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Long-term clinical results and MRI changes after tendon ball arthroplasty for advanced Kienböck's disease

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Abstract

The purpose of this study was to assess the long-term clinical results and morphological changes after tendon ball arthroplasty for advanced Kienböck's disease. Twenty-six patients were reviewed, with a mean follow-up interval of 125 months (range 50–226). At follow-up, mean score on the Disabilities of the Arm, Shoulder, and Hand questionnaire was 7.7 and mean visual analogue scale score for pain was 1. Mean carpal height ratio was significantly reduced with respect to the pre-operative value. On magnetic resonance imaging scans, cartilage damage, synovitis, and erosive or oedematous changes in the bones were detected in most patients. Calcification in the defect filled by the tendon ball was seen in all patients. Narrowing of the radioscaphoid joint and the presence of intercarpal synovitis were negatively associated with clinical outcome. Tendon ball arthroplasty in advanced Kienböck's disease results in long-term satisfactory clinical outcomes, despite widespread changes in the bones and joints within the wrist.

Keywords

Lunate, avascular necrosis, Kienböck's disease, tendon ball arthroplasty, wrist, magnetic resonance imaging

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Introduction

Kienböck's disease, or avascular necrosis of the lunate, is a progressive condition (Keith et al., 2004) that passes through various stages described by Lichtman et al. (1977) over time. As the disease progresses, there is alteration of the mechanics of the wrist, with abnormal stresses, and wear on the joints within the wrist itself. The development of carpal collapse, with joint instability and incongruity,

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ultimately leads to osteoarthritic changes in the wrist. There is lack of consensus on the superiority of surgical versus conservative treatment (Delaere et al., 1998). Simple lunate excision accelerates the reduction of carpal height (Gillespie, 1961; Kawai et al., 1988). Hence, many surgical options have been adopted for the late stages of Kienböck's disease, including tendon ball arthroplasty with or without a bone core (Kato et al., 1986; Küçük et al., 2011; Matsuhashi et al., 2011; Sakai et al., 2004; Ueba et al., 1999; Zeplin and Ziegler, 2012). The interposition of a tendon ball aims to maintain carpal height after lunate excision, preventing the proximal migration of the capitate (Sakai et al., 2004).

There are no magnetic resonance imaging (MRI) data concerning the fate of the interposed tendon ball or changes in the adjoining bones and joints within the wrist many years after surgery.

The purpose of this study was to determine the long-term subjective and objective results of palmaris longus tendon ball arthroplasty performed for advanced Kienböck's disease and investigate the frequency and characteristics of changes in the bones and joints within the wrist after this procedure using computed tomography (CT) and high-resolution MRI scanning. We also assessed possible relationships between the clinical and morphological findings.

Methods

From 1992 to 2007 we carried out palmaris longus tendon ball arthroplasty in 28 patients with advanced Kienböck's disease. We reviewed 26 of these patients (follow-up rate: 93%) with Lichtman stage IIIA (two patients), IIIB (23 patients), or IV (one patient) disease. There were 18 men and eight women. The right side was affected in 18 patients and the left side was affected in eight; the dominant and nondominant side was affected in 21 and five cases, respectively. The mean age of patients at time of surgery was 35 (range 19–62) years.

Palmaris longus tendon ball arthroplasty was carried out through a longitudinal incision on the dorsum of the wrist. After opening of the extensor retinaculum between the third and fourth compartments, a dorsal capsulotomy of the wrist joint was made. The collapsed lunate was excised and the resulting defect was filled with a tendon ball using an ipsilateral palmaris longus tendon strip that was rolled into a ball and sutured to itself. After surgery, the wrist was immobilized in a plaster cast for 4 weeks.

The mean duration of post-operative follow-up was 125 (range 50–226) months. On the follow-up visit and after informed consent was obtained, all participants underwent subjective and objective clinical assessment as well as being interviewed to obtain their occupational history. Patients were asked to score pain on a 10 cm visual analogue scale (VAS). The scale was graded from 0 to 10 cm, with 0 cm indicating no pain. We also obtained Disabilities of the Arm, Shoulder, and Hand (DASH) scores (0 points: no complaints; 100 points: worst possible outcome) for all patients (Hudak et al., 1996). VAS and DASH scores were obtained by giving patients a standardized questionnaire, which they returned. Flexion and extension of the wrist were measured with a goniometer and compared with the pre-operative values taken from the clinical records. Grip strength was determined using a standard, adjustable-handle mechanical Jamar dynamometer (FEI, Irvington, New York, USA); measurements were made on both the operated and non-operated hands.

All patients subsequently underwent standard radiographs of the wrist to calculate the carpal height ratio (e.g., carpal height divided by length of the third metacarpal) (Youm et al., 1978). The carpal–height ratio at follow-up was compared with the pre-operative data, calculated using standard radiographs obtained before surgery. On these latter examinations, pre-operative ulnar variance also was determined.

CT and MRI examinations of the wrist and hand were carried out in all but two patients. MRI was performed with a 3 T high field apparatus (Somatom Trio, Siemens, Erlangen, Germany) with the following sequences: 3D coronal T2 DESS, 3D coronal T1 VIBE, 2D axial T1 turbo spin echo, 2D axial T2 turbo spin echo, and 2D coronal PD turbo spin echo fat suppressed. A volumetric spiral CT scan was also obtained (Aquilion 64, Toshiba Medical Systems, Tokyo, Japan). All images were reviewed on a workstation using open-source OsiriX software so that the 3D MRI sequences and volumetric CT study could be reconstructed on different planes.

Using the MRI scans, we first made a thorough assessment of the radioscaphoid and midcarpal articular cartilage. The status of the cartilage in these joints was scored using a system based on the presence of joint space narrowing and/or chondral fissures: 0 (normal), 1 (definite narrowing of the joint space and/or presence of chondral fissures). The space between the distal radius and scaphoid was also measured to quantify the severity of cartilage damage. Using MRI scans, we looked for bone erosion and oedema as well as radioscaphoid and intercarpal synovitis, which are the changes scored by the OMERACT system, the standard MRI method for the assessment of rheumatoid arthritis in the wrist (McQueen et al., 2003). The scale of bone erosion was

0–10, based on the proportion of eroded bone compared to the "assessed bone volume" as judged on all available images: 0, no erosion; 1, 1–10% of bone eroded; 2, 11–20%, etc. The bone oedema was scored 0–3 by the volume of oedema: 0, no oedema; 1, 1–33% of bone oedematous; 2, 34–66%; 3, 67–100%. The synovitis was assessed in two wrist regions (i.e., the radioscaphoid joint and the intercarpal joints). The scale was 0–3. A score of 0 is normal, while scores of 1 to 3 (mild, moderate, severe) indicates increase by thirds of the presumed maximum volume of the synovial compartment.

CT scans were used to measure the distance between the scaphoid and triquetrum, and to identify and measure the presence of calcification or ossification in the defect filled by the palmaris longus tendon ball. If any ossification was present, the presence of lining cartilage was assessed on the MRI scans.

Statistical analysis

A paired Student's *t*-test was used when appropriate. Age-adjusted logistic regression analysis was used to assess the relationships between single abnormalities found on the imaging tests and clinical outcome. For this purpose, the clinical outcomes were dichotomized using arbitrary cut-offs (i.e., DASH score ≤ 9 points = 0; ≥ 10 points = 1; VAS 0 = 0; ≥ 1 = 1). Univariate and multiple step-wise linear regression analyses were used to determine whether any morphological change was significantly associated with grip strength.

Results

Clinical results

The subjective outcome measures at follow-up showed an average VAS score for pain of 1 (SD 1.4; range 0–5 points) and an average DASH score of 7.7 (SD 8.6; range 1–26 points). Fourteen of 26 patients were totally free of pain and 21 were currently engaged in manual work. Eighteen had been able to resume their pre-operative occupation or activity, and none had changed to less strenuous employment.

The mean range of palmar flexion of the affected wrist at follow-up was not significantly increased with respect to the pre-operative value (40° vs 38°; p = 0.069), and was 56% of the contralateral side (40° vs 72°; $p < 0.001$). The mean range of extension of the operated wrist at follow-up was significantly increased with respect to the pre-operative value (48° vs 42°; p = 0.002), and represented 58% of the range of motion of the contralateral wrist (39° vs 67°; p = 0.001). The mean grip strength was 33 kg (SD 11; range 14–54 kg) in the surgically treated hand and 40 kg (SD 12; range 18–68 kg) in the contralateral hand; thus, grip strength in the surgically treated hand was 84% of that of the untreated hand ($p < 0.001$).

Imaging results

Table 1 presents the MRI results. Cartilage damage, erosive changes in the bones, bony oedema, synovitis, and triangular fibrocartilage tears were detected in more than half of patients. The abnormalities found in the carpal bones and neighbouring joints were mostly of mild severity. The mean space between the distal radius and scaphoid was 17 mm (SD 3.7; range 10–21 mm). Pre-operatively, 17 patients had neutral variance and nine had negative ulnar variance. The mean carpal height ratio was 0.49 (SD 0.05; range 0.36–0.60) before surgery and 0.45 (SD 0.05; range 0.34–0.53) at the follow-up visit ($p < 0.001$). Calcification or ossification in the defect filled by the palmaris longus tendon ball was seen in all patients (Figure 1) imaged using MRI and CT scans, and were multiple in 19 of 24 patients. Mean diameter of the largest ossification was 10 mm (SD 4.3; range 3–19 mm). In 12 patients, the larger ossification was > 10 mm in diameter and the presence of lining cartilage was detected on MRI scans in 15 of 24 patients. The mean width of the surgical defect between the scaphoid and triquetrum was 14 mm (SD 3.8; range 8–22 mm).

Clinical and imaging relationships

In the age-adjusted logistic regression analysis, a higher score on the DASH questionnaire at follow-up was inversely associated with the width of the radioscaphoid joint (odds ratio [OR] 0.54; 95% CI 0.34 to 0.86; p = 0.010) and was directly related to the presence of oedema of the triquetrum (OR 5.12; 95% CI 1.0 to 25.1; p = 0.044) on MRI scans. When both of these abnormalities were included at the same time in the forward stepwise age-adjusted logistic regression analysis, the width of the radioscaphoid joint remained the only significant inverse predictor of the DASH score. Using the same analytic method, there was a positive association between a higher VAS score for pain and presence of intercarpal synovitis on the MRI (OR 6.5; 95% CI 1.1 to 40.1; p = 0.045).

Step-wise multiple linear regression analysis revealed that the grip strength in the operated hand at follow-up was inversely associated with increased age (coefficient (c) = −0.6; $p < 0.001$), as well as with the presence of oedema in the distal ulna (c = −14.7; $p < 0.001$) and intercarpal synovitis (c = −2.6; p = 0.017)

Table 1. Bone and joint abnormalities revealed by MRI examination

		Number of cases	Severity grade (n)
Cartilage damage	Total cases	13	
	Radioscaphoid joint	11	
	Midcarpal joint	9	
Bone erosion	Total cases	21	
	Distal radius	5	1 (5)
	Distal ulna	6	1 (4)
			2 (2)
	Scaphoid	13	1 (13)
	Triquetrum	16	1 (12)
			2 (4)
	Trapezoid	1	1 (1)
	Capitate	13	1 (8)
			2 (3)
			3 (2)
	Hamate	4	1 (4)
Bone oedema	Total cases	16	
	Distal radius	4	1 (2)
			2 (2)
	Distal ulna	4	1 (4)
	Scaphoid	7	1 (7)
	Triquetrum	8	1 (4)
			2 (2)
			3 (2)
Synovitis	Total cases	19	
	Radioscaphoid joint	5	1 (5)
	Intercarpal joints	16	1 (12)
			2 (2)
			3 (2)
Triangular fibrocartilage lesion	Total cases	20	

on MRI. Conversely, a significant positive association was found with being male ($c = 7.7$; $p = 0.006$).

With the numbers available, we did not detect other significant differences in the clinical outcomes in patients with different frequencies or severity of abnormalities on their MRI or CT scans. Neither the follow-up value of the carpal–height ratio nor its variation with respect to the pre-operative value was significantly associated with any clinical outcome.

Discussion

Nonsurgical management is a feasible option in the early phases of Kienböck's disease (Innes and Strauch, 2010), whereas radial shortening osteotomy is a reliable long-term treatment for patients with Lichtman stage II and IIIA disease, particularly when an ulnar minus variant is present (Takahara et al., 2009).

When the disease becomes advanced, carpal collapse, joint incongruity, and osteoarthritis develop and the pain and reduction in the range of motion can lead to severe disability (Takase and Imakiire, 2001). Therapeutic options in the late stages of the disease include nonsurgical treatment, simple lunate resection, partial arthrodesis, proximal row carpectomy, vascularized bone grafting, radial osteotomy, silicone implants, or tendon ball arthroplasty, but none of these methods has been proven to be superior (Innes and Strauch, 2010). A clinical and cadaver study carried out with dynamic radiographs showed that simple excision of the lunate results in limitation of movement, altered intercarpal motion, and disruption of the carpal architecture (McMurtry et al., 1978). The palmaris longus tendon ball arthroplasty is intended to reduce the alteration in intercarpal movements and carpal collapse, which follow simple lunate excision over time (Gillespie, 1961; Kawai et al., 1988). These changes may cause severe decrease in the grip strength of the operated hand so that excision alone is not advisable if strenuous activity is necessary (Kawai

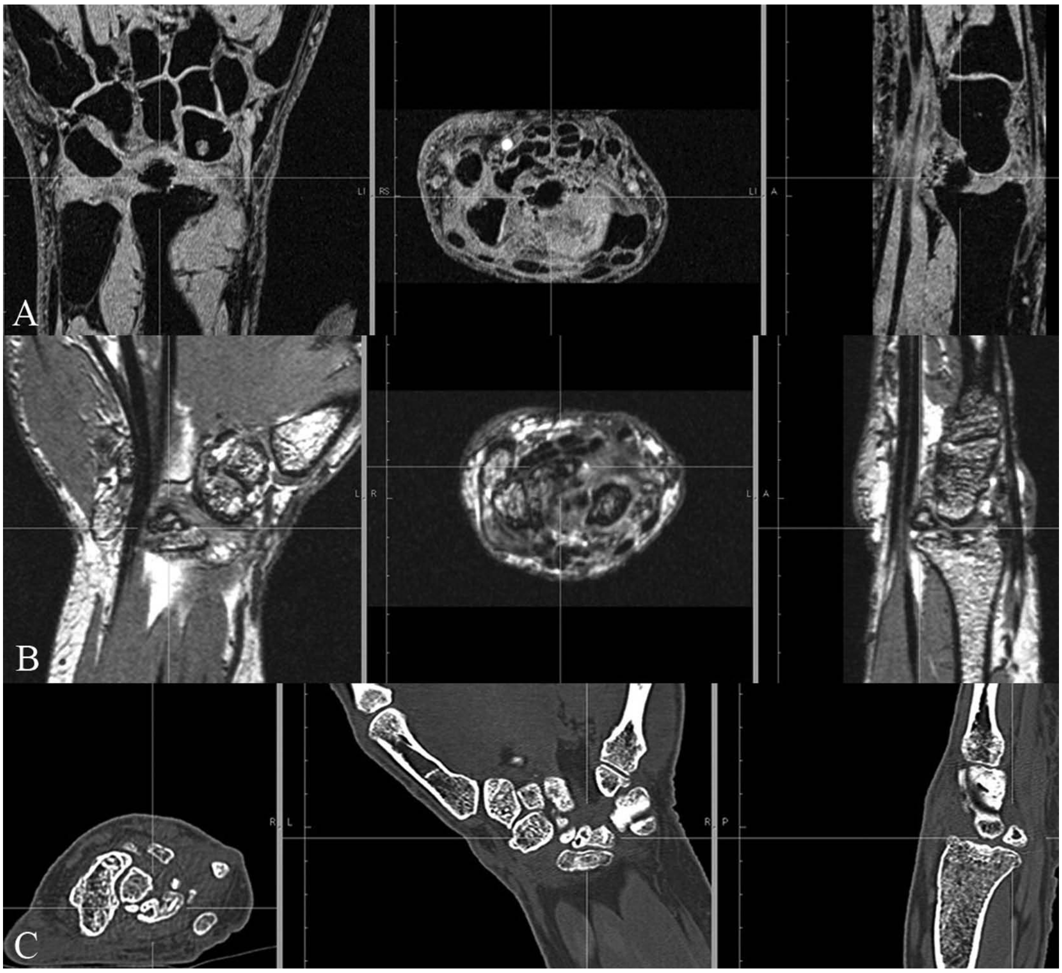

Figure 1. Ossification in the palmar side of the defect filled by the tendon ball. High resolution (A) coronal MRI 3D VIBE and (B) coronal MRI 3D DESS reconstructed on the axial and sagittal planes. (C) CT axial acquisition with coronal and sagittal reconstruction.

et al., 1988). The advantages of tendon ball arthroplasty include the avoidance of artificial materials and an easy post-operative recovery (Ueba et al., 1999). To our knowledge, no previous studies have investigated in detail the fate of the interposed tendon ball or changes in the adjoining bones and joints within the wrist many years after this procedure and their clinical significance.

We obtained satisfactory subjective and objective clinical results with respect to the functionality of the wrist, frequency of pain, and ability to work. The DASH score recorded in our study group was equal to the value reported after radial shortening osteotomy for Kienböck's disease in Lichtman stage II and III (Takahara et al., 2009) and compares favourably with the long-term results obtained with tendon ball arthroplasty (Zeplin and Ziegler, 2012), Saffar's procedure (lunate resection and vascularized pisiform transfer) (Daecke et al., 2005), and proximal row carpectomy (Croog and Stern, 2008) in advanced stages of the disease.

In our patients, the palmaris longus tendon ball arthroplasty improved extension of the wrist, whereas flexion remained unchanged after the operation. These findings concur with previous medium- and long-term post-operative data obtained with the same procedure (Kato et al., 1986; Küçük et al., 2011; Ueba et al., 1999).

The mean grip strength recorded in the present study also falls within the range of previous long-term follow-up reports on several surgical techniques used for advanced Kienböck's disease (Croog and Stern, 2008; Daecke et al., 2005; Kato et al., 1986; Kawai et al., 1988; Küçük et al., 2011; Takase and Imakiire, 2001; Ueba et al., 1999; Zeplin and Ziegler, 2012).

Standard radiographs have been routinely used to study long-term degenerative changes after surgery for Kienböck's disease. This method is usually reliable for the diagnosis of wrist osteoarthritis, but subchondral oedema of wrist bones, joint synovitis, and chondral lesions may precede the onset of abnormalities on standard radiographs and can be demonstrated only by CT arthrography or MRI (Feydy et al., 2009). Using the latter type of imaging, we detected a high frequency of erosion and oedema of the wrist bones, intercarpal synovitis, triangular fibrocartilage lesions, and chondral damage in the radioscaphoid and midcarpal joints. We cannot compare our findings with previous data because, to the best of our knowledge, this is the first study to use 3 T high-field MRI and CT to assess long-term alterations in the wrist bones and joints after surgery for advanced Kienböck's disease. The reported prevalence of long-term degenerative changes on standard radiographs is highly variable, ranging from 7% to 100% after tendon ball arthroplasty with or without a bone core (Kato et al., 1986; Küçük et al., 2011; Matsuhashi et al., 2011; Sakai et al., 2004; Zeplin and Ziegler, 2012), simple lunate excision (Kawai et al., 1988), partial arthrodesis (Takase and Imakiire, 2001), vascularized pisiform interposition (Daecke et al., 2005), or proximal row carpectomy (Croog and Stern, 2008). This discrepancy in the earlier data may be explained by the variable definition and pre-operative severity of degenerative changes, as well as by the different lengths of the follow-up intervals.

In the current study, the palmaris longus tendon ball arthroplasty failed to prevent the progression of carpal collapse over time, as demonstrated by the significant decrease in the carpal–height ratio at follow-up. This result has been observed in other long-term series of advanced Kienböck's disease treated with tendon ball arthroplasty (Kato et al., 1986; Küçük et al., 2011; Ueba et al., 1999), whereas studies with a shorter follow-up have shown that carpal height can be maintained when a tendon ball with a bone core is used as an interposition graft (Matsuhashi et al., 2011; Sakai et al., 2004). It is difficult to assess whether this improved result is attributable to the different structure of the graft or the shorter follow-up.

Despite the reported abnormalities found on the imaging, the clinical outcomes in our patients were satisfactory and unrelated to most of the morphological changes on the MRI or CT scans. Only narrowing of the radioscaphoid joint and presence of intercarpal synovitis showed a detrimental effect on the clinical outcomes. Poor correlation between imaging tests and clinical findings has already been reported in both conservatively (Evans et al., 1986; Kristensen et al., 1986; Mirabello et al., 1987) and surgically treated (Croog and Stern, 2008; Daecke et al., 2005; Kato et al., 1986; Küçük et al., 2011; Matshuashi et al., 2011) Kienböck's disease. In a systematic comparative review of the treatment of Kienböck's disease (Innes and Strauck, 2010), tendon ball arthroplasty achieved the highest percentage of late-stage patients with no pain after surgery, despite the loss of carpal height over time.

We detected calcification or solid ossification at the site of the implanted tendon in all the patients we studied. As stated in the long-term study by Ueba et al. (1999), these ectopic calcifications gradually transform into solid ossifications over time. Examining the wrist of our patients with high-quality scan on a 3T magnet, we found a thin and discontinuous hyperintense rim with the same signal as the cartilage partially coating the newly formed bone. Indeed, as reported by Saupe et al. (2007), the cartilage is easily recognized on MRI scans as a bright line on the joint surface of the bone. It can be hypothesized that the development of such ossifications in the surgical defect filled by the tendon ball, often surrounded by cartilage on our MRI scans, represents an attempt to reconstruct the morphology of the radiocarpal joint, with possible implications for its functionality.

The strengths of our study include use of reliable subjective and objective clinical measurements to assess the outcome, previously unused examination by high-field MRI to analyze long-term degenerative changes, and high rate of patient retention at follow-up. We also acknowledge some methodological weaknesses. First, this study suffers from the same limitations of any retrospective design. This and the lack of some baseline data prevented us from determining the post-operative changes in the functional status of these patients. Nor is there a comparison group which received an alternative treatment. However, it is difficult to carry out a prospective controlled analysis with such a follow-up, considering that Kienböck's disease is an uncommon condition. Another drawback is the relatively small sample size, which may have obscured significant relationships between morphological change and clinical outcome. Nevertheless, we reported on a study group that was larger with respect to most published series and significant relationships were detected despite the small study group.

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Conflict of interests

None declared.

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