. *Acta Radiol Diagn (Stockh)*. 1977; 18(4):481-491.
- 22) Louwerens, JW, Schrier, JC. Rheumatoid forefoot deformity: pathophysiology, evaluation and operative treatment options. *Int Orthop*. 2013;37(9):1719-1729.

doi:10.1007/s00264-013-2014-2.

- 23) Mann RA, Thompson FM. Arthrodesis of the first metatarsophalangeal joint for hallux valgus in rheumatoid arthritis. *J Bone Joint Surg Am.* 1984;66:687–692.
- 24) Mann RA, Schakel ME II. Surgical correction of rheumatoid forefoot deformities. *Foot Ankle Int.* 1995;16:1–6.
- 25) Matricali GA, Boonen A, Verduyck J, et al. The presence of forefoot problems and the role of surgery in patients with rheumatoid arthritis. *Ann Rheum Dis.* 2006;65(9):1254-1255. doi:10.1136/ard.2005.050823.
- 26) Matsumoto T, Kadono Y, Nishino J, et al. Midterm results of resection arthroplasty for forefoot deformities in patients with rheumatoid arthritis and the risk factors associated with patient dissatisfaction. *J Foot Ankle Surg.* 2014;53(1):41-46. doi: 10.1053/j.jfas.2013.09.014.
- 27) McGarvey SR, Johnson KA. Keller arthroplasty in combination with resection arthroplasty of the lesser metatarsophalangeal joints in rheumatoid arthritis. *Foot Ankle Int.* 1988;9(2):75-80.
- 28) Michelson J, Easley M, Wigley FM, Hellmann D. Foot and ankle problems in rheumatoid arthritis. *Foot Ankle Int.* 1994;15:608–613.
- 29) Momohara S, Inoue E, Ikari K, et al. Recent trends in orthopedic surgery aiming to

improve quality of life for those with rheumatoid arthritis: data from a large observational cohort. *J Rheumatol.* 2014;41(5):862-866. doi: 10.3899/jrheum.131018.

- 30) Miller, J. W. Distal first metatarsal displacement osteotomy. Its place in the schema of bunion surgery. *J Bone Joint Surg Am.* 1974;56:923-931.
- 31) Niki H, Aoki H, Inokuchi S, et al. Development and reliability of a standard rating system for outcome measurement of foot and ankle disorders I: interclinician and intraclinician reliability and validity of the newly established standard rating scales and Japanese Orthopaedic Association rating scale. *J Orthop Sci.* 2005;10(5):457-465. doi:10.1007/s00776-005-0936-2.
- 32) Niki H, Aoki H, Inokuchi S, et al. 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;10(5):466-474. doi:10.1007/s00776-005-0937-1.
- 33) Niki H, Hirano T, Akiyama Y, Mitsui H, Fujiya H. Long-term outcome of joint-preserving surgery by combination metatarsal osteotomies for shortening for forefoot deformity in patients with rheumatoid arthritis. *Mod Rheumatol.*

2015;25(5):683–688. doi:10.3109/14397595.2015.1008672.

- 34) Nishida, K, Machida, T, Horita, M, et al. Shortening Oblique Osteotomy with Screw Fixation for Correction of the Lesser Metatarsophalangeal Joints of Rheumatoid Forefoot. *Acta Med Okayama*. 2016;70(6):477-483.
- 35) Pincus T, Summey JA, Soraci SA Jr, Wallston KA, Hummon NP. Assessment of patient satisfaction in activities of daily living using a modified Stanford health assessment questionnaire. *Arthritis Rheum*. 1983;26(11):1346–1353.
- 36) Takakubo Y, Takagi M, Tamaki Y, et al. Mid-term results of joint-preserving procedures by a modified Mann method for big toe deformities in rheumatoid patients undergoing forefoot surgeries. *Mod Rheumatol*. 2010;20(2):147-153.
doi:10.1007/s10165-009-0253-2.
- 37) Tanaka Y, Takakura Y, Kumai T, et al. Proximal spherical metatarsal osteotomy for the foot with severe hallux valgus. *Foot Ankle Int*. 2008;29(10):1025-1030.
doi:10.3113/FAI.2008.1025.
- 38) Trieb, K. Management of the foot in rheumatoid arthritis. *J Bone Joint Surg Br*. 2005;87(9):1171-1177. doi:10.1302/0301-620X.87B9.16288.
- 39) Vahvanen V, Piirainen H, Kettunen P. Resection arthroplasty of the metatarsophalangeal joints in rheumatoid arthritis. A follow-up study of 100 patients.

Scand J Rheumatol. 1980;9(4):257–265.

- 40) Watson MS. A long-term follow-up of forefoot arthroplasty. *J Bone Joint Surg Br.* 1974;56B(3):527–533.
- 41) Wells G, Becker JC, Teng J, et al. Validation of the 28- joint Disease Activity Score (DAS28) and European League Against Rheumatism response criteria based on C-reactive protein against disease progression in patients with rheumatoid arthritis, and comparison with the DAS28 based on erythrocyte sedimentation rate. *Ann Rheum Dis.* 2009;68(6):954-960. doi:10.1136/ard.2007.084459.
- 42) Yano K, Ikari K, Iwamoto T, et al. Proximal rotational closing-wedge osteotomy of the first metatarsal in rheumatoid arthritis: clinical and radiographic evaluation of a continuous series of 35 cases. *Mod Rheumatol.* 2013;23(5):953-958.
doi:10.1007/s10165-012-0776-9.
- 43) Yano, K, Ikari, K, Ishibashi, M, Momohara, S. Preventing delayed union after distal shortening oblique osteotomy of metatarsals in the rheumatoid forefoot. *Mod Rheumatol.* 2016;26(4):546-550. doi: 10.3109/14397595.2015.1106638.

Legends

Table 1. Patients' demographic and clinical parameters.

All values are expressed as mean (range). *Statistically significant ($P < .05$)

Abbreviations: cs-DMARDs, conventional synthetic disease-modifying antirheumatic drugs; MTX, methotrexate; PSL, prednisolone; b-DMARDs, biologic disease-modifying antirheumatic drugs; DAS28, Disease Activity Score 28; mHAQ, modified Health Assessment Questionnaire.

Table 2. Clinical and radiographic outcomes of resection and joint-preservation groups.

All values are expressed as mean (range). *Statistically significant ($P < .05$)

Abbreviations: Preop., preoperative; Postop., postoperative; JSSF-RA scale, Japanese Society of Surgery of the Foot standard rating system for the RA foot and ankle scale.

HVA, hallux valgus angle; M1M2A, intermetatarsal angle of the first and second metatarsals; M1M5A, intermetatarsal angle of the first and fifth metatarsals.

Table 3. The number of complication in the resection and joint-preservation groups

All values are expressed as mean (range). *Statistically significant ($P < .05$)

Abbreviation: HVA, hallux valgus angle.

Figure 1. A, B: Radiographic findings before (A) and after (B) resection arthroplasty for severe destruction of the MTP joints. C, D: Radiographic findings before (C) and after (D) resection arthroplasty for moderate destruction of the MTP joints.

Figure 2. A, B: Radiographic findings before (A) and after (B) shortening oblique osteotomy for the lesser metatarsal bone with screw fixation for moderate destruction of the MTP joints. Correction osteotomy and plate fixation were performed for the first metatarsal bone. C, D: Radiographic findings before (C) and after (D) shortening oblique osteotomy for the lesser metatarsal bone with screw fixation for severe destruction of the MTP joints.

Figure 3. Surgical procedure for shortening oblique osteotomy for lesser metatarsal bone. An osteotomy is done first (A), distal fragment is slide up at the osteotomy site and dill hole for 2.0mm or 2.5mm diameter screw is made along with the guide wire inserted from center of distal fragment at the level of the metatarsal neck (B). Bones are then fixed by selected length of cannulated cancellous screw (C).