Hallux Rigidus. Grading and Long-Term Results of Operative Treatment

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HALLUX RIGIDUS

GRADING AND LONG-TERM RESULTS OF OPERATIVE TREATMENT

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Background: There have been few long-term studies documenting the outcome of surgical treatment of hallux rigidus. The purposes of this report were to evaluate the long-term results of the operative treatment of hallux rigidus over a nineteen-year period in one surgeon's practice and to assess a clinical grading system for use in the treatment of hallux rigidus.

Methods: All patients in whom degenerative hallux rigidus had been treated with cheilectomy or metatarsophalangeal joint arthrodesis between 1981 and 1999 and who were alive at the time of this review were identified and invited to return for a follow-up evaluation. At this follow-up evaluation, the hallux rigidus was graded with a new five-grade clinical and radiographic system. Outcomes were assessed by comparison of preoperative and postoperative pain and AOFAS (American Orthopaedic Foot and Ankle Society) scores and ranges of motion. These outcomes were then correlated with the preoperative grade and the radiographic appearance at the time of follow-up.

Results: One hundred and ten of 114 patients with a diagnosis of hallux rigidus returned for the final evaluation. Eighty patients (ninety-three feet) had undergone a cheilectomy, and thirty patients (thirty-four feet) had had an arthrodesis. The mean duration of follow-up was 9.6 years after the cheilectomies and 6.7 years after the arthrodeses. There was significant improvement in dorsiflexion and total motion following the cheilectomies ($p = 0.0001$) and significant improvement in postoperative pain and AOFAS scores in both treatment groups ($p = 0.0001$).

A good or excellent outcome based on patient self-assessment, the pain score, and the AOFAS score did not correlate with the radiographic appearance of the joint at the time of final follow-up. Dorsiflexion stress radiographs demonstrated correction of the elevation of the first ray to nearly zero. There was no association between hallux rigidus and hypermobility of the first ray, functional hallux limitus, or metatarsus primus elevatus.

Conclusions: Ninety-seven percent (107) of the 110 patients had a good or excellent subjective result, and 92% (eighty-six) of the ninety-three cheilectomy procedures were successful in terms of pain relief and function. Cheilectomy was used with predictable success to treat Grade-1 and 2 and selected Grade-3 cases. Patients with Grade-4 hallux rigidus or Grade-3 hallux rigidus with <50% of the metatarsal head cartilage remaining at the time of surgery should be treated with arthrodesis.

Level of Evidence: Therapeutic study, Level IV (case series [no, or historical, control group]). See Instructions to Authors for a complete description of levels of evidence.

Hallux rigidus is a term used to describe symptoms commonly associated with degenerative arthritis of the first metatarsophalangeal joint. Surgical treatment of protracted symptomatic hallux rigidus includes cheilectomy[1-13], excisional arthroplasty[14-20], interposition arthroplasty[13,21-25], phalangeal osteotomy[26-30], first metatarsal osteotomy[16,31-40], implant arthroplasty[16,41-47], and arthrodesis[14,48-68].

Cheilectomy has been recommended in a number of reports[1-4,6-8,11-13,69]; however, in many of the studies, the duration of follow-up was less than one year[2,3,12,69] or some or all of the patients were not examined at the time of final follow-up[12,69]. In some studies, a substantial number of patients were lost to final follow-up[11,13]; in others, cheilectomy was combined with phalangeal osteotomy[13,27,29], metatarsal osteotomy[34] , or interposition arthroplasty[23]. Some authors reported a technique consisting solely of the removal of the osteophytes in line with the dorsal metatarsal cortex[2,6,8-10,12,16,21,23,27,29,48], and several of them recommended cheilectomy as a treatment for early disease only[2,6,8,12]. Although Nilsonne[21] and Bonney and Macnab[70] found cheilectomy to be unsuccessful, others have reported successful results with cheilectomy for all levels of disease[3,7,11] and have recommended a more aggressive resection of the metatarsal head. Radiographic signs of deterioration of the metatarsophalangeal joint over time have been reported after cheilectomy[1,4,7,8], but continued good clinical function despite the worsening radiographic appearance has been noted in these studies.

Arthrodesis of the first metatarsophalangeal joint has

TABLE I Clinical-Radiographic System for Grading Hallux Rigidus

Grade	Dorsiflexion	Radiographic Findings*	Clinical Findings
0	40° to 60° and/or 10% to 20% loss compared with normal side	Normal	No pain; only stiffness and loss of motion on examination
1	30° to 40° and/or 20% to 50% loss compared with normal side	Dorsal osteophyte is main finding, minimal joint-space narrowing, minimal periarticular sclerosis, minimal flattening of metatarsal head	Mild or occasional pain and stiffness, pain at extremes of dorsiflexion and/or plantar flexion on examination
2	10° to 30° and/or 50% to 75% loss compared with normal side	Dorsal, lateral, and possibly medial osteophytes giving flattened appearance to metatarsal head, no more than 1/4 of dorsal joint space involved on lateral radiograph, mild-to-moderate joint-space narrowing and sclerosis, sesamoids not usually involved	Moderate-to-severe pain and stiffness that may be constant; pain occurs just before maximum dorsiflexion and maximum plantar flexion on examination
3	≤10° and/or 75% to 100% loss compared with normal side. There is notable loss of metatarsophalangeal plantar flexion as well (often ≤10° of plantar flexion)	Same as in Grade 2 but with substantial narrowing, possibly periarticular cystic changes, more than 1/4 of dorsal joint space involved on lateral radiograph, sesamoids enlarged and/or cystic and/or irregular	Nearly constant pain and substantial stiffness at extremes of range of motion but not at mid-range
4	Same as in Grade 3	Same as in Grade 3	Same criteria as Grade 3 BUT there is definite pain at mid-range of passive motion

*Weight-bearing and anteroposterior and lateral radiographs are used.

been evaluated as a treatment for hallux rigidus by several authors[48-68]. However, in many series, the duration of follow-up was less than one year[50,51,55-57], multiple surgeons were involved[52,56,61], or more than one technique was performed[53,56]. Some studies included patients with other diagnoses such as rheumatoid arthritis or hallux valgus[49,52,55,57,58,67], and others provided inadequate information on the patients or the method of evaluation[48,51,53,56,58,59,65-67] or patients were not evaluated at the time of final follow-up[66]. We found only two reports[50,68] that dealt exclusively with the treatment of hallux rigidus, and both included patients with less than one year of follow-up.

On the basis of their individual beliefs about the etiology of hallux rigidus, authors have proposed several grading systems with either three[1,2,12,22,71-73] or four stages[35,41,50,71,74] determined according to radiographic criteria only[12,71] or a combination of clinical and radiographic criteria[1,2,17,22,41,50,72,73]. Several of these grading systems add modifications to an existing scheme[2,4,6,8,11,69], while in others the grades or treatment recommendations are based on poorly studied concepts such as metatarsus primus elevatus[41,50,71] or functional hallux limitus[17,41,50]. All of these variations make comparisons between studies difficult.

The purpose of the present study was to evaluate the predictability of a clinical-radiographic grading scale for choosing a surgical procedure, and to examine the long-term results of cheilectomies and arthrodeses performed by one surgeon.

Materials and Methods

One hundred and forty consecutive patients were treated, by the senior author (M.J.C.), with either a cheilectomy or an arthrodesis of the first metatarsophalangeal joint as surgical treatment for a symptomatic hallux rigidus deformity between November 1981 and November 1999. Twenty-one patients were excluded from the present study because of a diagnosis of gout, rheumatoid arthritis, systemic lupus erythematosis, poliomyelitis, or previous pyarthrosis, and five other patients died during the study period. Of the 114 remaining patients with a diagnosis of hallux rigidus, four were unavailable or had moved away; 110 (96%) returned for a final follow-up evaluation.

Of these 110 patients (127 feet), eighty (ninety-three feet) were treated with cheilectomy and thirty (thirty-four feet) were treated with arthrodesis. Thirteen patients had bilateral cheilectomy, and four patients had bilateral arthrodesis. No patient underwent a cheilectomy on one side and an arthrodesis on the contralateral side. Sixty-nine (63%) of the 110 patients were female. The average age at the onset of symptoms was forty-three years (range, thirteen to seventy years), and the average age at surgery was fifty years (range, sixteen to seventy-six years).

Grading

At the time of final follow-up, the patients were evaluated with a five-level clinical-radiographic grading system (Table I and

Fig. 1-A

Fig. 1-B

Figs. 1-A and 1-B Radiographs demonstrating Grade-1 hallux rigidus. **Fig. 1-A** The anteroposterior radiograph demonstrates a small lateral marginal osteophyte (arrow) but a well-preserved joint space. **Fig. 1-B** The lateral radiograph demonstrates a small dorsal spur (arrow).

Fig. 2-A

Fig. 2-B

Figs. 2-A and 2-B Radiographs demonstrating Grade-2 hallux rigidus. **Fig. 2-A** The anteroposterior radiograph demonstrates a substantial lateral marginal osteophyte, mild flattening of the metatarsal head, mild joint-space narrowing, and sclerosis. **Fig. 2-B** The lateral radiograph demonstrates narrowing of less than one-fourth of the joint space (primarily dorsally) and a more prominent dorsal spur.

Figs. 1-A through 4-B) that incorporates many features of all of the classification systems used by previous authors[1,2,12,22,72,74] but is not based on hypothetical concepts or notions[17,41,50,71]. All range-of-motion measurements used in the system refer to passive motion. *Pain at mid-range of passive motion* refers to pain that is elicited not only at the extremes of passive dorsiflexion and plantar flexion of the metatarsophalangeal joint but also in between. Loose bodies or osteochondral defects can occur with any grade. Their presence does not affect the assigned grade. There is intentional overlap of the ranges of motion of the different grades as range of motion is only one of the three general factors determining the eventually assigned grade of hallux rigidus. Range-of-motion, clinical, and radiographic examinations are utilized to determine the individual grade.

Preoperative Findings

The indication for surgery was intractable pain isolated to the first metatarsophalangeal joint that was refractory to shoe modifications, use of rigid shoe inserts, nonsteroidal anti-inflammatory medications, and modification of activities. Symptoms referable to the great toe and foot were compiled from a chart review. The operative reports were also evaluated to record the estimated percentage of the cartilage surface of the metatarsal head that remained, which had been observed and routinely recorded at the time of surgery. A cheilectomy was always recommended for Grade-1 and Grade-2 hallux rigidus, whereas a cheilectomy or an arthrodesis was recommended for Grade-3 hallux rigidus. An arthrodesis was recommended when radiographs demonstrated end-stage arthrosis and the clinical examination demonstrated a painful range of motion. When an arthrodesis was performed, such patients were typically found to have <50% of the cartilage surface remaining on inspection at surgery. Determining the best type of treatment was the most difficult for patients with similar radiographic findings who had minimal pain during the range of motion except at maximum plantar flexion and dorsiflexion. If it was acceptable to them, such patients gave consent for both arthrodesis and cheilectomy, and the surgeon chose the procedure at the time of the operation on the basis of the amount of cartilage surface that remained. Although an arthrodesis was always recommended to patients with end-stage arthritis, which we later characterized as Grade-4 hallux rigidus, eight of these patients refused the arthrodesis and underwent cheilectomy instead.

Early in the study, the magnitude of preoperative pain was quantified as none, mild, moderate, severe, or quite severe; later, a visual analog scale was used by the patients to quantify the level of pain numerically. In order to compare the preoperative and postoperative pain scores in the treatment

Fig. 3-A

Fig. 3-B

Figs. 3-A and 3-B Radiographs demonstrating Grade-3 hallux rigidus. **Fig. 3-A** The anteroposterior radiograph demonstrates substantial joint-space narrowing and sesamoid irregularity. **Fig. 3-B** The lateral radiograph demonstrates narrowing of more than one-fourth of the joint space and a prominent dorsal spur.

Fig. 4-A

Fig. 4-B

Figs. 4-A and 4-B Radiographs demonstrating Grade-4 hallux rigidus. Both the anteroposterior (Fig. 4-A) and the lateral (Fig. 4-B) radiographs demonstrate more advanced degenerative changes than the radiographs showing the Grade-3 disease. (Grades 3 and 4 may look identical radiographically and must be distinguished clinically.)

groups (cheilectomy and arthrodesis) on the basis of the 10-point visual analog score that was eventually used, a number was assigned retrospectively to the preoperative pain described by the patients seen early in the study. None was quantified as 0; mild, as 3; moderate, as 6; severe, as 9; and quite severe, as 10.

Preoperatively, twenty-one patients had moderate pain and the remainder had severe or quite severe pain. Although the AOFAS (American Orthopaedic Foot and Ankle Society) hallux metatarsophalangeal scale[75] was not available until 1994, the chart information and radiographs allowed us to also calculate a preoperative AOFAS score retrospectively for each patient.

Follow-up Evaluation

The mean duration of follow-up was 9.6 years (range, 2.3 to 20.3 years) after the cheilectomies and 6.7 years (range, 2.1 to 12.2 years) after the arthrodeses. At the time of follow-up, patients were assessed with a standardized questionnaire and examination.

Patients were asked to characterize their postoperative pain as none, mild, moderate, severe, or quite severe and also to rate it on a 10-point visual analog scale in which 0 indicated no pain and 10 indicated the most severe pain. Patients were also asked to localize the pain, if they had any, and to specify their main symptom (pain, stiffness, cosmetic appearance, locking, or a gait problem). In addition, patients were questioned about their clinical history, including use of orthotics, age at the onset of the symptoms, and duration of pain or other symptoms.

Patients were asked to rate their satisfaction with the result of the surgery according to a previously published scale[76]. In that scale, a result is considered excellent if the patient has no problems related to the foot, is very satisfied, has mild or no pain, walks with mild or no difficulty, and would have the surgery again under similar circumstances. A result is considered good if the patient has a few problems, is satisfied, has mild pain, walks with no or mild difficulty, and would have the surgery again under similar circumstances. A fair result means that the patient has moderate pain, some difficulty with walking, and reservations about the success of the surgery. A poor result indicates that the patient has continued pain, has little or no improvement in walking, and regrets having had the surgery.

More specific questions regarding shoe wear were asked to determine whether the patient could wear fashionable shoes (a 2-in [5-cm] or higher heel) postoperatively, felt pressure from constricting shoes, or had any other difficulty with shoe wear. Patients were asked to characterize their shoe-wear restrictions (preoperatively and postoperatively) as none (could wear fashionable shoes), could wear comfortable shoes only, or required modified custom shoes or orthotic devices.

Patients were asked if they could walk on tiptoe and the time to maximal comfort and recovery from the surgery. They were asked to characterize any activity restrictions (preoperatively and postoperatively) as none (no restriction of sports

or recreational activity), mild (not enough to interfere with everyday activity but some limitation of sports or recreational activity), moderate (limitation of daily and recreational or sports activity), or severe (major limitation of any activity).

The physical examination included inspection and palpation of the foot with attention to posture, sensation, motion, motor function, strength, and appearance. Both feet of all patients were examined. Stance and gait were assessed with attention to the position of the foot when the patient walked. Passive motion of the metatarsophalangeal and interphalangeal joints of the great toe was measured with a goniometer, with the plantar aspect of the foot considered to be neutral. These joints were then assessed for stability in the sagittal plane. Pain that occurred in the mid-range, between maximum plantar and dorsiflexion, of a passive range of motion of the hallux metatarsophalangeal joint was noted. The plantar aspect of the foot was assessed for callosities or areas of tenderness. Motor strength of the hallux was quantitated on a 5-point scale in which 1 indicated no strength; 2, active movement with gravity eliminated; 3, active movement against gravity only, without resistance; 4, active movement against gravity with some resistance; and 5, active movement against gravity with full resistance.

An AOFAS hallux metatarsophalangeal score[75] was determined for all patients at the time of final follow-up. This is a 100-point scale composed of separate sections for pain (40 points), function (45 points), and alignment (15 points). In the scale for pain, 40 points is given for no pain; 30 points, for mild, occasional pain; 20 points, for moderate, daily pain; and 0 points, for severe, constant pain. Function is graded on the basis of activity (10 points for no limitation, 7 points for limitation of recreational activity but not daily or job-related activities, 4 points for limitation of daily and recreational activities, and 0 points for severe limitation of daily and recreational activities), shoe wear (10 points for the ability to wear fashionable and regular shoes with no insert, 5 points for the ability to wear only comfortable shoes or the need for an insert, and 0 points for the need to wear modified shoes or a brace), motion (dorsiflexion plus plantar flexion) of the metatarsophalangeal joint (10 points for ≥75°, 5 points for 30° to 74°, and 0 points for <30°), motion (plantar flexion) of the interphalangeal joint (5 points for no restriction and 0 points for <10°), stability (in all directions) of the metatarsophalangeal joint (5 points for stable and 0 points for unstable), and callus related to the metatarsophalangeal and interphalangeal joints (5 points for no or an asymptomatic callus and 0 points for a symptomatic callus). In the alignment section of the scale, 15 points is given for a well-aligned

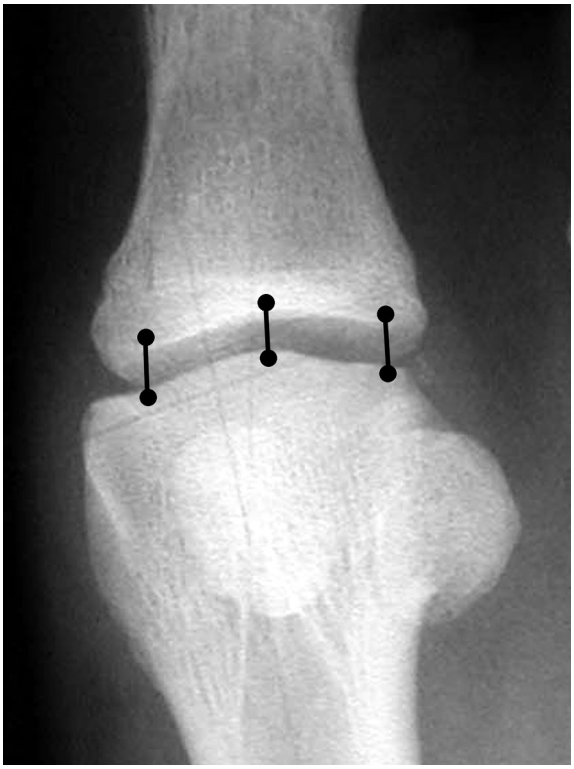

Fig. 5-A

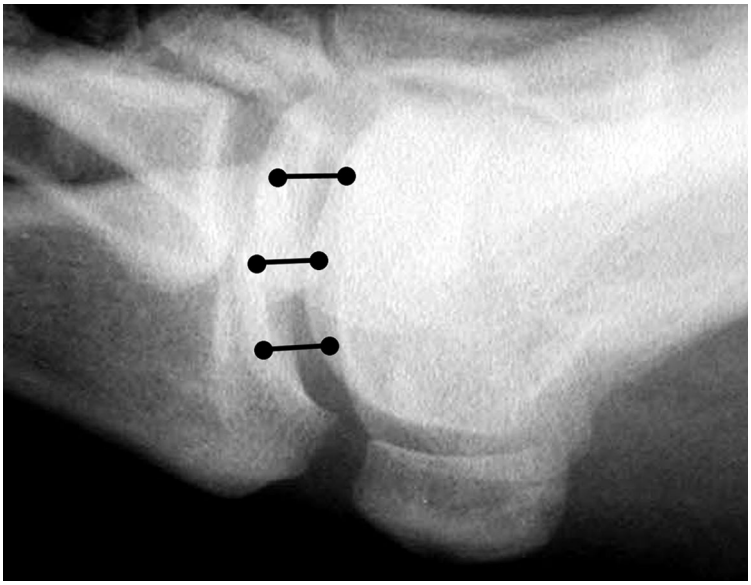

Fig. 5-B

Radiographs demonstrating the technique for measuring the joint width. On the preoperative and postoperative radiographs, three points were placed along the corresponding articular surfaces of the base of the proximal phalanx and the distal part of the metatarsal. On the anteroposterior radiograph (Fig. 5-A), these points were placed at the medial, central, and lateral aspects of the joint surfaces. On the lateral radiograph (Fig. 5-B), these points were placed at the dorsal, middle, and plantar aspects of the joint surface. On a line connecting each pair of corresponding points, the joint width was measured in millimeters. The six scores were added and then divided by six, to provide an average width for each joint.

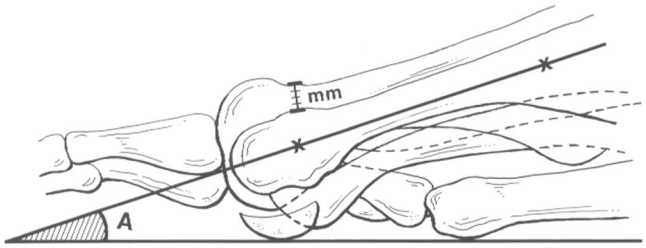

Fig. 6

Diagram demonstrating measurement of metatarsus primus elevatus and the first metatarsal declination angle on weight-bearing lateral radiographs. To measure metatarsus primus elevatus, a line is drawn along the distal dorsal metaphyseal cortex of the first and second metatarsals. A perpendicular line is drawn between the two cortical lines, and the distance between the two lines is measured in millimeters. To measure the first metatarsal declination angle, the lateral longitudinal axis of the first metatarsal is drawn with use of mid-diaphyseal reference points. A second line estimating the plantar surface of the foot is drawn, intersecting reference points on the plantar aspect of the calcaneus and the medial sesamoid. The intersection of these two lines forms the first metatarsal declination angle (angle A).

hallux; 8 points, for fair alignment with some deformity but no symptoms; and 0 points, for symptomatic malalignment. With use of this scale, 90 points is the highest score attainable after an arthrodesis.

Radiographic Evaluation

Standardized preoperative weight-bearing radiographs[77] were reviewed and compared with standardized postoperative weight-bearing radiographs made at the time of the final follow-up. The width of the metatarsophalangeal joint was determined by a summation method based on six separate measurements (Figs. 5-A and 5-B). Recurrence of the dorsal osteophyte was assessed on the lateral radiograph by drawing a line along the dorsal cortex of the metatarsal and measuring any osteophyte above that line in millimeters.

Interphalangeal joint arthritis was graded on the anteroposterior radiograph with use of a previously described method[78]. With this method, Grade 1 indicates no degenerative changes; Grade 2, mild changes with <1 mm of chondrolysis; Grade 3, moderate changes with 1 to 2 mm of chondrolysis; and Grade 4, severe changes with malalignment, cysts, and/or joint destruction. Periarticular sclerosis at the metatarsophalangeal joint was recorded as 0 (no sclerosis), +1 (mild), +2 (moderate), or +3 (severe), as seen on the preoperative and postoperative anteroposterior radiographs of the patients treated with cheilectomy.

Elevation of the first ray (metatarsus primus elevatus) was measured on the weight-bearing lateral radiograph[79]. The difference between the dorsal cortices of the first and second metatarsals measured at the head-neck junction was recorded in millimeters. A normal value is ≤8 mm[79]. The first metatarsal declination angle was measured as well[79]. Normal values are reported to range from 19° to 25°[80] (Fig. 6). A dorsiflexion stress lateral radiograph was made for all feet[3]. This is a weight-bearing lateral radiograph made with manual dorsiflexion stress applied by grasping the proximal phalanx and passively extending the metatarsophalangeal joint (Figs. 7-A and 7-B). The dorsiflexion measured on the weight-bearing stress radiograph was compared with the dorsiflexion measured with a goniometer without weight-bearing, and any discrepancy was recorded in order to measure the magnitude of functional hallux limitus[81-83]. In addition, metatarsus primus elevatus was measured on the stress radiograph and compared with the metatarsus primus elevatus on the non-stress standard weight-bearing lateral radiograph to evaluate the extent to which the metatarsus primus elevatus was a secondary change.

Fig. 7-A

Figs. 7-A and 7-B Metatarsus primus elevatus and dorsiflexion stress test. **Fig. 7-A** A postoperative standing lateral radiograph demonstrating 9 mm of metatarsus primus elevatus.

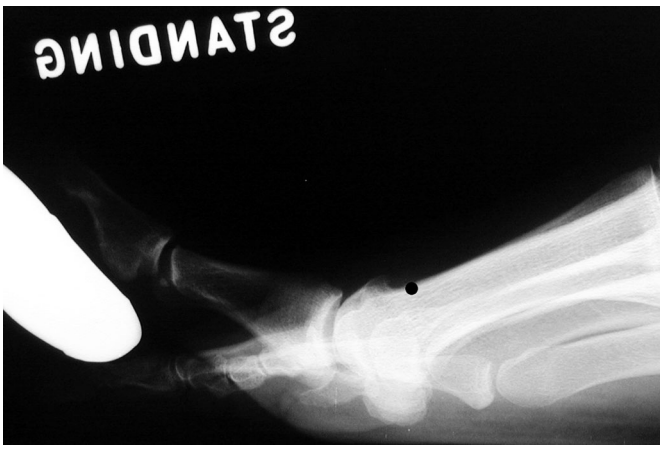

Fig. 7-B

A standing lateral radiograph of the same foot with application of dorsiflexion stress, demonstrating an absence of metatarsus primus elevatus.

Surgical Techniques

A cheilectomy is performed with use of regional anesthesia and with an Esmark bandage (Medline Industries, Mundelein, Illinois) employed as a tourniquet[1,3,7]. A 3-cm dorsal longitudinal incision is centered over the metatarsophalangeal joint and is deepened through the capsule on the medial aspect of the extensor hallucis longus tendon. The capsule is preserved for later repair. Hypertrophic synovial tissue and loose bodies are fully débrided from the joint, and the percentage of viable cartilage remaining on the metatarsal head is estimated. The proximal phalanx is plantar flexed, exposing the metatarsal head. An osteotome is used to remove the dorsal, medial, and lateral osteophytes along with 25% to 33% of the metatarsal head dorsally. Usually, all or almost all of the cartilage-deficient surface of the metatarsal head is resected. At least 70° of dorsiflexion should be achieved intraoperatively. The osteophytes are then removed from the dorsal aspect of the base of the proximal phalanx, and the joint is lavaged. Bone wax is applied to the dorsal region of the metatarsal head. The capsule is repaired beneath the extensor hallucis longus tendon with interrupted absorbable sutures, and the skin is approximated in a routine fashion.

A gauze-and-tape compression dressing is applied at the conclusion of the surgery and is changed every ten days. Passive range-of-motion exercises are begun within ten days after surgery, and aggressive stretching is allowed as pain and swelling subside. Walking is permitted following surgery with the patient wearing a stiff-soled postoperative shoe and bearing weight as tolerated.

Arthrodesis of the first metatarsophalangeal joint is performed with use of regional anesthesia and with use of an Esmark bandage as a tourniquet[1,52,76,84]. A dorsal longitudinal incision, 4 to 5 cm long, is centered over the metatarsophalangeal joint and is deepened through the capsule on the medial aspect of the extensor hallucis longus tendon. The capsule is preserved for later repair. The joint is débrided, and osteophytes and loose bodies are removed. The proximal phalanx is plantar flexed, a 0.62-mm Kirschner wire is proximally centered on the first metatarsal articular surface and driven in, and an appropriately sized cannulated cylindrical reamer is used to create a cylinder-shaped metatarsal. A concave cannulated metatarsal reamer (small joint reamer; Howmedica, Rutherford, New Jersey) is then utilized to create a convex cancellous metatarsal surface. The Kirschner wire is removed, and attention is then directed to the proximal phalanx. A Kirschner wire is centered on the articular surface of the base of the proximal phalanx and is driven distally to prepare for cannulated reaming. Convex phalangeal reamers are used to create a concentric matching surface on the phalangeal base to match the metatarsal head. The hallux is placed in neutral rotation, 15° of valgus, and 20° of dorsiflexion in reference to the axis of the first metatarsal. It is stabilized with a six-hole Vitallium mini-compression plate and a lag screw. A gentle dorsal bend in the plate allows better conformity to the dorsal osseous surfaces to achieve approximately 20° of dorsiflexion. Closure is identical to that used for a cheilectomy.

A gauze-and-tape compression dressing is applied at the conclusion of the surgery and is changed every ten days for eight to twelve weeks, until there is radiographic evidence of a successful fusion. The foot is placed in a stiff-soled postoperative shoe after surgery, and weight-bearing on the heel and the lateral aspect of the involved foot is permitted. The first ray is

TABLE II Preoperative and Postoperative Symptoms and Functional Factors in Patients Treated with Cheilectomy or Arthrodesis*

Symptom or Functional Factor	Preop. (N = 110)	Postop.		
		Cheilectomy (N = 80)	Arthrodesis (N = 30)	Total (N = 110)
Stiffness	109	10 (13%)	14 (47%)	24
Pain	110	46 (58%)	9 (30%)	55
Locking	20	0	0	0
Dissatisfaction with cosmetic appearance	60	0	0	0
Eversion gait	108	10 (13%)	2 (7%)	12
Able to rise up on toes	11	66 (83%)	15 (50%)	81
Pain at metatarsophalangeal joint (main symptom)	55	46 (58%)	9 (30%)	55
Painful dorsal bump (main symptom)	55	0	0	0
Insert or orthotic	20	9	9	18
Able to wear fashionable shoes	50	56	21	77
Able to wear comfortable shoes	110	80	30	110
Discomfort from shoe pressure	110	10	3	13

*The values are given as the number of patients.

TABLE III Preoperative and Postoperative Clinical Scores and Findings on Examination for Patients Treated with Cheilectomy or Arthrodesis

Score or Finding on Examination	Cheilectomy		Arthrodesis		Total Series (Postop.)
	Preop.	Postop.	Preop.	Postop.	
Pain score on visual analog scale* *(points)*	8 (6-10)	1.5 (0-8)	8.7 (6-10)	0.4 (0-5)	
AOFAS score* *(points)*	45 (24-70)	90 (67-100)	38 (24-60)	89 (72-90)	
Subjective patient self-assessment score *(no.)*	All fair or poor	58 excellent, 19 good, 3 fair, 0 poor	All fair or poor	26 excellent, 4 good, 0 fair or poor	
MTP dorsiflexion*† *(deg)*	14.5 (0-45)	39 (10-65)	7 (–15-10)	0	Dorsiflexion improved 24.5°
MTP total motion*† *(deg)*	39.2 (5-80)	63.7 (15-110)	22.1 (5-30)	0	Total motion improved 24.5°
Callus† (no. of patients/location)	5/2nd MTP, plantar	5/IP joint, plantar	4/2nd MTP, plantar	4/IP joint, plantar	9/IP joint, plantar and medial

*The values are given as the mean with the range in parentheses. †MTP = metatarsophalangeal joint and IP = interphalangeal joint.

unweighted in this fashion until there is radiographic evidence of a fusion.

Statistical Analysis

Descriptive and comparative statistical analysis was performed with use of InStat software (GraphPad Software, San Diego, California). Standard chi-square analysis was performed on continuous variables. Pearson and binary correlation coefficients were used to evaluate the noncontinuous data, and positive coefficients (r values) closer to one indicate strong correlation while values closer to zero indicate weak or no correlation. Differences were considered to be significant when the p value was ≤ 0.05.

Results

Eighty patients (ninety-three feet) treated with a cheilectomy and thirty patients (thirty-four feet) treated with an arthrodesis were evaluated at the final examination. At the time of follow-up, at a mean of 9.6 years postoperatively, seven (8%) of the ninety-three cheilectomies had failed. At the time of follow-up, at a mean of 6.7 years postoperatively, thirty-two (94%) of the thirty-four arthrodeses had successfully fused.

There were sixteen associated surgical procedures, including four repairs to treat a hammertoe deformity of the second toe, nine repairs to treat capsular instability of the second metatarsophalangeal joint, and three Akin phalangeal osteotomies performed for severe hallux valgus interphalangeus at the time of metatarsophalangeal joint arthrodesis.

Historical Data (Table II)

The most common primary preoperative symptoms were metatarsophalangeal joint pain (fifty-five patients) and a painful dorsal bump (fifty-five patients). These symptoms decreased postoperatively in both treatment groups. Interestingly, the same number of patients listed their primary symptom as metatarsophalangeal joint pain both preoperatively and postoperatively. However, there was a significant reduction ($p = 0.0001$) in the postoperative pain score indicated on the visual analog scale. Postoperatively, patients no longer complained of a dorsal bump or pressure from the shoe, but they continued to have metatarsophalangeal joint pain. The time to maximum postoperative improvement averaged 2.4 months (range, one to 4.5 months) after the cheilectomies and 2.8 months (range, 1.5 to four months) after the arthrodeses.

Clinical Scores (Table III)

One hundred and seven (97%) of the 110 patients had an excellent or good self-assessment (subjective) score at the time of follow-up, whereas all patients had a fair or poor score preoperatively (as estimated retrospectively). A good or excellent outcome based on the patient self-assessment score, visual analog score for pain, and AOFAS score did not correlate with the radiographic appearance of the joint (loss of joint space) at the time of final follow-up ($r = 0.08$, $p = 0.34$).

At the time of final follow-up, the mean AOFAS score was significantly improved in both the group treated with cheilectomy ($p = 0.0001$, difference in the means = 45.7, 95% confidence interval = 43.3 to 48.1) and the group treated with arthrodesis ($p = 0.045$, difference in the means = 50.4, 95% confidence interval = 46.5 and 54.4). The cheilectomy group had a significantly higher preoperative mean AOFAS score than did the arthrodesis group (45 compared with 38 points, $p = 0.025$, difference in the means = 6.6, 95% confidence interval = 1.8 and 9.1), but there was no difference in the mean postoperative AOFAS scores (89 compared with 90 points, $p = 0.3$). However, the maximum possible AOFAS score in the arthrodesis group was 90 points, as 10 points are unavailable because of loss of motion.

When the patients treated with cheilectomy were grouped according to the grade of the hallux rigidus, a significant difference in both preoperative and postoperative AOFAS score was found among the subgroups ($r = 0.3$, $p = 0.02$). Also, a

TABLE IV Mean Range of Motion and Follow-up Scores for Patients Treated with Cheilectomy

Grade	Dorsiflexion *(deg)*			Total Motion *(deg)*			Postop. AOFAS score *(points)*	Postop. Pain Score on Visual Analog Scale *(points)*
	Preop.	Postop.	Change	Preop.	Postop.	Change		
1	33.3	56.7	23.4	53.3	76.7	23.4	95.7	1.1
2	21.1	46.4	25.3	38.9	62.1	23.2	92.9	1.5
3	9.5	34.5	25	21.5	44.7	23.2	89.8	1.7
4*	5.8		–5.8	12.5		–12.5	88.9	0.4

*Five of nine Grade-4 feet underwent arthrodesis and had a mean loss of motion.

TABLE V Mean Radiographic Values for Patients Treated with Cheilectomy or Arthrodesis

Radiographic Parameter	Cheilectomy*		Arthrodesis*	
	Preop.	Postop.	Preop.	Postop.
Metatarsus primus elevatus *(mm)*	5.3 (0-10)	6.1 (0-15)	5.6 (0-12)	1.8 (0-10)
First metatarsal declination angle *(deg)*	20.4 (15-27)	21.1 (12-30)	23.4 (19-30)	20 (15-26)
Hallux valgus angle *(deg)*	12.2 (0-20)	12.6 (0-24)	12.2 (0-20)	11.7 (5-19)
1st-2nd intermetatarsal angle *(deg)*	7.3 (2-24)	7.7 (2-15)	8.1 (4-14)	8.1 (4-13)
Joint width *(mm)*	1.6 (0.3-2.7)	1.2 (0-3)	0.9 (0.5-1.6)	0.01 (0-0.5)
Periarticular sclerosis	1.8 (0-3)	2.2 (0-3)	2.6 (2-3)	Fused
Interphalangeal joint width *(mm)*	1.1 (1-2)	1.1 (1-2)	1.1 (1-2)	1.2 (1-2)

*The values are given as the mean with the range in parentheses for the feet.

correlation was found between increasing grade and lower preoperative AOFAS scores ($r = 0.4$, $p = 0.01$).

Results of Clinical Examination (Table IV)

The total range of motion of the metatarsophalangeal joint at the time of final follow-up after the cheilectomies averaged 64°: the average dorsiflexion of the metatarsophalangeal joint improved from 14.5° preoperatively to 38.4° postoperatively ($p = 0.0001$, difference in the means = 23.8°, 95% confidence interval = 20.9° to 26.6°). Postoperatively, no significant difference was noted between passive dorsiflexion and dorsiflexion with stress at either the metatarsophalangeal or the interphalangeal joint of the hallux ($p = 0.4$, difference in the means = 1.2°). Dorsiflexion of the interphalangeal joint averaged 8° in both treatment groups at the time of final follow-up. Motor strength was graded as 5/5 (normal) in all subjects. All first metatarsophalangeal joints were stable on manual examination following cheilectomy. Three patients had a Tinel sign over the dorsal-medial aspect of the metatarsophalangeal joint preoperatively, but no patient had a sensory disturbance postoperatively.

Radiographic Data (Table V)

Comparison of the extent of arthritic changes in the interphalangeal joint between the preoperative and postoperative radiographs demonstrated no progression of arthritis in either treatment group.

There was significant progression of periarticular sclerosis of the metatarsophalangeal joint ($p = 0.0001$, difference in the means = 0.5, $r = 0.84$, 95% confidence interval = 0.3 to 0.6) and of loss of the metatarsophalangeal joint width ($p = 0.0001$, difference in the means = 0.4 mm, $r = 0.8$, 95% confidence interval = 0.25 and 0.46) in the cheilectomy group. Twenty-one metatarsophalangeal joints were noted to have a loose body on preoperative radiographs and confirmatory findings at the time of surgery, but no loose bodies were noted on final follow-up radiographs. The average size of the recurrent dorsal osteophytes was 0.72 mm (range, 0 to 3 mm) after the cheilectomies and 0 mm after the arthrodeses.

Grading of the Hallux Rigidus (Table VI)

In the cheilectomy group, the mean clinical-radiographic grade of the hallux rigidus was 2.50 (range, 1 to 4) preoperatively compared with 2.59 (range, 1 to 4) postoperatively ($p = 0.1$). Nine patients had an increase of one grade at the time of final follow-up. In the cheilectomy group, patients with a lower grade preoperatively had a better AOFAS score both preoperatively and postoperatively. No patient had an increase in the grade after an arthrodesis, and no patient in the series had an increase of more than one grade. Following

TABLE VI Preoperative and Postoperative Clinical-Radiographic Grades for Patients Treated with Cheilectomy or Arthrodesis*

	Grade 1	Grade 2	Grade 3	Grade 4
Before cheilectomy	6 (8%)	32 (40%)	34 (43%)	8 (10%)
After cheilectomy	4 (5%)	31 (39%)	33 (41%)	12 (15%)
Before arthrodesis			10 (33%)	20 (67%)

*The values are given as the number of patients with the percentage in parentheses.

the cheilectomies, the patients with Grade-1 hallux rigidus had a mean AOFAS score of 95.7 points and a mean pain score on the visual analog scale of 1.1 points, and all four feet were subjectively rated as excellent. Patients with Grade 2 had a mean AOFAS score of 92.9 points and a mean pain score on the visual analog scale of 1.5 points; of the thirty-eight feet, thirty-five were rated as excellent and three were rated as good. Patients with a Grade-3 rating had a mean postoperative AOFAS score of 89.8 points and a mean pain score on the visual analog scale of 1.7 points; of the thirty-four feet, twenty-nine were rated as excellent and five were rated as good.

Integrity of the Articular Surface at the Time of Surgery

As estimated by inspection of the metatarsophalangeal joint at the time of surgery, an average of 17% (range, 0% to 40%) of the articular surface of the metatarsal head remained in the arthrodesis group and an average of 60% (range, 55% to 90%) remained in the cheilectomy group. There was a correlation between an estimation of <50% of the metatarsal head cartilage remaining and failure of cheilectomy ($p = 0.002$, $r = 0.4$). Also, an estimation of >50% of the metatarsal head cartilage remaining in a patient undergoing a cheilectomy correlated with a long-term AOFAS score of >80 points and a good or excellent subjective score ($p = 0.01$, $r = 0.4$) at the time of final follow-up.

Metatarsus Primus Elevatus (Table VII)

There was good correlation between the first metatarsal declination angle and metatarsus primus elevatus in both treatment groups ($r = 0.6$, $p = 0.01$). Preoperatively, 120 (94%) of the 127 feet had <8 mm of elevation, which was within the range of normal.

The mean preoperative and postoperative measurements of elevatus were 5.3 mm and 6.1 mm in the cheilectomy group. There was a correlation between the postoperative grade and the amount of elevatus ($r = 0.44$, $p = 0.02$). Moreover, the elevatus reduced to a mean of 1.2 mm on dorsiflexion stress examination in the cheilectomy group at the time of final follow-up. This value was significantly different from the measurements of elevatus on weight-bearing lateral radiographs both preoperatively ($p = 0.001$, difference in the means = 3.9 mm, 95% confidence interval = 1.6 to 5.2 mm) and postoperatively ($p = 0.001$, difference in the means = 4.5 mm, 95% confidence interval = 1.3 to 5.1 mm).

Both before and following cheilectomy, an increased value for elevatus was associated with a higher grade of hallux rigidus ($p = 0.04$, $r = 0.44$). In addition, elevatus decreased postoperatively in patients with Grade-1 or 2 hallux rigidus but it increased in those with Grade-3 or 4. The mean preoperative elevatus in the arthrodesis group was 5.6 mm, and this was significantly reduced postoperatively to 1.7 mm ($p = 0.009$, difference in the means = 3.9 mm, 95% confidence interval = 2.7 to 4.9 mm).

Complications

Five of the eighty patients in the cheilectomy group and two of the thirty in the arthrodesis group required oral antibiotics for the treatment of mild postoperative cellulitis. There were no deep wound infections. No patient in either group had tenodesis or scarring of the extensor hallucis longus, concerns

TABLE VII Metatarsus Primus Elevatus, According to Grade of Hallux Rigidus, in the Patients Treated with Cheilectomy or Arthrodesis

	Metatarsus Primus Elevatus *(mm)*			
	Grade 1	Grade 2	Grade 3	Grade 4
Before cheilectomy*	2.6 (0-8)	5.2 (0-8)	5.2 (0-10)	6 (5-10)
After cheilectomy*	2.5 (0-5)	4.7 (0-8)	8 (0-15)	8.4 (5-10)
P value	0.086	0.0001	0.0001	0.0001
Before arthrodesis*			5.3 (0-10)	6.2 (0-12)
After arthrodesis*			1.1 (0-5)	1.5 (0-6)

*The values are given as the mean with the range in parentheses.

about the cosmetic appearance of the foot, neuritis, or a hypertrophic dorsal scar.

Seven failed cheilectomies in six patients resulted in seven additional surgical procedures. There were two outcomes that were unexpected on the basis of the grades assigned with our rating system during the study period. These two outcomes consisted of rapid chondrolysis (within one year after the surgery), and both patients had a metatarsophalangeal joint arthrodesis (at seven and eight years following the cheilectomy). The other four patients (five feet) in which the cheilectomy failed had originally been advised to have an arthrodesis for the treatment of Grade-4 disease; a metatarsophalangeal joint arthrodesis was eventually performed in these four patients. The other four patients with Grade-4 changes (who did not have additional surgery after the initial cheilectomy) had a mean long-term AOFAS score of 74 points (range, 67 to 80 points); three rated the result as fair and one rated it as good after a mean duration of follow-up of 7.4 years (range, 2.5 to 8.4 years). Thus, of the nine feet with Grade-4 changes for which arthrodesis was recommended but cheilectomy was performed at the patient's request, five had failure of the procedure and later underwent arthrodesis (at a mean 6.9 years after the cheilectomy) as initially recommended. The other four had inferior subjective results (three fair and one good) at the time of follow-up but had radiographic signs of deterioration of the joint space and a mean pain score of 4.7 points on the visual analog scale.

Two plates were removed because of pain following a successful fusion. Two of the thirty-four feet that had undergone arthrodesis had a painless fibrous union, and the AOFAS score was 90 points for both of these feet at the time of follow-up.

Discussion

Grading System

The grading system used in this study had been modified on the basis of the findings of Easley et al.[1] in order to add Grade 4 for advanced hallux rigidus. A grade-0 stage was also added to include asymptomatic patients with early loss of metatarsophalangeal joint motion. The initial grading system was a clinical-radiographic scheme described by one of us (M.J.C.)[73].

The classification system shown in Table I and Figures 1-A through 4-B incorporates many of the best elements of prior grading systems[1,12,22,72] and requires both subjective and objective examination and radiographic data to determine the grade. When applied retrospectively, the system appeared to be reliable as it correctly predicted a successful outcome in 108 of 110 patients. Moreover, it accurately predicted a fair or poor outcome in patients with Grade-4 hallux rigidus treated with cheilectomy. Its key utility was in the distinction between Grade-3 and Grade-4 hallux rigidus. Cheilectomy uniformly failed in patients with Grade-4 hallux rigidus, as predicted; five of the nine feet in which Grade-4 hallux rigidus was treated with cheilectomy subsequently had an arthrodesis, and two of the four remaining patients had moderate to severe metatarsophalangeal joint pain (mean pain score, 4.4 points). However, the cheilectomy unexpectedly failed in two of thirty-four patients with Grade-3 hallux rigidus. Both had radiographic evidence of chondrolysis within one year after the surgery, with progressive pain, and subsequently underwent arthrodesis of the metatarsophalangeal joint at seven and eight years following the cheilectomy.

To improve the accuracy and predictability for Grade-3 hallux rigidus, the percentage of metatarsal head cartilage remaining, as estimated with direct surgical inspection, should be considered, as <50% of the cartilage remaining correlated with failure.

The indications for cheilectomy described in the literature have varied greatly. While some authors have recommended cheilectomy for early disease only[2,12], others have used the procedure to treat both early and moderate disease[4,5]; still others have used it for all levels of disease[3,7,11,69]. The results of this study support the use of cheilectomy for all levels of disease except Grade 4.

As a result of all of the different grading systems (or a lack of grading) and differences in the technique of cheilectomy, it is difficult to compare the results of different studies. However, rates of satisfaction after cheilectomy have been favorable, ranging from 72% to 90%[2-4,11-13,69]. We favor a uniform grading system to allow comparisons between studies and to distinguish between a Grade-3 and a Grade-4 metatarsophalangeal joint.

Of interest was a significant progression in objective evidence of periarticular sclerosis as well as loss of joint space width in our patients who had undergone cheilectomy; however, there was no correlation between loss of joint width and the AOFAS score, pain score, or patient self-assessment.

Recurrence and Chondrolysis

Easley et al.[1] reported that dorsal osteophytes recurred in twenty-one of sixty-eight feet following cheilectomy, although the authors did not specify how the recurrence was quantified. Several authors have noted that the metatarsophalangeal joint deteriorates radiographically following cheilectomy[1,4,7,11]. Others have reported that cheilectomy hastens deterioration of the joint[2], and still others have reported that deterioration is uncommon[3]. Smith et al.[85] reported on the natural history of hallux rigidus treated nonoperatively and observed that the metatarsophalangeal joint deteriorated radiographically and clinically with time (in sixteen of twenty-four feet). The results of our study support the finding of those authors that a metatarsophalangeal joint with hallux rigidus naturally deteriorates if followed for a long enough period of time. Cheilectomy does not appear to alter the natural progression of the disease process, but it enables a patient to be more comfortable during the course of degeneration.

Metatarsophalangeal Joint Motion

Improved metatarsophalangeal joint motion following cheilectomy has been emphasized in several studies[1,2,6,11]. Dorsiflexion has reportedly been improved by 28° to 50°, depending on

the individual study and the specific surgical technique used for the cheilectomy[1,3,7,13]. Authors using the technique described by Mann et al.[3] have reported 20° to 30° improvements in dorsiflexion and total range of motion[1,3,4,7,11,13], whereas those using a minimal resection technique have reported about 50% less improvement in dorsiflexion[2,6,12]. Several authors have reported diminishing improvements in motion with increases in the grade of the disease[2,6,12], whereas others[1], including us, have found fairly uniform improvement in motion even in patients with more advanced disease. We reported an increase in mean dorsiflexion from 14.5° preoperatively to 38.4° postoperatively and an increase in mean total motion from 39.2° to 64°. This improvement occurred consistently across all grades, and it corresponds very closely with the findings reported by several authors[1,3,7,11,13], confirming the reliability of our cheilectomy technique.

Thus, it appears that minimal resection techniques are not as versatile, especially for more advanced grades of disease[2,6,8,12]. With our more aggressive resection technique, the indications can be extended to include more advanced disease without compromising the result or creating an unstable joint[3,7,13,69].

Pain Relief

Pain relief has been reported consistently following cheilectomy[1,3,7,69], but some authors have noted less pain relief with higher grades of disease[2,12,13]. A cheilectomy alters the joint in some fashion, providing pain relief even in the presence of more advanced disease. However, there is a point (Grade-4 disease) at which reliable results are more difficult to obtain. We support the notion of Easley et al.[1] that a clinical finding of pain at the mid-range of motion (Grade 4) is a harbinger of a poor result following cheilectomy and that it is critical to recognize this finding especially in the presence of advanced radiographic changes. However, as noted by others[7,69], radiographic findings alone do not correlate with the final clinical result, and we believe that purely radiographic grading systems should be discarded.

Arthrodesis

There is little information on the performance of arthrodesis solely for the treatment of hallux rigidus[52,53,57,58]. Fitzgerald[53] reported that arthritis developed in the interphalangeal joint when the metatarsophalangeal joint had been fused in <15° of valgus. One of us (M.J.C.)[78] previously reported that arthritis was more common in interphalangeal joints when the metatarsophalangeal joint had been fused in <22° of dorsiflexion. Other studies have shown progression of interphalangeal joint arthritis after metatarsophalangeal joint arthrodesis[78,86,87]. However, these studies included a large number of patients with rheumatoid arthritis. In the current study, which dealt only with hallux rigidus, we noted no progression of degener-

Fig. 8-A

Fig. 8-B

Figs. 8-A and 8-B Radiographs of a foot with a long-term good result of cheilectomy. **Fig. 8-A** Preoperative anteroposterior radiograph showing a foot with Grade-3 hallux rigidus. **Fig. 8-B** Anteroposterior radiograph made eighteen years following cheilectomy; the foot still has Grade-3 hallux rigidus.

Fig. 9-A

Fig. 9-B

Figs. 9-A and 9-B Failure of cheilectomy. **Fig. 9-A** The preoperative anteroposterior radiograph shows a foot with symptomatic hallux rigidus. **Fig. 9-B** Two years following cheilectomy, painful arthrosis developed.

ative changes in the interphalangeal joint following cheilectomy or arthrodesis.

Complications

Arthrodesis resulted in a 94% fusion rate, and neither of the fibrous unions was painful. Two patients underwent hardware removal because of pain. There were no failures of hardware or other complications.

Although Easley et al.[1] suggested that a medial approach is preferable for cheilectomy because of the risk of tenodesis or scarring of the extensor hallucis longus tendon, because of cosmetic concerns, and to avoid creating a hypertrophic dorsal scar, we found no evidence of these complications in any patient.

Metatarsus Primus Elevatus

The concept of metatarsus primus elevatus as a cause of hallux rigidus has been endorsed in several reports[2,8,23,28,30,34,36,37,41,50,70,81,82,88,89], whereas radiographic evidence to the contrary[79,80,90] has also been reported. Functional hallux limitus (reduction of dorsiflexion of the first metatarsophalangeal joint with loading of the foot compared with passive dorsiflexion with non-weight-bearing) has also been proposed as a cause of hallux rigidus[81-83]. Attempts to quantitate the magnitude of elevatus have been

Fig. 9-C

Radiograph made following arthrodesis of the metatarsophalangeal joint.

made with use of two different measurements, the first metatarsal declination angle[80] and the difference in elevation between the dorsal cortices of the first and second metatarsals as seen on a weight-bearing lateral radiograph[79,90].

Normal elevatus is considered to be ≤8 mm, and the normal first metatarsal declination angle has been reported to be between 19° and 25°[79,90]. The mean preoperative elevatus was 5.5 mm in our patients, well within the limits of normal. Moreover, the mean first metatarsal declination angle was within normal limits both preoperatively and postoperatively in our patients.

Metatarsus primus elevatus is rarely a structural problem that needs to be corrected by an osteotomy, as has been recommended by others[32,34,36-39,74]. In our series, it consistently decreased after cheilectomy in patients with lower grades of disease. We noted that these patients had the least amount of elevatus. Elevatus corrected to nearly zero with the dorsiflexion stress test (with any grade of hallux rigidus). While the elevatus decreased with passive dorsiflexion stress, we found no difference between first metatarsophalangeal joint motion with the dorsiflexion stress test and passive metatarsophalangeal joint motion. These findings call into question the concept of functional hallux limitus that has been reported in the literature[81-83]. However, we hypothesized that functional hallux limitus may represent the residual elevatus that we occasionally noted on the dorsiflexion stress radiographs of patients with more advanced disease.

This study demonstrates that a simple procedure such as cheilectomy tends to reduce elevation of the first ray as the joint functions more normally. We believe that when the joint has deteriorated clinically to the point where elevation of the first ray is pronounced, it is an indication for metatarsophalangeal arthrodesis because first-ray elevation significantly diminished after arthrodesis in our series.

Our study had the longest mean duration of follow-up after both cheilectomy and arthrodesis for the treatment of hallux rigidus. Ninety-six percent of the patients followed for an average of 9.6 years after cheilectomy and 100% of those followed for an average 6.7 years after arthrodesis had a good or excellent subjective result. Pain scores in both groups were significantly reduced compared with the preoperative scores, and AOFAS scores were significantly improved.

The clinical-radiographic grading system used in this study appears to be reliable. We believe that cheilectomy can be used with success for Grades 1, 2, and 3 hallux rigidus (Figs. 8-A and 8-B), but patients with Grade 4 or with <50% of the cartilage surface of the metatarsal head remaining at the time of surgery should be treated with arthrodesis (Figs. 9-A, 9-B, and 9-C). For patients who desire preservation of motion and are willing to accept less than total pain relief, cheilectomy provides a high proportion of good and excellent long-term results. However, arthrodesis should be considered for patients who clearly have pain in the mid-range of motion on examination. A high proportion of these patients can be expected to have a good or excellent long-term result after arthrodesis performed with the technique described in this study. ■

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