Clinical Benefit of Joint Distraction in the Treatment of Severe Osteoarthritis of the Ankle

Proof of Concept in an Open Prospective Study and in a Randomized Controlled Study

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Objective. **Osteoarthritis (OA) is a degenerative, disabling joint disease that affects >10% of the adult population. No effective disease-modifying treatment is available. In the present study, we used joint distraction, a relatively new treatment in which mechanical contact between the articular surfaces is avoided while intraarticular intermittent fluid pressure is maintained, to treat patients with severe OA of the ankle.**

Methods. **Patients with severe ankle OA (n = 57) who were being considered for joint fusion (arthrodesis) were treated with joint distraction in an open prospective study. In addition, a randomized trial was performed in 17 patients to determine whether joint distraction had a better outcome than debridement. A standardized evaluation protocol (physical examination, assessment of pain, mobility, and functional ability) was used, and changes in radiographic joint space width and subchondral sclerosis were measured. Thirty-eight patients in the open study have been followed up for >1 year, with up to 5 years of followup in 7 of them (mean ± SD followup 2.8 ± 0.3 years). Patients in the randomized study have been followed up for 1 year.**

Results. **Significant clinical benefit was found in three-fourths of the 57 patients in the open prospective study. Most interestingly, the improvement increased over time. Radiographic evaluation showed increased joint space width and decreased subchondral sclerosis. Moreover, joint distraction showed significantly better results than debridement.**

Conclusion. **The clinical benefit of joint distraction in the treatment of severe OA is proof of the concept. Although the followup remains relatively short and effects over time remain unpredictable, our study creates possibilities for the treatment of severe OA in general. Considering the high prevalence of OA and the lack of a cure for it, joint distraction as a treatment of severe OA may have great medical, social, and economic impact.**

Osteoarthritis (OA) is a highly prevalent degenerative joint disorder. It is a multifactorial disease characterized by damage to articular cartilage and subchondral bone. It is frequently accompanied by secondary synovitis. OA causes pain and joint stiffness and, in the long term, may lead to severe restriction of activity and, eventually, to disability (1,2). The disease develops over many years, and age is the main risk factor (1). However, young adults with severe joint injuries are also at increased risk of OA (3). Adequate therapy to prevent or delay joint destruction in OA is presently lacking.

Pain can be effectively treated with medication (nonsteroidal antiinflammatory drugs), possibly suppressing secondary inflammation, which, to some extent, might delay the destruction of articular cartilage (4,5). There are also studies suggesting positive effects of disease-modifying drugs (chondroprotective drugs) that

may have the potential to modify the function of chondrocytes and, with that, the structure of the articular cartilage (6,7). However, there are no adequate prospective long-term followup studies that show significant efficacy of these treatments.

In late stages of the disease, joint fusion (arthrodesis) or joint replacement (endoprosthesis) is frequently the treatment of choice. Arthrodesis is effective in relieving pain, but the pain relief comes at the expense of joint motion, which increases the risk of overloading adjacent or contralateral joints (8). This is a major problem, especially in young patients with posttraumatic OA. Arthrodesis of the major joints is not well tolerated because of the loss of function associated with the loss of physical ability. Moreover, failure of arthrodesis, with continuing pain and secondary complaints, has been reported, although in a small number of cases (9). Joint replacement is mainly used for the hip and knee joints. The results of these joint replacements are satisfactory; however, the implants have a limited lifespan (10), and the results of revision surgery are frequently disappointing. Therefore, and in light of the proportionally increasing age of the population, joint replacements should be delayed as long as possible.

Strategies that would decrease pain and improve joint function, rather than replace the joint itself, would be of great advantage, particularly in young patients. Patients with less-advanced joint degeneration who want to maintain a high level of activity may also benefit from such strategies.

Arthroscopic debridement or corrective osteotomy is frequently performed for treatment of OA. Results are reported to be unpredictable, especially in the late stages of OA, and positive results last for only a short time (10–12). Much effort has gone into the development of new approaches to stimulate articular cartilage repair (13–15). However, until now, none of these modalities have been shown to be effective (6,12).

A relatively new approach to the treatment of OA is joint distraction. This surgical technique is based on the hypothesis that OA cartilage has some reparative activity. This reparative activity may become effective when the damaged cartilage is mechanically unloaded, preventing further wear and tear, while the intermittent synovial fluid pressure, which is essential for the nutrition of cartilage, is maintained (16). The joint is distracted by means of an external fixation frame, which eliminates mechanical contact between the degenerating articular surfaces. Intermittent fluid pressure is maintained by the use of hinges in the distraction frame. The clinical benefit of this technique in the treatment of OA

was demonstrated in a study of articulating hip distraction (17). Intermittent fluid pressure can also be achieved by the use of an Ilizarov frame with thin wires tensioned to external rings. Due to the flexibility of the wires, loading and unloading of the joint, which occurs during walking, results in intermittent intraarticular fluid pressure. Walking is allowed within a few days after surgical placement of the fixator.

In a retrospective study, we found that distraction of severely affected ankle joints by means of an Ilizarov external ring fixator resulted in clinical improvement (18). In a prospective, uncontrolled study of 15 patients, we showed that joint distraction for the treatment of severe ankle OA resulted in significant relief of pain after 1 year, with further improvement during the following year. Function and clinical status also improved after 1 year and further improved during the following year (19).

In the present study, we treated a larger population of patients who had severe ankle OA (n = 57). Findings of long-term followup (mean 3 years; maximum 7 years) and objective parameters (joint space width and subchondral sclerosis) in these patients are described herein. In addition, we performed a prospective, randomized controlled trial with a followup of 1 year, in which the short-term effects of joint distraction were compared with the short-term effects of arthroscopic debridement.

PATIENTS AND METHODS

Patients in the open prospective study. Fifty-seven patients with severe ankle OA were included in the open prospective study between May 1993 and September 2000. Study inclusion was based on the presence of refractory, severely painful OA. Patients were treated at the University Medical Center of Utrecht (Utrecht, The Netherlands) (n = 24), the Onze Lieve Vrouwe Middelares Hospital (Antwerp, Belgium) (n = 20), and the University Hospital Groningen (Groningen, The Netherlands) (n = 13). Exclusion criteria were an intraarticular infection, OA in both ankle joints, and psychological problems that would not allow a 3-month period of distraction.

Patients had severe pain, functional impairment, and limited joint mobility, and had radiographic features of OA. Previous treatment with analgesics, antiinflammatory drugs, intraarticular injections of corticosteroids, or arthroscopic debridement had not been successful. Probable causes of OA consisted of congenital deformity (n = 3), deformity secondary to poliomyelitis (n = 1), fracture or subluxation of the ankle joint (n = 35), fracture of the tibia (n = 9), and unknown (n = 9). The mean (±SD) interval between the probable disease-related trauma and joint distraction was 10.8 ± 10.1 years. The mean (±SD) age of the patients was 44 ± 11 years (range 18–65 years), including 26 female and 31 male.

Patients in the randomized controlled trial. Seventeen patients with severe ankle OA were included in the randomized controlled trial between June 1997 and September 1999 at the University Medical Center Utrecht. Patients were included if scores on 3 of the 5 clinical parameters (pain, functional impairment, physical impairment, impaired joint mobility, and joint space narrowing) exceeded 50% of the maximum score. Joint mobility and narrowing of the joint space were as compared with the contralateral control joint. Exclusion criteria were the same as in the open prospective study.

In 15 of 17 patients, the cause of OA was fracture or subluxation of the ankle joint. One patient developed OA due to deformation of the ankle caused by poliomyelitis. The cause of OA was not known in 1 patient. The mean ($\pm$SD) interval between the probable disease-related trauma and joint distraction was 11.8 $\pm$ 7.0 years. Patients were randomly assigned to 1 of 2 treatment groups: 9 patients (mean $\pm$ SD age 44 $\pm$ 10 years; 3 women and 6 men) were randomized to undergo joint distraction, and 8 patients (mean age 45 $\pm$ 10 years; 3 women and 5 men) were randomized to undergo debridement. The patients in the randomized controlled study were not included in the open prospective study.

Treatment. In the *open prospective study*, distraction of the tibiotalar joint was preceded, when necessary, by arthroscopic debridement. Intraarticular fibrotic tissue and osteophytes, if present, were removed by shaving in 35 of 57 patients so that the foot could be placed in the plantigrade position that is necessary for distraction.

In the *randomized controlled trial*, all patients were examined arthroscopically. Debridement was performed in 7 of the 9 patients in the Ilizarov fixator group and in all 8 patients in the debridement control group. No articular cartilage surgery was performed.

The severity of cartilage destruction on the talus and tibia was graded according to the modified Outerbridge criteria (20). In 13% of the patients in the open prospective study, cartilage degradation was graded as 1 or 2; in the remaining 87%, cartilage degradation was graded as $\geq$3. This grading was mostly based on a local cartilage defect. Moderate synovial hypertrophy was seen in ~50% of the patients. This distribution was similar in both the uncontrolled and the controlled studies.

Surgical placement of the Ilizarov fixator. Immediately following arthroscopic surgery, the Ilizarov external ring fixator was applied. Two Kirschner wires were drilled at different angles proximally and distally through the tibia and fixed under tension (1.3 kN) to an external ring (Figure 1). Four threaded rods connected these external rings. Two wires with olives were drilled through the calcaneus and tensioned (0.9 kN) to a half-ring around the heel. One wire with olive was drilled through the metatarsal bones and tensioned (1.3 kN) to a half-ring over the forefoot. The half-ring was connected to plates at the medial and lateral sides of the foot and extended from the half-ring around the heel. One Kirschner wire was drilled through the talus and fixed to the foot frame without tension, in order to prevent subtalar distraction. The rings around the foot and the tibia were connected with 4 lengthening rods.

Distraction of the tibiotalar joint was performed twice a day for 0.5 mm each until a total distraction of at least 5 mm (as seen radiographically during full weight bearing) was
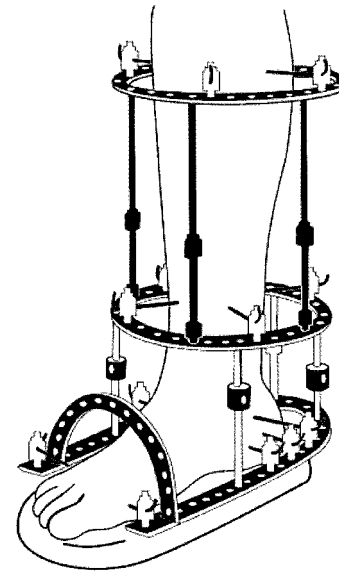
Figure 1. Application of the Ilizarov external ring fixator for distraction of the ankle joint in the treatment of severe osteoarthritis.

reached. In 2 patients in the uncontrolled study, equinus position of the foot was gradually corrected in combination with the distraction. This was carried out by adjustment of the ring over the forefoot using a connection with the distal tibia ring. Ankle distraction was maintained for 3 months (radiographically controlled). Full weight bearing was allowed within a week after surgery. The loss of plantar flexion in the ankle during walking was compensated by use of an anterior rounded plaster sole fitted below the foot. Physical therapy and medication were administered at the patient's request only.

Evaluation. Pain, function, clinical status, ankle joint mobility, radiographic joint space width, and subchondral sclerosis were evaluated before treatment and yearly thereafter. One observer (ACAM) who was not involved in the surgery performed the clinical examinations of all patients in the 3 hospitals.

Pain was measured with the use of a box scale on which patients were asked to score their pain between 0 and 10 (with 10 being the worst); patients were reminded of their previous score. Loss of function was measured using a slight modification of the score described by Van Valburg et al (19), based on the functional index for hip and knee OA (21); the maximum score for this measure is 30 (Table 1). The clinical condition of the patients was measured by assessment of 4 features (maximum score 8) (Table 1). All 3 parameters were expressed as the percentage of the maximum score.

Ankle joint mobility was measured by the range of motion between maximum dorsal flexion and maximum plantar flexion and was expressed as a percentage of the maximum range of motion of the contralateral ankle before treatment. At the start of the study, no other measures were available, making this method the most appropriate for evaluating ankle OA. During the study, Domsic and Saltzman (22) described a validated measure of ankle OA. However, it would have been

Table 1. Clinical evaluation of the osteoarthritis study patients

Parameter, feature assessed/question asked of patient	Range of scores
Clinical condition*	
Pain during passive movement of the unloaded ankle joint	0–2
Crepitus during movement of the ankle joint	0–2
Pain during compression of the ankle joint	0–2
Swelling of the ankle joint compared with the contralateral ankle joint	0–2
Mobility†	
Treated ankle joint	ROM
Contralateral control ankle joint	ROM
Function‡	
Do you experience morning stiffness or regressive pain after arising?	0–3
Do you experience pain when sleeping?	0–3
Do you experience pain during rest?	0–3
Do you experience pain when getting started (e.g., while getting up from a chair when you start to walk)?	0–3
Do you experience pain while you are standing?	0–3
Do you experience pain while you are walking?	0–3
Do you experience pain while you are walking on uneven ground?	0–3
Do you experience pain while going upstairs?	0–3
Do you experience pain while going downstairs?	0–3
What is your maximum walking distance?	0–3
Pain	
Judge the severity of the pain in the treated ankle, using a scale of 0 to 10, where 0 = no pain and 10 = pain as bad as it could be.	0–10

* Clinical condition answers were rated as follows: none = 0, moderate/sometimes = 1, and obvious/yes = 2.
† Mobility was determined as the range of motion (ROM; i.e., range between maximum dorsal flexion and maximum plantar flexion [in degrees]) of the ankle joint. The maximum ROM in the treated joint was expressed as a percentage of the maximum ROM of the contralateral control joint before treatment.
‡ Function answers were rated as follows: none = 0, little = 1, mild = 2, and much = 3. Maximum walking distance was rated as follows: unlimited = 0, up to 1,000 meters = 1, up to 500 meters = 2, and up to 100 meters = 3.

inappropriate to change the method of evaluating a feature halfway through the study.

Standardized radiographs suitable for digital analysis according to the recently described ankle images digital analysis (AIDA) method (23) were taken only at the University Medical Center Utrecht. Radiographs were taken of both ankles before treatment and of the OA ankle each year after treatment. Since contralateral control ankles did not show any signs of OA, no followup radiographs were taken. With regard to the reproducibility of the radiographic procedures, coefficients of variation in measurements of joint space width ranged from 3.8% to 6.5%. Coefficients of variation in measurements of subchondral sclerosis ranged from 1.9% to 7.9%.

Digitization of the radiographs was performed at 8 bits, with a spatial resolution of 300 dots per inch. Each image was transformed into a standard orientation, such that the fibula was located on the right side of the image. These digital images were used for analysis of the mean joint space width and subchondral bone density by using the semiautomatic method AIDA (23). Radiographs were evaluated by one observer (FPJGL) who had no clinical background and who was blinded to the source of the radiographs.

Joint space width was defined as the interbone distance of the tibiotalar joint and was normalized to the width of the ankle joint, normalizing for a possible enlargement of the radiograph. Subchondral bone density of each radiograph was normalized to the reference value of the radiograph of the OA ankle before treatment to be able to compare subchondral bone density over time. AIDA is a reliable method for measuring small changes in joint space width and subchondral sclerosis. Intra- and interobserver variation of both measures was evaluated according to the method of Bland and Altman (24). In that study, there were only small differences between the first and the second measurement for each observer. For example, for a mean ($\pm$SD) joint space width of 2.00 $\pm$ 0.85 mm (n = 32) measured with AIDA, the mean difference between the first and second measurements was -0.01 ± 0.22 mm.

Subchondral sclerosis was quantified relative to the reference circle in the tibial shaft, which did not change statistically ($P > 0.5$) over the 5 years of followup. Intra- and interobserver variation was modest, that is, the measurements were highly reliable. For example, for a mean ($\pm$SD) subchondral sclerosis value of 1.52 $\pm$ 0.29 (n = 32), the mean difference between the first and second measurements was 0.00 $\pm$ 0.22.
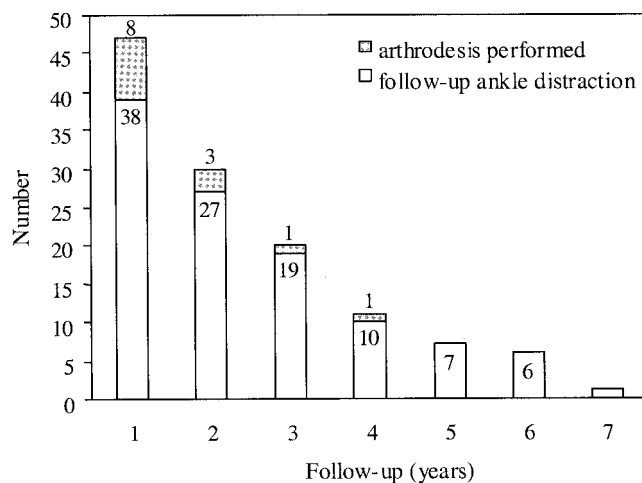
Statistical analysis. The Wilcoxon signed rank test for correlated data was used to compare data obtained before and after treatment and to compare data from different time points after treatment. For the randomized controlled trial, power

analysis dictated 8 patients per group. The Mann-Whitney U test was used to evaluate whether joint distraction has a better clinical result than arthroscopic debridement alone. Statistical evaluation was performed by intent-to-treat analysis for all randomized patients. The Spearman correlation was used to compare clinical outcome with radiographic parameters. P values less than 0.05 were considered statistically significant.
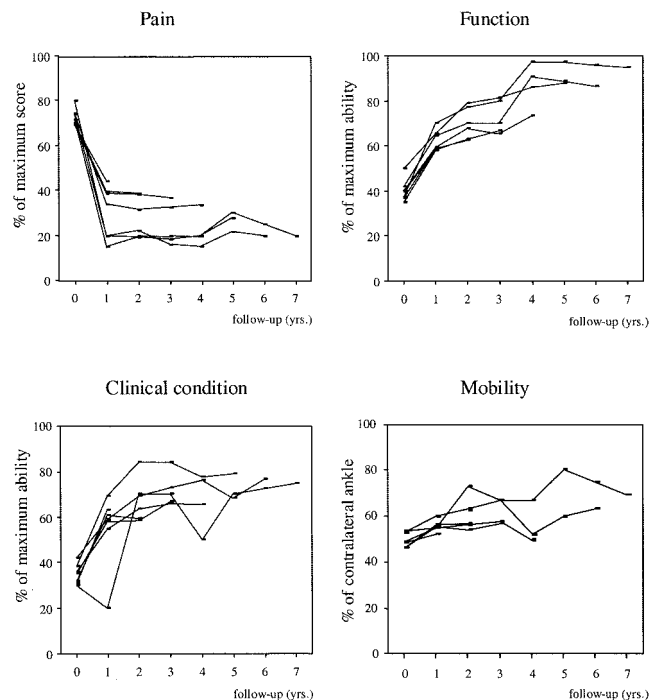
RESULTS

Findings of the open prospective study. At the time of evaluation, 11 patients had been followed up for <1 year and were therefore not included in the evaluation. The numbers of patients evaluated at each year of followup are shown in Figure 2. The mean ± SEM period of followup was 2.8 ± 0.3 years. Thirteen patients withdrew from the study; 8 of them withdrew within 1 year after distraction. Persistent pain was always the reason for withdrawal, and all these patients underwent arthrodesis, which was the treatment being considered before they entered this study.

During joint distraction, no serious complaints were reported. Infections at the pin sites were found occasionally (n = 16), but these were effectively treated with antibiotics. In 8 patients, the wires through the forefoot broke, probably because of excessive strain during walking. In 5 of these patients, the broken pin was removed, and in the 3 other patients, the pin was replaced; local infections were prevented (or treated) with antibiotics. After removal of the frame, all patients

Figure 3. Clinical results of joint distraction in the open prospective study. Average scores for pain, function, clinical condition, and mobility are given before treatment (n = 38) and at 1 year (n = 38), 2 years (n = 27), 3 years (n = 19), 4 years (n = 10), 5 years (n = 7), 6 years (n = 6), and 7 years (n = 1) after initiation of treatment. Values are the percentage of the maximum score (10 points for pain, 30 points for function, and 8 points for clinical condition), except for joint mobility, which is the percentage of mobility of the contralateral ankle.

Figure 2. Followup of patients in the open prospective study, by year. Numbers in the open bars are the number of patients evaluated each year. Shaded bars with numbers above are the number of patients who underwent ankle distraction but withdrew from the study because of persistent pain. These patients underwent arthrodesis during the indicated year.

were able to walk; most of them used crutches during the first month.

Clinical changes. Average scores for pain, function, clinical condition, and ankle joint mobility are shown in Figure 3. One year postsurgery (n = 38), the average score for pain decreased by 38% ($P < 0.0001$), the average score for function increased by 69% ($P < 0.0001$), the average score for clinical condition increased by 120% ($P < 0.0001$), and joint mobility increased by 8% (P not significant). Most interestingly, the improvement in these parameters increased over time. For example, at 3 years of followup (n = 19), function and clinical condition were statistically significantly improved compared with the outcome at 1 year (20% [$P < 0.03$] and 43% [$P < 0.05$] increase, respectively). The progressive clinical benefit was maintained during the entire period of followup.

It is possible that the patients' answers to the questions about clinical changes were influenced by their

Table 2. Percentage of treated patients showing clinically important differences during followup*

	≥35% improvement in clinical parameters†				≥25% improvement in objective parameters	
Followup	Pain	Function	Clinical condition	Mobility	Joint space width‡	Sclerosis§
1 year	55	53	55	13	33	10
2 years	63	41	63	30	70	0
3 years	58	53	68	32	71	40
4 years	50	70	60	10	67	0
5 years	71	86	71	14	67	50
6 years	83	100	83	17	–	–
7 years	100	100	100	0	–	–

* The percentages of patients who showed ≥35% improvement in clinical parameters and ≥25% improvement in objective parameters were calculated according to the Outcome Measures in Rheumatology Clinical Trials criteria (25).
† The total number of patients evaluated at each year of followup were as follows: 38 patients at 1 year, 27 at 2 years, 19 at 3 years, 10 at 4 years, 7 at 5 years, 6 at 6 years, and 1 at 7 years.
‡ Changes in joint space width were evaluated in patients who had >10% joint space narrowing before treatment: 12 patients at 1 year, 10 at 2 years, 7 at 3 years, 3 at 4 years, and 3 at 5 years.
§ Changes in subchondral sclerosis were evaluated in patients who had increased subchondral bone density (compared with the contralateral ankle) before treatment: 10 patients at 1 year, 7 at 2 years, 5 at 3 years, 3 at 4 years, and 2 at 5 years.

level of activity. This was not the case, however, because if patients were not able to perform the specific activities referred to in the questions, they were given the maximum score. In addition, we evaluated the question about maximum walking distance separately to verify each patient's level of activity. Impairment of maximum walking distance changed beneficially over time, with a score of 1.46 ± 0.18 before treatment and 0.92 ± 0.2 at 1 year after treatment ($P < 0.03$). Five years after treatment, maximum walking distance was unlimited (mean score for impaired walking distance was 0.0 ± 0; $P < 0.04$).

Clinically important differences. We calculated clinically important changes in outcome based on the criteria described by Goldsmith et al (25) (Table 2). Three years after initiation of treatment, >35% improvement in pain, function, and clinical condition was achieved in, respectively, 11, 10, and 13 of the 19 treated patients assessed at that time point. In 7 patients at 3 years of followup, all 3 parameters had improved by >35%. Six patients showed >35% improvement in mobility.

Radiographic changes. Radiographs from only 17 of the 24 patients at the University Medical Center Utrecht were useful for evaluation. In 12 of these 17

patients (>70%), there was joint space narrowing of >10% (mean ± SEM $47.1 \pm 8.6\%$) in the affected joint compared with the contralateral ankle joint before treatment (Figure 4A). One year postsurgery (n = 12), the average joint space width increased by 17% ($P < 0.04$) (Figure 4A). Joint space width also improved over time. For example, at 3 years postsurgery, the joint space width was increased by an additional 10% ($P < 0.05$) compared with the width at 1 year of followup. In the remaining 5 patients, joint space narrowing in the affected joint before treatment was <10%. On average, these patients showed no significant change in joint space width over time.

Subchondral sclerosis (higher mean subchondral bone intensity according to the AIDA method in the experimental joint compared with the contralateral joint before treatment) was found in 10 of the 17 patients. A mean ± SEM subchondral bone density of 1.81 ± 0.3 was calculated in the affected ankle joint compared with 1.59 ± 0.3 in the control joint (Figure 4B). One year postsurgery, subchondral bone density was decreased by
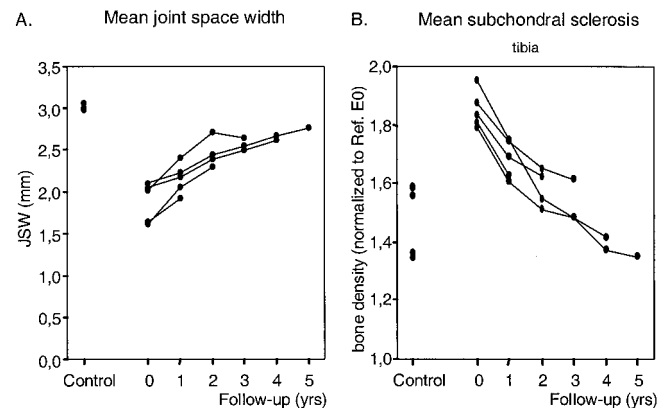
Figure 4. Radiographic changes after joint distraction in the open prospective study. Changes in joint space width and subchondral sclerosis were assessed using ankle images digital analysis (23). **A,** Mean joint space width (JSW) in the contralateral control ankle before treatment only (n = 12) and in the affected ankle before treatment (n = 12) and at yearly intervals after initiation of treatment (n = 12 at 1 year, n = 10 at 2 years, n = 7 at 3 years, n = 3 at 4 years, and n = 2 at 5 years). Only patients with joint space narrowing of >10% before treatment (12 of 17 patients) are shown. **B,** Subchondral bone density in the tibia of the contralateral control ankle before treatment only (n = 10) and in the affected ankle before treatment (n = 10) and at yearly intervals after initiation of treatment (n = 10 at 1 year, n = 7 at 2 years, n = 5 at 3 years, n = 3 at 4 years, and n = 2 at 5 years). Only patients with increased subchondral sclerosis in the affected ankle compared with the control ankle before treatment (10 of 17 patients) are shown. Subchondral bone density was quantified relative to the reference circle in the tibial shaft and normalized to the reference circle of the osteoarthritic ankle before treatment (Ref. E0) (23).

an average of 10% ($P < 0.003$). Subchondral sclerosis remained diminished during the years of followup, and a tendency toward improvement over time was observed (3 years postsurgery, subchondral bone density was diminished by an additional 7%, on average, compared with that at 1 year of followup; $P > 0.23$). In the remaining 7 patients without measurable subchondral sclerosis before treatment, no significant decrease in bone density over time was found on average.

With respect to all clinical outcome parameters, no subpopulations could be identified. For example, no differences in outcome between patients at the 3 institutions could be found. Moreover, the cause of OA, presence or absence of preceding debridement, age, sex, and the degree of joint space narrowing did not significantly influence clinical outcome.

Findings of the randomized controlled trial. To investigate whether the beneficial effects of joint distraction in the treatment of severe OA were mainly achieved by the arthroscopic debridement that often, but not always, preceded the distraction procedure, we compared the effects of joint distraction with the effects of debridement alone in a randomized controlled trial of a separate group of 17 patients. Infections at the pin sites occurred in 3 patients in this study. In 1 patient, the pin through the forefoot was replaced, and in 1 patient, the pin through the proximal tibia was replaced. After removal of the frame, all patients walked with or without crutches, depending on the level of pain they were experiencing.

Clinical changes. Consistent with the findings in the open prospective study, the average score for pain decreased from 72% to 37% of the maximum score ($P < 0.003$), function increased from 19% to 61% ($P < 0.004$), and clinical status increased from 20% to 69% ($P < 0.005$) 1 year after joint distraction (see Figure 5). Mobility decreased from 56% to 46% (P not significant). In the group treated with debridement alone, 3 of the 8 patients did not reach 1 year of followup despite the experimental setup. Because of persistent severe pain, they were considered treatment failures and underwent joint distraction between 4 months and 11 months after debridement. For these 3 patients, the last evaluation before joint distraction was used to calculate the averages for the control group. The effects of joint distraction in these 3 patients were not included in the joint distraction group.

The values before treatment in the debridement group were not significantly different from those in the distraction group in this study and in the open prospective study. The average scores were 76%, 72%, and 70%
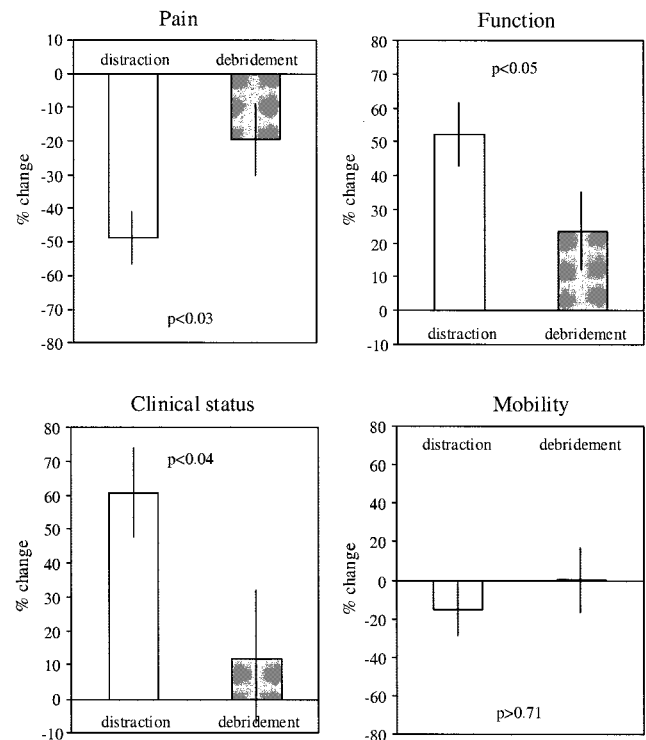
Figure 5. Clinical changes after joint distraction versus debridement in the randomized controlled trial of 17 patients with severe ankle osteoarthritis. Shown are changes in pain, function, clinical condition, and joint mobility 1 year after treatment. Values are the mean ± SEM change, calculated as the percentage of the pretreatment values.

for pain, 28%, 19%, and 34% for function, 30%, 20%, and 29% for clinical status, and 67%, 56%, and 51% for mobility in, respectively, the debridement group in the randomized study, the distraction group in the randomized study, and all patients in the open uncontrolled study (P not significant). Changes after debridement alone, however, were significantly less profound at 1 year of followup compared with those in the distraction group (statistically significant differences except for joint mobility). Moreover, the 3 failures from the debridement group underwent joint distraction and experienced 59% improvement in pain, 55% improvement in function, and 74% improvement in clinical condition (compare with the data in Figure 5).

Radiographic changes. Changes in joint space width and subchondral sclerosis 1 year after initiation of treatment are shown in Figure 6. Joint space narrowing of >10% before treatment was present in 9 of the 17 patients (comparable to the open prospective study), 4 of whom were treated with joint distraction and 4 were treated with debridement alone. The patients treated

A.

Change in JSW

B.

Change in subchondral sclerosis
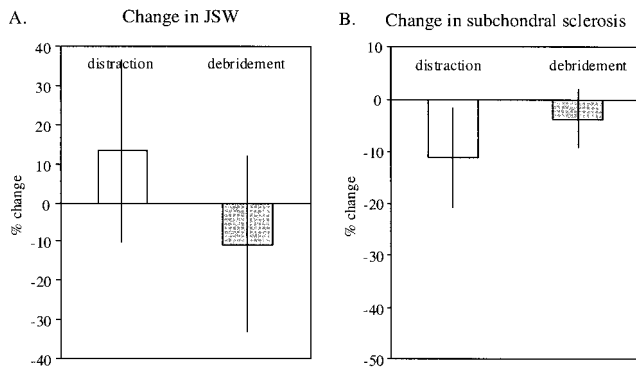
Figure 6. Radiographic changes after joint distraction versus debridement in the randomized controlled trial. Changes in joint space width (JSW) and subchondral sclerosis were assessed using ankle images digital analysis (23) and were calculated as the percentage of the parameters before treatment. **A,** Mean (±SEM) percentage of change in radiographic JSW of the affected ankle in patients with joint space narrowing >10% before treatment, of whom 4 were treated with distraction and 4 with debridement. **B,** Mean (±SEM) percentage of change in subchondral bone density in the affected ankle in patients with increased subchondral sclerosis in the affected ankle (compared with the contralateral control ankle) before treatment, of whom 3 were treated with distraction and 6 with debridement. Subchondral bone density was quantified relative to the reference circle in the tibial shaft and normalized to the reference circle of the osteoarthritic ankle before treatment (23).

with joint distraction showed a slightly increased joint space width (1.81 ± 0.32 mm before treatment and 1.96 ± 0.45 mm after treatment; P not significant), a finding consistent with those of the open prospective study. The patients treated with debridement alone showed a further decrease in joint space width (1.29 ± 0.13 mm before treatment and 1.16 ± 0.40 mm after treatment; P not significant).

Subchondral sclerosis was found in the affected ankle before treatment in 9 of the 17 patients, 3 of whom were treated with joint distraction and 6 were treated with debridement alone. The patients treated with joint distraction showed a slightly decreased subchondral bone density (1.57 ± 0.16 before treatment and 1.37 ± 0.10 after treatment; P not significant), consistent with the findings in the larger group of the open prospective study. The patients treated with debridement alone showed no change in subchondral bone density (1.56 ± 0.13 before treatment and 1.55 ± 0.08 after treatment; P not significant).

For both radiographic parameters, the patients without joint space narrowing and those without subchondral sclerosis showed, on average, no significant changes during the first year of evaluation. These findings are consistent with the findings of the open study.

Relationship between clinical parameters and radiographic parameters. In patients of both studies who were treated with joint distraction and who had subchondral sclerosis in the affected ankle before treatment, a statistically significant correlation was found between subchondral bone density and pain (R = 0.271, $P < 0.05$) as well as clinical condition (R = −0.442, $P < 0.001$).

DISCUSSION

From the results of the present study, it can be concluded that joint distraction may be a treatment of choice for severe ankle OA. A prolonged followup showed that joint distraction for ankle OA is a beneficial treatment and that the observed improvement increased with time after treatment. The objective parameters, such as subchondral bone density and joint space width, tended to normalize in patients who had subchondral sclerosis and/or joint space narrowing before treatment. However, the followup is still relatively short, and the results over longer periods of time remain to be elucidated.

It is important to consider the relatively young age of the patients and the severity of the OA. The average age of the patients was 44 years, and all of the patients were being considered for joint fusion. Currently available treatment modalities, especially for young patients with severe disabling OA, are few.

The purpose of the present study was to evaluate the concept of joint distraction as a treatment of OA. Although in this group of patients with OA of the ankle, arthrodesis might be beneficial for reduction or elimination of pain, this comes at the expense of joint mobility, which creates a risk of problems in adjacent and contralateral joints (8), particularly in relatively young patients.

Our finding that joint distraction is beneficial in the treatment of severe OA of the ankle joint creates the possibility for developing this technique for the treatment of OA of the knee and hip. If joint distraction also proves useful for the treatment of severe OA of other joints, young patients with severe knee and hip OA may recognize the greatest benefit from such treatment. In light of the increasing age of the population and the limited lifespan of an endoprosthesis, the successful application of this treatment for severe OA is of major importance. Moreover, the social, medical, and economic impact of delaying or even eliminating the need for arthrodesis or endoprosthesis would be great.

The present study proves that the clinical benefit

achieved was not the result of preceding debridement. In the uncontrolled study, patients without preceding debridement showed similar clinical outcomes as those with preceding debridement. Moreover, the previous debridement performed in almost all patients had not been effective. Most important, in the randomized controlled study, joint distraction showed a better clinical outcome than debridement alone. This is consistent with the findings that debridement in late stage OA has generally little benefit (26). In the controlled study, the 3 patients from the debridement group who, because of lack of efficacy, were treated with joint distraction within 1 year reported significant clinical benefit after joint distraction.

In one-fourth of the patients, joint distraction did not result in clinical benefit. We can only speculate about the possible explanation. In 8 patients, arthrodesis was performed within 1 year. We now know that clinical benefit from joint distraction is often not achieved until 1 year after treatment. In other words, joint distraction in these 8 patients might have been beneficial after longer followup. Indeed, most of the failures occurred in patients who were included during the beginning of the study. The presence of capsular restriction and progressive muscle weakness in severe OA, unknown intraarticular inflammatory activity, differences in loading during distraction (and with that, joint fluid flow and cartilage nutrition), differences in the underlying bone structure at the time of treatment, or even differences in etiology of the OA may all influence the final outcome of this treatment. The setup and the results of the present study do not allow for more than speculation in this respect, and therefore, additional studies are needed.

The underlying mechanisms of the clinical benefit obtained with joint distraction also remain a matter of speculation. It is probably a combination of several mechanisms that leads to the clinical benefit. Although evaluated in a limited number of patients, the increase in joint space width suggests the presence of structural changes. This may be related to actual cartilage repair, although the formation of fibrous tissue may be involved as well. The absence of mechanical stress on the cartilage surfaces while intermittent fluid flow is maintained during distraction may be of importance. In vitro experiments and in vivo experiments in dogs have shown that the combination of these two parameters is beneficial for OA cartilage and diminishes OA-related inflammatory activity (16,27,28). The persistent decrease in subchondral sclerosis after joint distraction might contribute to the clinical improvement observed. Diminished subchondral sclerosis might indicate a decreased stiffness of the subchondral bone. The improved capacity to absorb stress during joint loading reduces impact on the articular cartilage (12,29). On the other hand, cartilage repair protects subchondral bone from overload and thereby diminishes subchondral sclerosis (12,29). In both cases, changes in the subchondral bone may be involved in the persistently decreased pain (30) that occurs as a result of distraction.

The use of an external fixator may have a significant placebo effect. However, application of an external fixator without application of joint distraction is not ethically feasible. Although it is not unlikely with regard to pain, the structural changes found after joint distraction and the persistence of the clinical benefit argue against a placebo effect.

Irrespective of potential cartilage repair and underlying mechanisms, the structural changes after joint distraction and the continued efficacy over several years prove the concept of joint distraction as a treatment of OA. In light of the increased aging of the population and the limited lifespan of endoprostheses, evaluation of joint distraction for the treatment of OA of the knee and hip is justified.

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