Ulnar Lengthening in the Treatment of Kienböck’s Disease

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ABSTRACT: Twenty patients with Kienböck’s disease were treated with a modification of the Persson ulnar-lengthening procedure to remove compressive stress from the damaged lunate. After an average follow-up of thirty-seven months, relief of pain was satisfactory in eighteen patients who had returned to work (nine of whom had strenuous occupations), and two patients were dissatisfied because they had persistent pain and were not able to return to their previous occupations.

Non-union at the site of the ulnar osteotomy occurred in three patients who were treated early in the series and was the result of inadequate internal fixation or insufficient duration of protective splinting. All three of the patients had satisfactory results after replating and bone-grafting.

The procedure appears to help to maintain carpal height, prevent further collapse of the lunate, encourage consolidation of the fragmented lunate, and increase grip strength. Except for ulnar deviation, which the procedure may further diminish, the postoperative motions of the wrist were moderately improved.

Kienböck’s disease, or avascular necrosis of the carpal lunate, has been treated by a variety of surgical and non-surgical methods. This report details the technique and the results of ulnar lengthening by the procedure being performed at the Mayo Clinic at the time of writing. We have used the technique, a modification of that first proposed by Persson in 1945, in twenty patients, all of whom were followed for two years or more.

The rationale for lengthening the ulna to treat Kienböck’s disease is based on the observed association of the disease with the condition known as ulnar-minus variance. Hultén suggested this term to describe a wrist in which the distal articular surface of the radius extends beyond that of the ulna. In his original study, 74 per cent of the wrists with necrosis of the lunate had this variation, whereas only 26 per cent of 400 normal wrists had it. No patient with Kienböck’s disease had a so-called ulnar-plus wrist, but 16 per cent of the control group had such a finding.

After a review of the literature prior to 1945, Persson concluded that Kienböck’s disease is associated with the ulnar-minus condition. He cited this association in support of his concept of the pathogenesis of Kienböck’s disease and devised a surgical treatment that corrected the ulnar-minus condition. He suspected that Kienböck’s disease began with a compression fracture of the lunate and that after the fracture, certain areas of the bone lost their blood supply and became necrotic. He believed that stress fractures of the lunate have an increased tendency to occur in patients with an ulnar-minus wrist because the lunate abuts against surfaces of greatly differing hardnesses. While the firm articular surface of the radius, the so-called radial corner, supports the radial portion of the lunate, the relatively retracted ulna offers only the softer discus articularis, the so-called triangular fibrocartilage, as support for the ulnar portion of the lunate. To correct this unfavorable mechanical relationship and to allow for healing and reconstitution of the lunate, Persson proposed lengthening the ulna to remove the concentration of stress produced at the radiolunate articulation.

As stated previously, various operative and non-operative methods, ranging from simple immobilization to wrist arthrodesis, have been advocated as treatment for Kienböck’s disease. Simple extirpation of the lunate, used for treatment by some clinicians, has been criticized by others, who noted that loss of the space effect of the lunate allows relative proximal translation of the remaining carpal bones. This carpal realignment causes later degenerative changes and disability.

Nahigian et al. developed a dorsal flap arthroplasty to fill the space of the excised lunate and reported good early results. Several authors have advocated the use of a prosthesis to replace the excised lunate. Results using Silastic implants have been promising, but occasional dislocation of the prosthesis when the early models were used, as well as the inevitable dissociation of the proximal carpal bones that follows implantation of the prosthesis, have tempered enthusiasm for this form of treatment to some degree.

The ulnar-lengthening procedure proposed by
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Fig. 1-A
Typical radiographic changes of Kienböck’s disease, showing an ulnar variance of −8 millimeters, sclerosis, cystic changes, and fragmentation of the lunate.

Persson³⁰,³¹ allows for healing of the lunate while avoiding many of the problems encountered in other procedures. The apparent advantages of this technique prompted our clinical investigation.

Material

During the period from 1975 to early 1979, twenty-eight patients with a diagnosis of Kienböck’s disease were seen at the Mayo Clinic. At first, the ulnar lengthening procedure was used primarily in patients with limited fragmentation and collapse of the lunate. Therefore, six patients were treated by silicone replacement arthroplasty and two others, who had persistent pain after silicone replacement arthroplasty done elsewhere, were treated by proximal row carpectomy. We now consider arthroplasty to be definitely indicated only if the distal articular surface of the lunate is fragmented, if an extra-articular procedure has failed, or if there are contraindications to either ulnar lengthening or radial shortening.

Twenty patients were treated by an ulnar-lengthening procedure. The diagnosis was based on clinical symptoms and signs and on radiographic evidence of sclerosis, cystic changes, or fragmentation of the lunate with or without collapse (Figs. 1-A, 1-B, and 2). All of the patients were evaluated before and after the operation, which was performed by one of us (R. L. L.).

All twenty patients had unilateral involvement: on the left side in seven and on the right in thirteen. The non-dominant hand was involved in seven patients and the dominant hand, in thirteen. Nine of the patients were employed in occupations requiring heavy labor, five did light labor, and six performed mainly sedentary tasks. Fifteen

Fig. 2
Anteroposterior trispiral tomograms of the wrist made at two-millimeter intervals show the fine detail of the fragmentation and collapse of the lunate, particularly where it articulates with the radius.
of the patients were men and five were women. Their ages ranged from eighteen to fifty years; the average age was twenty-eight years.

Clinical Findings

In all patients the duration of related symptoms before operation averaged twenty months (range, eight months to six years). Ten patients were unaware of a specific injury, eight described a hyperextension injury of the involved wrist, and two said that there had been a direct blow to the wrist. At admission, five of the patients complained of moderate pain (persistent, but causing little restriction of work-related activities) and fifteen complained of more severe pain (unable to perform all work-related duties). Wrist motion or attempting a firm grip aggravated the symptoms.

Wrist motion and grip strength were measured in all patients preoperatively. Compared with the average ranges of motion of the uninvolved wrists, dorsiflexion averaged 81 per cent; palmar flexion, 62 per cent; radial deviation, 59 per cent; and ulnar deviation, 62 per cent of normal. Supination and pronation were not appreciably diminished in any patient. On the involved side, the average grip strength was 53 per cent of that on the opposite side.

Radiographic Findings

Standard radiographs and trispiral tomograms of the involved wrist were made for all patients. There was obvious sclerosis of the lunate at the time of admission in all patients but one, and in this patient the sclerotic changes eventually occurred. In two of the patients there were pronounced cystic changes in the lunate as well. All but three patients had a fracture of the lunate at the time of diagnosis. The predominant fracture type, a so-called anterior-pole fracture, occurred in ten wrists and was most clearly demonstrated on lateral tomograms (Fig. 3). In these fractures the fracture line was in the frontal plane and separated the anterior pole from the remaining portion of the lunate. In nine wrists, there was significant collapse of the lunate’s proximal convex surface, especially over the area articulating with the radius. Four patients had a so-called dorsal-pole fracture; two, a sagittal-plane fracture that divided the lunate into equal medial and lateral halves; and one, a comminuted fracture involving both the anterior and the posterior pole. Collapse of the proximal surface of the lunate was also a common finding in these seven patients.

The degree of carpal collapse or proximal carpal migration was quantitated by the method of Youm et al. and McMurtry et al., which uses the ratio of the carpal height to the length of the third metacarpal (Fig. 4). The ratio for the wrists in their control group was 0.54 ± 0.03. Using this value as a standard, we found that eleven of our twenty patients initially had carpal collapse, with ratios

*Fig. 3*

The common fracture pattern in Kienböck’s disease is the so-called anterior-pole type, isolating the lunate’s anterior pole from the remaining portion of the bone. Distraction of the fracture caused by the compressive force exerted by the capitae diminishes the likelihood of fracture-healing. This detail usually is not visible on routine radiographs because the radial styloid process is superimposed on the fracture gap. As the dorsal portion of the lunate collapses further, the anterior pole may be extruded volarly.
ranging from 0.50 to 0.46 (equivalent to a collapse of one to three millimeters).

None of the radiographs showed significant degenerative changes in the intercarpal or radiocarpal joint.

Sixteen of the twenty patients had an ulnar-minus variance, while the other four did not have any appreciable difference (no more than 0.5 millimeter) between the lengths of the ulna and the radius. For all twenty patients, the average ulnar-minus variance was 3.1 millimeters and the range was zero to 8 millimeters.

**Surgical Procedure and Postoperative Routine**

The procedure (Fig. 5) is performed under general anesthesia with a pneumatic tourniquet applied to the patient's arm. Both the involved extremity and the ipsilateral iliac crest (anterolateral portion) are prepared and draped initially.

A longitudinal incision is made over the medial border of the distal portion of the ulna. The extensor carpi ulnaris and flexor carpi ulnaris are reflected, and the distal one-third of the ulna is exposed subperiosteally. A transverse cut is made with a power saw through the medial three-fourths of the ulna. A plate with four or more slotted holes (Eggers type, Zimmer 539.01 or 539.02) is placed over the exposed ulna and centered at the osteotomy site. Four screws are inserted fully, so that each lies at the end of its respective slot nearest the center of the plate.

The osteotomy is then completed through the ulna, and a cervical laminectomy spreader is utilized to distract the fragments after the screws are loosened slightly. This procedure allows for distraction of the ulnar fragments but prevents rotatory malalignment at the osteotomy site. The correct amount of distraction, as determined from the preoperative radiographs, is equal to the negative ulnar variance plus one or two millimeters. The screws are tightened to maintain distraction. A bicortical iliac graft of the same width is then inserted into the osteotomy gap. The two screws in the proximal fragment are loosened to allow the surrounding elastic tissues to apply compression across the grafted area; all four screws are then retightened.

Any projecting part of the graft is trimmed, and radiographs are made to determine the new ulnar variance. These radiographs usually show that the space between the radius and the lunate is opened slightly compared with that visible on preoperative radiographs. The wounds are closed over suction drains (which are removed in twenty-four hours), and a well padded palm-to-axilla dressing with an external plaster splint is applied.

Two weeks after operation, radiographs are made, the sutures are removed, and a palm-to-elbow plaster cast is applied. This cast is removed after an additional four to six weeks. An Orthoplast splint is then worn if the osteotomy site is not clinically stable with radiographic evidence of healing, indicated by callus formation at both ends of the
graft and signs of early trabeculation extending across the cuts at each end of the graft.

The plate and screws were not removed from the three patients who required a secondary procedure for non-union. Of the other seventeen patients, who had primary healing twelve to fifteen months after operation, the plate and screws were removed from sixteen a year after union was established and from the seventeenth patient at twenty-six months, when the patient finally returned for follow-up. In each patient, removal was accomplished with local anesthesia as an out-patient procedure. The decision to remove the plate and screws was based on the concept that the grafted area would become stronger after the fixation was removed.

**Results**

All twenty patients were available for follow-up and were re-examined after periods ranging from twenty-four to seventy-five months, with an average follow-up of thirty-seven months. For the three patients who required reoperation for non-union during the study period, the follow-up was recorded as the elapsed time since the second procedure. At the last evaluation, seven patients had complete relief of all symptoms; eleven had only infrequent, minor symptoms; and two had incomplete relief of symptoms. All but three patients expressed satisfaction with the outcome of the procedure. Of these three, two believed that the wrist was insufficiently improved and one, although the wrist was improved, did not think that the procedure had been worth while in view of the length of the convalescence and the complications. All but two of the twenty patients had returned to their original jobs or avocations.

**Clinical Findings**

At the time of follow-up, the average range of wrist motion, compared with that before operation, was increased at least slightly in all planes with the exception of ulnar deviation. The average motions at follow-up, expressed as percentages of the motion on the uninvolved side, were 84 per cent for dorsiflexion, 70 per cent for palmar flexion, 86 per cent for radial deviation, and 53 per cent for ulnar deviation. A full range of pronation and supination remained in all patients except one, in whom the changed relationship of the distal radio-ulnar joint seemed responsible for a modest loss of pronation. On the average, the grip strength on the involved side was 70 per cent of that on the normal side, a postoperative improvement of 17 per cent.

Three of the patients had non-union of the ulnar osteotomy. All three non-unions occurred in the early part of the study and were attributable to the use of too small a plate or to insufficient postoperative external immobilization. These patients required reoperation, at which a six-hole plate was applied, and all three rated the long-term result as good. Each returned to strenuous manual labor. There were no other complications.

**Radiographic Findings**

All patients except one had lengthening of the ulna to an ulnar-zero or ulnar-plus position. At operation the ulnar length in the one exception could be increased only from −6 to −2 millimeters. In the four patients with neutral

![Fig. 6-A](image)

Lateral tomogram of a wrist, showing a typical anterior-pole fracture.

![Fig. 6-B](image)

Twelve months after ulnar lengthening, the lunate shows no further collapse and there is a suggestion of early healing.
variance the length was increased approximately two millimeters.

A point of special interest was the change in radiographic density of the lunate and in the status of the lunate fractures. Of the twenty patients, six had an apparent decrease in sclerosis, one had increased sclerosis, and thirteen showed no change. Of thirteen patients with an obvious fracture of the lunate at the time of follow-up, seven showed some evidence of consolidation and healing (Figs. 6-A and 6-B) as determined by trispiral tomography. Of the ten wrists in which an anterior-pole fragment was distracted initially, only one showed healing of this fragment to the body of the lunate.

The ratio of Youm et al.46 and McMurtry et al.46 was used to determine changes in the degree of carpal collapse on the follow-up radiographs. Only one patient had increased collapse, with a small decrease in the ratio from 0.47 to 0.46. Interestingly, at follow-up nine patients showed increases in carpal height, with corresponding increases in the ratio46,48 ranging from 0.01 to 0.04.

Discussion

The concept that some cases of Kienböck’s disease are sequelae of fractures of the lunate is becoming widely accepted18,19,28. Fractures in this series were oriented primarily in the frontal plane, so that either the palmar or the dorsal pole was isolated from the remaining portion of the bone15. That such fractures may lead to avascular necrosis is understandable when the blood supply of the lunate is considered1. Lee25 identified three vascular patterns in the lunate: a single vessel entering at either the anterior or the dorsal pole and supplying the whole bone, several vessels entering at both poles but with no central anastomosis between them, and bipolar vessels that do anastomose. Obviously, the first two vascular patterns place the carpal lunate at more risk for avascular necrosis after a fracture, although this was disputed by Gelberman et al.11. Also, it is conceivable that injury to a vessel entering the lunate through a ligament at either pole may interrupt the blood supply in the absence of fracture41.

The high correlation between Kienböck’s disease and the presence of negative ulnar variance has continued to be confirmed in the recent literature12. Hultén16, Persson20,21, and Brolin5 all thought that the lunate selectively transmits a major proportion of the forces crossing the wrist. They concluded that a retracted or short ulna allowed a concentration of these forces on the proximal radial portion of the lunate. In Brolin’s words5, this is ‘a circumstance conducive to compression fracture’.

To study the stresses in the lunate, Kashiwagi et al.20 developed a photoelastic model of the wrist, and Keshesi et al.21 used a direct electrostress model. Their findings lend support to the earlier observations of Hultén16, Persson20,21, and Brolin5. Kashiwagi et al.20 found that when their wrist model was dorsiflexed and ulnarly deviated, compression forces across the wrist produced isochromatic stress lines that were concentrated in the lunate. They suggested that tensile forces on the distal concave surface predisposed the lunate to fracture.

The findings of these authors, in addition to unpublished data from our own biomechanics laboratory, suggest the following pathogenesis for Kienböck’s disease. When the wrist is forced into extreme dorsiflexion, excessive tension is placed on the radiolunate and lunatomotriquetral ligaments (Fig. 7) because the triquetrum, which is supported only by the relatively soft and compliant discus articulares, is displaced posteriorly and proximally. This ligament tension is transmitted to the anterior pole of the lunate. The lunate is therefore compressed between the radius and the capitate, and failure, most commonly at the junction of the anterior and middle one-thirds, is caused by tensile stress. Vascular injury, usually secondary to lunate fracture, is produced by these stresses. Later, compressive forces acting across the wrist cause collapse of the prox-

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fig. 7

Diagram showing a proposed mechanism for an anterior-pole fracture of the lunate in the right wrist. The end-on view (right) shows the anterior aspect below and the ulna on the left. As the wrist is forced into extreme dorsiflexion, excessive tension is transmitted to the anterior pole of the lunate through the lunatomotriquetral and radiolunate ligaments. As the triquetrum is displaced dorsally and proximally, the lunate fractures, beginning at its proximal surface. The anterior fragment is rotated and translated anteriorly as the capitate displaces proximally and separates the fragments further.
imal surface of the devascularized lunate, especially where it abuts against the radial articular surface. Collapse of the lunate is then followed by proximal migration of other carpal bones, producing an over-all decrease in the height of the carpus.

Persson\textsuperscript{30,31} thought that the logical therapeutic approach to Kienböck’s disease was to correct the unfavorable concentration of stresses on the lunate. He described a method in which the ulna was osteotomized obliquely and the fragments were distracted and then wired in new positions. The method outlined in this paper is similar to that of Potma\textsuperscript{32} and accomplishes the same objective but uses an interpositional bone graft and plating to give more precise control and to stabilize the lengthened ulna.

Apparently, the distal advancement of the ulnar articular surface provides support for the carpus through the triangular fibrocartilage. In two of our patients intraoperative arthograms before and after ulnar lengthening demonstrated an increased radiolunate joint space (Figs. 8-A and 8-B). Presumably, the reduction of forces concentrated at this joint surface facilitates the healing and revascularization of the lunate. In addition, over-all carpal collapse is halted or reversed when the ulnar part of the carpus is supported better.

The described procedure allows for retention of the lunate bone, even though it may be distorted, so that it can serve as a spacer in the proximal carpal row. The retained lunate is not prone to subluxation or dislocation. The operative procedure does not violate any of the intact ligament attachments of the lunate to the other carpal bones, specifically the scapholunate and lunatotriquetral interosseous membranes. Prosthetic spacers, such as silicone implants, have given good results, but there have been occasional unsatisfactory results due to subluxation or dislocation of the prosthesis\textsuperscript{24,25}. Also, after silicone-rubber replacement, persistent pain necessitating secondary procedures has been reported\textsuperscript{4}.

Ulnar lengthening may produce a slight decrease in the range of ulnar deviation of the wrist (in this series, an approximate 10 per cent average reduction compared with the preoperative average value). Excessive lengthening of the ulna or a long ulnar styloid process may be a factor in decreasing this motion. The increased ulnar length also may affect the radioscapoid articulation, although our patients have not complained of pain there and no evidence of degenerative changes in this area had been found at the time of writing. The failure to obtain good relief in one patient may have been secondary to discomfort at the distal radio-ulnar joint. The geometry of this joint varies considerably and an oblique orientation may be a contraindication to a lengthening procedure. A longer follow-up period will be required before there is a definitive answer to this question.

Radial-shortening procedures have been performed as treatment for Kienböck’s disease by several surgeons\textsuperscript{2,17,37,45}. Theoretically, they should provide the same mechanical effect as ulnar lengthening and, in addition, reduce compressive forces by shortening the muscles crossing the carpus. Non-union or malunion of the radius may pose a complication if accurate, stable fixation is not obtained. Another disadvantage is that dissection to expose the radius involves more soft-tissue structures.

In our series, the patients’ satisfaction and the improvement as determined by objective measurements
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compared favorably with the results of implant techniques and also correlated well with the outcome of Person’s original series 30,31. The complications that have occurred with modified ulnar lengthening should be largely overcome by the improvements in technique that are now used.

Conclusions

The modified procedure of ulnar lengthening by means of an intercalated biconical iliac-bone graft and rigid plate fixation is a simple surgical treatment of Kienböck’s disease that gives predictable results. At the time of writing, we found that the objective and subjective results were promising.

The number of complications should be reduced by adhering to a precise surgical protocol and by using external splitting for a sufficient period of time. The method requires a second procedure for plate removal, but in most patients this can be performed under local anesthesia on an out-patient basis.

Finally, it should be noted that the carpus is not surgically violated in this procedure. Should further treatment be necessary, the option to perform soft-tissue interpositional arthroplasty or prosthetic replacement of the lunate still remains.

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Rupture of Digital Extensor Tendons following Distal Ulnar Resection

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ABSTRACT: We have treated four patients with rupture of one or more digital extensor tendons following a distal ulnar resection for a traumatic problem. The rupture was caused by the abrasive effect of the distal part of the ulna at the site of resection during pronation and supination.

Two patients were treated with a silicone-rubber prosthesis and tendon grafts and two, with resection of an ulnar bone spike and local tendon transfers. Tendon rupture is best avoided by strict adherence to the surgical technique described by Darrach. If rupture of the tendon occurs, reconstructive procedures must be devised to repair the individual lesion found at operation.

Rupture of one or more digital extensor tendons at the wrist has been reported in patients with rheumatoid arthritis. Despite the frequency with which distal ulnar resection is done for post-traumatic problems, we did not find any reports of this rupture following distal ulnar resection in patients who did not have rheumatoid arthritis.

Case Reports

Case 1. A thirty-three-year-old man sustained a comminuted fracture of the radial head in the right, dominant arm and it was excised primarily. Five months after returning to work in a heavy-equipment operator, pain developed in the right wrist which was not relieved by the use of a leather wrist-band. Two and a half years following the radial head resection the distal portion of the right ulna was resected (Figs. 1-A and 1-B). Two months following this procedure the patient was seen for the complaints of grating and grinding in the right wrist on pronation and supination of the forearm and inability to extend the long, ring, and little fingers at the metacarpophalangeal joints (Fig. 1-C). At operation, there was an extensive synovitis surrounding the distal part of the ulna and the digital extensors on the ulnar side of the wrist. The extensor digitorum communis tendons to the long, ring, and little fingers, the extensor indicis proprius, and the extensor digiti quinti minimi tendons were ruptured. Palmaris longus tendon grafts successfully restored full extension at the third, fourth, and fifth metacarpophalangeal joints (Fig. 1-D). A silicone-rubber prosthesis with an intramedullary stem and a cap to cover the cut end of the bone was fitted to the distal end of the ulna.

The patient was relatively asymptomatic for about eight to ten months but then pain developed in the right elbow which required an arthroscopy for removal of a cartilaginous loose body. He continued, however, to have mild symptoms of pain and swelling in the wrist and some clicking on pronation and supination. Examination showed the silicone-rubber prosthesis to be easily palpable and visibly moving on motion of the forearm. Forty-three months following the second operation on the wrist, the swelling and pain around the distal part of the ulna had increased and a roentgenogram showed displacement of the prosthesis. At reoperation, a thick fibrous capsule was found around the distal part of the ulna and the loose prosthesis was removed. The grafted tendons were intact although surrounded by considerable reactive synovitis. A synovecmy was performed and the fibrous capsule was tightened to close the dead space around the distal part of the ulna. Eighteen months later the patient had full pronation, some restriction of supination, slight restriction of extension-flexion of the wrist, and normal finger motion. Grip strength was 25 per cent of normal as measured by a dynamometer.

Case 2. A fifty-five-year-old woman had a distal ulnar resection in the right, dominant wrist for a radio-ulnar instability caused by twisting trauma. She was seen two months later, complaining of inability to extend the little finger at the metacarpophalangeal joint. Examination revealed a well healed surgical incision over the dorsal aspect of the distal part of the ulna with an underlying soft, boggy swelling characteristic of synovitis. There was no active extension of the little finger at the