

A STUDY OF FUNCTIONAL OUTCOMES FOLLOWING IMPLANTATION OF A TOTAL DISTAL RADIOULNAR JOINT PROSTHESIS

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This paper reports a long-term follow-up measuring pain, range of motion and weight-bearing ability, following implantation of a total distal radioulnar joint prosthesis. This prosthesis differs from excision arthroplasties and ulnar head replacements by replacing all three components of the distal radioulnar joint, viz. the sigmoid notch, the ulnar head and the triangular fibrocartilage. The design allows longitudinal migration of the radius throughout pronation and supination, as well as load bearing of the wrist. Thirty-one patients receiving the prosthesis returned or were interviewed by telephone at a mean of 5.9 (range 4–9) years. Pronation increased from a mean of 65.5° (range 5–90°) to 74° (range 20–90°) and supination from 53° (range 5–90°) to 70° (range 20–90°) while greatly diminishing and/or eliminating pain. Grip increased from a mean of 10 kg (22 lbs) to 24 kg (52 lbs). Weight bearing was restored or increased in 29 of 31 patients.

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Several surgical procedures have been developed to alleviate the pain of a dysfunctional distal radioulnar joint. These include partial, or complete, resection of the distal ulna (Bowers, 1985; Darrach, 1913; Taleisnik, 1992; Watson et al., 1986; Watson and Gabuzda, 1992), with or without its replacement using a silicone (Swanson, 1973), steel (Sauerbier et al., 2002a, b) or composite (Herbert and van Schoonhoven, 2000; Van Schoonhoven et al., 2003) ulnar head implant.

Several authors (Bell et al., 1985; Bieber et al., 1988; Dingman, 1952; Gonzalez del Pino and Fernandez, 1998; Gordon et al., 1991; Rana and Taylor, 1973; Schneider and Imbriglia, 1991) have reported questionable functional outcomes following resection of the distal ulna. In particular, the ulna remnant may impinge on the radius, causing pain. Lees and Scheker (1997) demonstrated that, under loading in the neutral pronation/supination position of the forearm following resection of the distal ulna, it is the radius that impinges onto the end of the ulna as the distal support of the radius has been ablated, partially or totally, with these techniques (Fig 1). This contact between the two bones tends to occur more commonly in young and active patients, irrespective of the resection technique used. Anatomical studies further demonstrate the need for an intact triangular fibrocartilage (Acosta et al., 1993; Bowers, 1985; Scheker et al., 1994; Schuind et al., 1991). These studies also showed the necessity for an anatomically intact ulnar head, normal cartilage and a sigmoid notch that retains its relationship with the longitudinal axis of the radius, a relationship frequently lost with distal radius fractures (Bowers, 1985; Scheker et al., 1994; Schuind et al., 1991). These aspects of normal joint anatomy are necessary to maintain stability of the distal radioulnar joint throughout its range of

motion. Partial or total resection of the distal ulna, with or without ulnar head replacement, disrupts these stabilising mechanisms and may lead to distal radioulnar joint instability, pain, loss of grip strength and impaired function of the forearm (Imbriglia and Matthews, 1993). This tends to occur particularly in younger manual labour patients with high upper extremity demand. In older patients, the damage created by an excision arthroplasty may be less noticeable because of lower demand on the upper extremity.

This study was designed to examine the functional and subjective outcomes following distal radioulnar joint replacement with a total distal radioulnar joint replacement endoprosthesis.

PATIENTS AND METHODS

The prosthesis

The Scheker distal radioulnar joint prosthesis (APTIS Medical, Louisville, KY, USA) used in this pilot study was composed of a stainless steel ulnar stem, an ultrahigh molecular weight polyethylene ball and a radius plate with a cover creating a socket (Scheker et al., 2001) (Fig 2). It has been designed to restore the precise anatomical relationship between the distal radius and ulna. This is achieved by allowing longitudinal migration of the radius throughout pronation and supination, along with the ability to change the angle of the stem inside the ball within the socket, which obviates the need for relative palmar and dorsal displacement of the sigmoid notch over the ulnar head (Fig 3). This prosthesis also allows load bearing of the distal forearm (Fig 4). The prosthesis aims at



Fig 1 *Top*: Unloaded forearm with a wide ulnar resection and suspension sling arthroplasty. *Bottom*: The same patient lifting a 2 kg (5lb) load demonstrating radioulnar impingement.

maintaining the function of the distal radioulnar joint by replacing the function of its three elements, viz. the sigmoid notch, the ulnar head and the triangular fibrocartilage. To date, it is the only total, bipolar prosthesis available.

This prosthesis is a semi-constrained ball and socket joint composed of a radial and an ulnar component. The stem, made of medical grade 316 stainless steel, is made in two different shapes and strengths, both uncemented. The first 11 patients had three-point fixation using a single size ulnar stem. The intraosseous length was 20 cm, with a diameter of 3 mm. The other 20 patients had a stem similar to the one used today, measuring 11 cm in intraosseous length. The small size 20 is 4.5 mm

in diameter, while the size 30 is 5.0 mm in diameter. The intraosseous part is fluted in shape for better fixation inside the medullary cavity of the ulna. It is flared distally to prevent proximal migration and to provide support for the ball. At the distal end of the stem is a highly polished peg, which remains extraosseous, for the placement of an ultrahigh molecular weight polyethylene ball. The ball constitutes the pivot point for the prosthesis. The ball was made in two sizes: size 20 with a diameter of 9.5 mm and size 30 with a diameter of 11 mm. The ball matches the corresponding socket at the end of the radial plate. A centred hole within the ball is placed over the distal peg of the ulnar stem. The ball-and-peg design allows the ball to rotate freely within the



Fig 2 The first-generation Scheker distal radioulnar joint prosthesis.

socket and the peg to rotate and migrate both proximally and distally inside the ball and, therefore, in relation to the radial plate. This combination replaces the function of the ulnar head. When the ball is enclosed inside the socket, joint stability is created, while still allowing rotation in two planes and migration.

The radial component is shaped in the form of a plate with a hemi-socket on the distal end. The body of the plate is contoured to fit against the distal 6–7 cm of the radius' interosseous crest. In the region of the sigmoid notch, there is a hemi-socket designed to replace the function of this structure. The plate is fixed to the radius by two means: a distal peg that is driven into the distal radius in an ulno-radial direction and five specially

designed 3.5mm cortical screws. The hemi-socket portion of the plate is directed ulnarwards and is designed to receive the ultrahigh molecular weight polyethylene ball at the end of the ulnar peg. A radial plate cover made of 316 medical grade stainless steel is designed to enclose the ball and complete the socket portion of the radial component. The cover is first aligned with the radial plate and secured to the plate by four screws. This enclosure replaces the stabilising function of the triangular fibrocartilage by mechanically preventing dislocation. It also allows free rotation of the radius about the ulna as well as proximal and distal migration. The cover comes in two sizes: size 20 with a 15 mm width and size 30 with a 17 mm width.

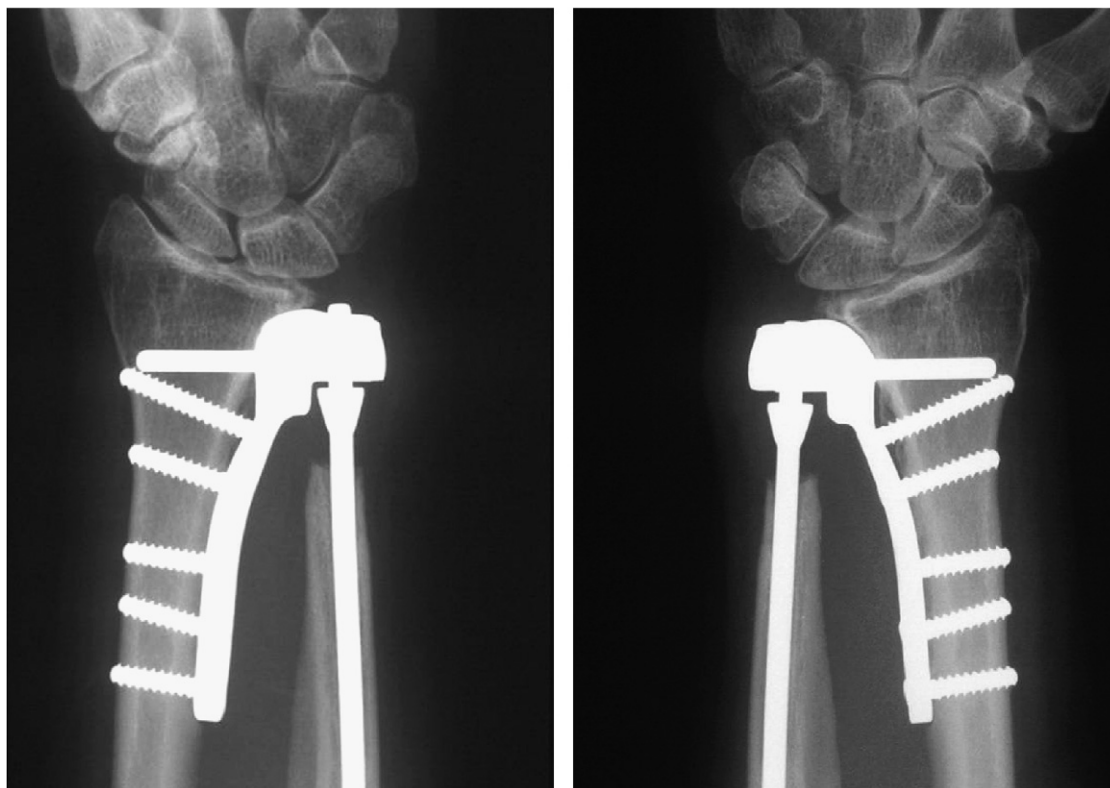


Fig 3 The implant in situ, with pronation and supination demonstrating longitudinal migration of the radius while maintaining radioulnar stability.

Patient population

Between May 1997 and August 2001, 31 patients underwent total distal radioulnar joint prosthesis arthroplasty using the initial Scheker prosthesis. The patients had a mean age of 45.5 (range 18–70) years. Seventeen patients had undergone a previous partial or total distal ulna resection, five patients had had a previous distal radioulnar joint fusion and nine patients had degenerative arthritis of the distal radioulnar joint. Seventeen patients were women and 14 patients were men. Twenty-three patients were right-hand dominant and eight were left-hand dominant. Fifteen implants were inserted into the left wrist and 16 into the right wrist. The time since the accident or development of arthritis varied from 32 years, for a Vietnam war veteran who had undergone total distal radioulnar joint and wrist fusion, to as little as 4 months.

Eighteen of the 31 patients receiving the first generation prosthesis returned for follow-up at a mean of 5.9 (range 4–8) years. These patients had a mean age of 42.8 (range 18–65) years. Thirteen of the 31 patients could not travel to our hospital for this study, as the distance involved was greater than 1500 miles. These patients, with a mean age of 49 (range 29–70) years, were interviewed by telephone and the measurements were extracted from the last follow-up visit in

the chart. The mean follow-up of the 13 patients was 3.5 (range 1–7) years for the office visit and 6.3 (range 5–9) years for the telephone interview.

Assessment

All 31 patients completed the Patient-Rated Wrist Evaluation (PRWE) (MacDermid et al., 1998) and the disabilities of the arm, shoulder and hand (DASH) questionnaire (Hudak et al., 1996; Gummesson et al., 2003), using the current version from “The DASH outcome measure. Disability of the arm, shoulder and hand” Web site (<http://www.dash.iwh.on.ca>).

The 13 of the 31 patients who were unable to return their completed final questionnaires by telephone interview and the range of motion and weight-bearing measurements were extracted from the last follow-up visit in the chart.

All patients also completed pre- and postoperative pain score questionnaires. The pain score questionnaire is a subjective analogue scale questionnaire based on a scale of 0 through 5, 0 being no pain and 5 the worst pain ever experienced by the patient. Pain was measured on a scale of 0 to 5 when at rest and when bearing weight in the pronated and supinated positions (see below).



Fig 4 Lifting capacity restored 2 weeks postoperatively.

In all patients, range of motion (ROM), grip strength and weight-bearing ability in the pronated and neutral positions of the forearm were recorded. The measurement was not taken in supination, as the radius does not cross over the ulna in this position. In supination, the ulna and radius are lifted in parallel as the brachialis anterior and the biceps, which is relaxed in pronation, now work together. This synergistic flexion of the elbow lowers the shear forces applied to the radial plate. Range of motion measurements included the degree of pronation and supination of the forearm, and, flexion, extension, and radial and ulnar deviations of the wrist. The ranges of motion were evaluated following the standards published by the AMA in the Guides to the Evaluation of Permanent

Impairment (Cocchiarella and Andersson, 2001). All measurements were performed three times and the average of each three ranges of motion was recorded.

To evaluate pronation, the hand and forearm were placed in a neutral position with the elbow at 90° of flexion. The goniometer was positioned perpendicular to a horizontal plane over the dorsal aspect of the wrist and measurements were recorded after the forearm achieved maximum possible active pronation. The initial supination position was as in pronation and the measurement was performed with the goniometer placed over the volar aspect of the wrist. Measurement was recorded after the forearm had achieved maximum possible active supination.

To measure wrist flexion, the starting position was with the elbow at 90° of flexion and the shoulder at 90° of abduction. The goniometer was placed dorsally over the wrist and hand. The measurement was recorded after moving the hand to the maximum possible active flexion. The extension measurement was performed in the same position as for flexion. To measure extension, the goniometer was placed on the flexor aspect of the wrist and hand. The measurement was recorded after moving the hand to the maximum possible active extension.

In measuring radial deviation, the forearm and hand were placed over a flat and horizontal surface with the elbow at 90° of flexion and the shoulder abducted at 45°. The goniometer was positioned over the dorsum of the forearm and hand, following a longitudinal line that courses through the DRUJ and the mid-dorsal line of the middle finger. Measurement was recorded after moving the hand to the maximum possible active radial deviation. Ulnar deviation was measured with the hand and forearm positioned as for radial deviation measurement. Measurement was recorded after moving the hand to the maximum possible active ulnar deviation.

Grip strength was measured in the standard position stated in the Guides to the Evaluation of Permanent Impairment (Cocchiarella and Andersson, 2001). The shoulder was held in adduction and the elbow was held at 90° of flexion. All measurements were performed with the Jamar Hydraulic Hand Dynamometer (Asimov Engineering Company, Los Angeles, USA) in position 2 (4 cm). Three measurements were performed during the examination, with an interval of time between them to prevent fatigue of the patient. The average of the three measurements was recorded.

Weight-bearing ability was evaluated with the patient standing by lifting different weights of 2.3, 4.5, 6.8 and 9.1 kg (5, 10, 15 and 20 lbs) beginning with the elbows in extension and raising the weight to the horizontal plane, with the elbows at 90° of flexion.

Return to work following prosthesis implantation was recorded.

All patients were X-rayed pre-operatively, on the first visit postoperatively and at 6 months, 1 year and 2 years to assess the condition of the implant as well as for radiolucency, which is considered an indirect radiological sign of implant loosening (Ragab et al., 1999).

All patients were screened for common complications following insertion of joint implants, viz. infections, implant loosening, implant failure and decreased range of motion because of implant misalignment.

RESULTS

All 31 patients scored a mean PRWE of 29 (range 1–68) following implantation of the distal radioulnar joint prosthesis, and the mean DASH score was 23 (range 0–76).

Subjectively, these 31 patients scored pre-operative pain on a five-point scale at a mean of 4.2 (range 1–5) and postoperative pain at 1.0 (range 0–4).

Mean pronation was 79° (range 15–90°) and mean supination was 72° (range 30–90°) at final follow-up. In the 22 wrists that had not previously undergone partial or total wrist fusion, mean extension was 56° (range 14–90°) and mean flexion was 52° (range 5–85°) at final follow-up. Mean ulnar deviation was 21.5° (range 5–30°) and mean radial deviation was 10.5° (range 5–15°) at final follow-up.

Pre-operatively, grip strength was a mean of 11 kg (25 lbs) (range 0–36 kg; 0–80 lbs), postoperatively a mean of 22 kg (49 lbs) (range 0–46 kg; 0–100 lbs) for the operated side, compared with an average of 36 kg (80 lbs) (range 9–52 kg; 20–114 lbs) for the contralateral side. Twenty-nine patients were able to bear weight on the operative side (range 2–9 kg; 5–20 lbs); notably, thirteen of these were able to lift 4.5 kg (10 lbs) or more, 11 without any pain in the neutral position. Eight were able to lift 9 kg (20 lbs), five without any pain in the neutral position. Lifting in the pronated position, these patients were able to bear a mean weight 7 kg (15 lbs) (range 2–9 kg; 5–20 lbs), but experienced pain at approximately half the weight lifted in the neutral position. Two patients with CRPS Type 1 (syn. Reflex Sympathetic Dystrophy, Algodystrophy) pre- and post-operatively had reduced grip strength and were unable to bear weight.

Twenty-four of the 31 patients returned to their regular activities, four returned to their previous activities with a permanent weight-bearing restriction, one patient filed for disability and two patients retired. The two patients who retired stated that they had no problems with their activities of daily living. The youngest patient, aged 18, completed studies to become a small-animal veterinarian and has continued in this activity without problems.

One patient developed a wound infection due to *Staphylococcus epidermidis* 3 months after the primary procedure. X-rays demonstrated radiolucency around the implant. The complete construct was removed, antibiotic beads were inserted and systemic antibiotic treatment was given. Once the patient was infection free (3 months after removal of the initial implant), a new implant was inserted and the patient has had no further problems in this respect 5 years and 5 months after the secondary procedure.

At final follow-up X-ray, all 31 cases demonstrated no radiolucency around the implant.

No implant has been reported to have failed under normal conditions. However, two patients were involved in motor vehicle accidents (one motorcycle and one automobile) at 6 years 3 months and 3 years 10 days after the primary procedure, respectively. The accidents caused the ulnar stems to break mid shaft. Although the radial components remained undisturbed, the entire prostheses were replaced with the current cobalt

chromium version, for added strength due to the material. These patients have had no further problems in this respect at 2 years and 2 years and 11 months after secondary surgery, respectively.

One patient developed heterotopic ossification around the ulnar stem within 4 months of the primary procedure, causing decreased range of motion. This patient underwent excision of the ectopic bone and treatment postoperatively with indomethacin 50 mg three times a day for 3 months. To date, 7 years after the secondary procedure, range of motion continues to be full in this patient and heterotopic ossification has not recurred.

DISCUSSION

Complications following ablation of the ulnar head are more common than currently described in the literature. Residual pain due to impingement, impaired gripping and reduced load bearing are those most frequently experienced. Without the support provided by an intact ulnar head, the radius impinges against the remaining ulna when the forearm is bearing weight in the neutral or the pronated position. [Dingman \(1952\)](#) reviewed 24 cases of [Darrach's](#) procedure with a mean age of 38 (range 6–72) years and noted pain in 11 of 24 patients. This occurred specifically when lifting objects. This impingement was demonstrated radiographically by [Lees and Schecker \(1997\)](#) and has, also, been described by other authors as secondary to impingement between the stump of the ulna and the radius upon weight bearing ([Bell et al., 1985](#); [McKee and Richards, 1996](#); [Sauerbier et al., 2002a, b](#)). [Shaaban et al. \(2006\)](#), in a recent biomechanical study, reported that ulnar head excision disrupted the force transmission profile through the forearm, producing the biomechanical equivalent of a one-bone forearm.

[Bieber et al. \(1988\)](#) reported that 20 of 288 (7%) patients had unsatisfactory results following [Darrach](#) procedures carried out for chronic pain or instability in the distal radioulnar joint. Eighteen of those patients required a mean of 2.2 additional surgical procedures, including 12 ulnar head replacements, of which five were subsequently removed. [Ekenstam \(1998\)](#) reported no relief of distal radioulnar joint symptoms in 50% of patients following [Darrach's](#) procedure carried out for malunion after [Colles' fracture](#). Clicking has also been described in up to 25% of patients ([Rana and Taylor, 1973](#)) and loss of grip in up to 20% ([Gordon et al., 1991](#)). In order to reduce the incidence of postoperative ulnar abutment and instability, [Bowers \(1985\)](#) proposed the hemiresection-interpositional arthroplasty technique, in which the hemi-ulnar resection is accompanied by the interposition of soft tissue (the pronator quadratus muscle) and preservation of the triangular fibrocartilage, although the author conceded that not all triangular fibrocartilages could be saved. Five of 38

patients undergoing this technique noticed postoperative pain. Subsequently, [Gonzalez del Pino and Fernandez \(1998\)](#) have reported three cases of [Bowers' procedure](#) which failed because of persistent ulnar impingement.

Several techniques of tendon stabilisation of the distal radioulnar joint using the extensor carpi ulnaris or flexor carpi ulnaris have been described after ulnar head excision ([Breen and Jupiter, 1989, 1991](#); [Kleinman and Graham, 1998](#); [Tsai and Stilwell, 1984](#); [Tsai et al., 1993](#)) in an attempt to prevent ulnar subluxation and impingement. [Breen and Jupiter \(1991\)](#) reported the use of this technique after [Darrach's](#) procedure in seven cases of post-traumatic arthritis and one case of rheumatoid arthritis. Stability was the only parameter evaluated. Evaluation upon weight loading of the hand was not presented. [Tsai and Stilwell \(1984\)](#) reported the use of the flexor carpi ulnaris to stabilise the ulna following [Darrach's](#) procedure in five patients treated for post-traumatic arthritis, with or without distal radioulnar joint involvement. Postoperatively, pain relief was reported in four of five patients. Evaluation during weight loading of the hand was not reported. In a subsequent publication, [Tsai et al. \(1993\)](#) describe tenodesis with extensor carpi ulnaris in 14 patients who had undergone [Darrach's](#) procedure to treat primary osteoarthritis in three patients, post-traumatic arthritis in seven patients and rheumatoid arthritis in the remaining four patients. Pain relief was reported in nine patients and radiographic stability was reported in 11 cases. Evaluation during weight loading of the hand was not reported.

Tendon stabilisation techniques using the extensor carpi ulnaris following the [Sauvé-Kapandji](#) procedure have also been reported ([Couturier et al., 2002](#); [Minami et al., 2000, 2006](#)). [Minami et al. \(2000\)](#) used this technique to prevent radioulnar convergence and dorsal instability following [Sauvé-Kapandji](#) procedure, which had been used to treat osteoarthritis of the distal radioulnar joint. Pain relief was reported in eight of 12 patients. Radioulnar convergence and dorsal instability during weight loading of the hand were not reported in either publication. [Couturier et al. \(2002\)](#) used the same tenodesis technique to prevent instability following [Sauvé-Kapandji](#) procedures. This tenodesis was performed to treat five cases of post-traumatic arthritis of the distal radioulnar joint and four cases of rheumatoid arthritis. Pain decrease was reported in eight of nine cases, with radiological reduction of the instability. There is no mention of evaluation during weight loading of the hand. While a number of these studies quote a significant number of patients relieved of pain, they did not test the functional abilities required of a useful extremity. As might be expected from the use of any of the tendon stabilisation techniques, using a tendon that inserts on the ulnar side of the wrist to support the radius in relation to the ulna has proven functionally unsuccessful, as the wrist deviates ulnarly, and the



Fig 5 The latest generation of the distal radioulnar joint prosthesis.

tendon support becomes lax, allowing the radius to move towards the ulna, impinging on the end of it and causing pain.

In an attempt to save the joint in early post-traumatic cases, or cases of mild instability, [Scheker and Severo \(2001\)](#) proposed an ulnar shortening of 2.5mm to change the contact point between the ulnar head and the sigmoid notch, as well as tightening the triangular fibrocartilage. In 22 of 32 cases, this procedure worked to relieve pain and/or improve function. However, 10 of these cases required a further intervention. In cases in which the joint is unsalvageable, the authors now recommend total distal radioulnar joint replacement. This, typically, allows the patient to return to full useful function within 1 month of surgery.

In our series of patients with total distal radioulnar joint replacement, weight lifting was measured in the neutral and pronated positions. As flexion of the forearm occurs, the prosthesis has the maximum stress over the ulnar component in these positions. In these two positions, flexion of the forearm is accomplished

solely by the brachialis anterior with its insertion distal to the coronoid process in the ulna, while the biceps is in a relatively relaxed state. It is, therefore, the ulna that carries all the weight of the load from the radius. In supination of the forearm, elbow flexion is aided by the biceps muscle by pulling on the radius through its insertion in the radial tuberosity, decreasing the load and the stress over the ulna.

Experimentally, the increase in force transmission corresponds to the ulnar head directly aligning with the carpus in supination and pronation, with a range of wrist pronation and supination from $+60^\circ$ to -60° ([Shaaban et al., 2006](#)). This corresponds clinically with the experience of patients with pathological conditions of the distal radioulnar joint: they have most difficulty in lifting loads in this range of positions. The force transmission across the distal radioulnar joint reported by [Shaaban et al. \(2006\)](#) showed a consistent reduction as the forearm was rotated from $+60^\circ$ to its maximum possible supination. Increasing pronation beyond 60° will cause the force transmitted to fall away. This



Fig 6 A sample of patients using the first-generation Scheker distal radioulnar joint prosthesis.

corresponds to the ulnar head moving dorsally relative to the carpus. Conversely, load transmission across the distal radioulnar joint and in the ulna peaks at -60° supination; again, corresponding to the ulnar head lying directly under the carpus. The peak of this force transmission corresponds with the position at which brachialis works at its maximum efficiency and the biceps begins to act as an elbow flexor.

In this series, 31 patients with distal radioulnar joint problems following arthritic changes and/or mechanical derangement after distal ulna resection techniques were followed to assess the effectiveness of the prosthesis. There was a significant decrease in subjective pain scores at medium-term follow-up with range of motion and patient-rated functional scores better than those shown after ulnar ablative techniques (Bieber et al., 1988; Bowers, 1985; Daecke et al., 2004; Gordon et al., 1991; Wolfe et al., 1998; Zimmermann et al., 2003). Grip strength and the ability to bear weight were restored, or increased, while also preventing, or greatly decreasing, pain in all but two cases. Patients with CRPS Type 1 (syn. Reflex Sympathetic Dystrophy, Algodystrophy)

have not shown improvement with use of the device. Patients receiving the prosthesis earlier in their treatment progression have demonstrated better results. Patients who have admitted to far exceeding weight-bearing recommendations have experienced irritation located at the distal end of the ulna. We believe this is due to the early stainless steel stem flexing under extreme load.

The 18 year-old patient included in this study suffered radial growth arrest at the age of 12 following a Salter-Harris Type V fracture of her distal radius. The resulting ulnar positive variance was first treated at another major centre by ulnar shortening, followed by a Bower's/Watson procedure for persistent pain. This patient was referred to us at the age of 17 years. Conservative measures were attempted with no alleviation of the pain. On her 18th birthday, the patient returned to consult and demanded a more radical procedure to alleviate her pain. Currently, 7 years after insertion of the prosthesis, this patient is pain free, a small animal veterinarian, married with two children and working without complications. We believe that this

device offers an opportunity for the young patient to have a functioning replacement joint with limited restrictions, allowing an early return to his, or her, desired endeavours. It should be stated clearly to such patients that it is unknown how long this device will last, but that removal will return the forearm to the status of a Darrach procedure.

Despite the above results, the implant has undergone some changes. In order to increase the strength of the ulnar stem and to prevent its flexion during heavy lifting, it is no longer made of stainless steel. The new prosthesis (APTIS Medical, Louisville, Kentucky, USA) is made of cobalt chromium and the stem is a press-fit for greater strength. The new alloy provides a stronger material and allows application of a porous plasma titanium spray to its surface. This provides the secondary gain of bone in-growth. These changes are intended to achieve better osseointegration and stronger fixation of the stem, potentially improving lifting capabilities. The radial plate design has also been changed to allow better contact with the radius (Fig 5).

When the various salvage techniques for clinical problems of the distal radioulnar joint fail, or when this joint is beyond repair, we believe that total replacement provides an alternative to the last resorts of radioulnar joint fusion or a single bone forearm (Fig 6).

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