Clinical Biomechanics 26 (2011) 718–724

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Effects of proximal row carpectomy on wrist biomechanics: A cadaveric study

S. Sobczak [a], P. Rotsaert [b,*], M. Vancabeke [b], S. Van Sint Jan [a], P. Salvia [a], V. Feipel [c]

[a] Laboratory of Anatomy, Biomechanics and Organogenesis, Pr. M. Rooze, Faculty of Medicine, Université Libre de Bruxelles (ULB), Lennik Street 808, 1070 Brussels, Belgium
[b] Department of Orthopaedics and Traumatology, Pr. F. Schuind, Cliniques Universitaires de Bruxelles, Hôpital Erasme, Brussels, Belgium
[c] Laboratory of Functional Anatomy, Faculty for Motor Sciences, Université Libre de Bruxelles, Bruxelles, Belgium

ARTICLE INFO

Article history:
Received 21 December 2010
Accepted 1 March 2011

Keywords:
Proximal row carpectomy
Resection
Moment arm
Pivot point
Kinematics
Wrist joint
Cadaveric study

ABSTRACT

Background: Many studies show good clinical results after proximal row carpectomy. Some biomechanical consequences are documented, but to our knowledge muscle moment arm variations have not previously been quantified.

Methods: In five fresh–frozen wrist, kinematics and tendon excursions were measured using a 3D electrogoniometer and Linear Variable Differential Transformers (SOLARTRON Inc., AMETEK Advanced Measurement Technology, Inc, 801 South Illinois Avenue, Oak Ridge, TN 37831-2011, USA), respectively, in three conditions: intact wrist, after posterior capsulotomy and after proximal row carpectomy. Mean pivot point, defined as the point whose sum of the squared distances to the helical axes is minimum, wrist range of motion and mean moment arms were measured during dorso-palmar flexion, radioulnar deviation and circumduction movements.

Findings: No alteration of the range of motion was observed. On the other hand, the mean pivot point shifted proximally (6.8–9.1 mm) after proximal row carpectomy ($p<0.05$) for all motions tested and most muscle moment arms decreased significantly after proximal row carpectomy.

Interpretation: The results of this study allow a better understanding of the biomechanical effects of this procedure. The important moment arm reduction and pivot point displacement suggest modifications of joint biomechanical parameters which could influence the functional outcome of PRC.

1. Introduction

Proximal Row Carpectomy (PRC) is a simplification of the wrist joint which is created by excision of the scaphoid, lunate and triquetrum bone, and thereby creating a new joint between the head of the capitate and the lunate fossa of the radius. This relatively simple technique, is still considered by some surgeons as a "*mutilating salvage*" procedure, which is to be performed only as a last option after multiple operations of the wrist. The best clinical results for PRC have been obtained for moderate radioscaphoid arthrosis, which corresponds to stages I and II of Watson's classification (Watson and Ballet, 1984).

The literature reports relatively good results after PRC, with a significant pain improvement in 83% of cases and the global Range of Motion (RoM) relatively-well preserved with 76° and 45° during dorso-palmar flexion and radioulnar deviation, respectively. The decrease of grip strength has been reported in several studies. Most studies indicate that grip strength after surgery ranges between 60 and 90% of that of the normal hand (Didonna et al., 2004; Jebson et al., 2003; Jorgensen, 1969; Richou et al., 2010; Tomaino et al., 1994). Most patients were satisfied and showed little professional limitations (Kuhlmann, 1992). In some cases, severe cartilage degeneration on either side of the radiocapitate joint was likely to lead to a poorer outcome (Inoue and Miura, 1990; Tomaino et al., 1994).

Clinical results of PRC have been relatively well studied, but the biomechanical consequences of removing the first carpal row are still not well known. It therefore remains difficult to understand the mechanisms underlying the changes induced by this procedure. After experimental PRC, ulnar deviation was maintained relatively well but in radial deviation, an impingement was found between the trapezoid and the radial styloid process. In palmar flexion (70°) the trapezoid was also found to impinge on the anterior border of the radial styloid process. Dorsal flexion was limited to 60° by an early contact of the capitate on the posterior border of the distal radius (Kuhlmann, 1992). Recently, Nichols et al. (2010) observed after simulate PRC and Scaphoid Excision Four-Corner Fusion by a validate model of upper extremity that PRC induced a greater reduction of wrist range of motion.Other authors (Hogan et al., 2004; Richou et al., 2010; Tang et al., 2009; Zhu et al., 2010) have studied the variation of joint contacts applied on the lunate fossa after PRC. They noted a significant decrease of the contact area and a significant increase of the contact pressure. No study of the effect of PRC on the prime wrist movers, i.e., the muscles crossing the wrist joint, was found in the literature.

This cadaveric study aimed to quantify PRC repercussions on wrist biomechanics relevant in a clinical context, specifically evaluating the

* Corresponding author at: Department of Orthopaedics and Traumatology, Cliniques Universitaires de Bruxelles, Hôpital Erasme, 808 route de Lennik, 1070 Brussels, Belgium.
E-mail address: philipperotsaert@yahoo.fr (P. Rotsaert).

0268-0033/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.clinbiomech.2011.03.002

alterations of mean pivot point locations and the offset distance, the overall joint RoM and the modifications of prime wrist movers moment arms in three experimental conditions: intact wrist, after posterior capsulotomy and after PRC.

2. Methods

Five fresh–frozen upper limbs of elderly subjects were obtained from the ULB Body Donation programme. Thawing occurred at room temperature 24 h before specimen preparation and experiment. Imaging acquisitions were performed after thawing on each specimen in neutral position using computed tomography (Siemens SOMATOM, helical mode, reconstruction: slice thickness = 0.5 mm, inter-slice spacing = 1 mm, image data format = Dicom) to make sure that specimens were free of any degenerative bone and joint pathology and to create a 3D bone model that was used to define the joint anatomical reference frame to express joint kinematics. The superior part of the humeral diaphysis was sawed in the upper limb of each specimen. The distal tendon of all muscles of interest was cut at the distal musculoskeletal junction and carefully dissected. Distal muscle attachments on the hand and the wrist retinacula were left intact. The specimens were rigidly mounted (Fig. 1A) on a loading jig in neutral radiological positions (Horii et al., 1993; Schernberg, 1992) using Schanz screw pins. Two pins (∅ 5) were placed into the distal part of the humeral diaphysis, two pins (∅ 4) were placed into the distal part of the radial diaphysis and four pins (∅ 4, two into the distal part and two into the proximal part) into the diaphysis of the ulna. Pronation–supination was blocked by a double distal radioulnar fixation by external fixation. All metacarpal bones were solidarised by several Kirchner pins. An amputation of the third finger was carried out at the metacarpophalangeal joint to introduce a Schanz screw pin (∅ 5) into the shaft of metacarpal III (Fig. 1B) to allow guiding of the various motions studied. To express the coordinates of anatomical landmarks and kinematics, clusters of four technical markers made of aluminium balls were glued on the diaphysis of the radius and the dorsal face of the 3rd metacarpal (Van Sint Jan et al., 2002). Coordinates of technical markers were obtained using a 3D digitizer (Faro arm, model 08 Bronze, Faro Technologies Inc., Lake Mary, FL, USA, point probe, accuracy = 0.305 mm). A fishing wire (Surflon®, Nylon coated, American Fishing Wire, 90 Lb., Alltackle.com, Inc., Annapolis, MD, USA) was attached to each dissected tendon to allow tendon loading (Bull et al., 1998). The tendons of *Flexor carpi ulnaris* m. (FCU), *Extensor carpi ulnaris* m. (ECU) and *Flexor carpi radialis* m. (FCR) were each loaded with 5 N. The tendons of *Extensor carpi radialis longus* m. (ECRL), *Extensor carpi radialis brevis* m. (ECRB), *Abductor pollicis longus* m. (APL), *Extensor digitorum* m., *Flexor digitorum profundus* m. and *Flexor digitorum superficialis* m. were each loaded with 2.5 N. Muscle loading was based on loads used in previous cadaveric studies (An et al., 1983; Horii et al., 1993). Muscle loading was used to provide tension in the different tendons. The ECRL, ECRB and FCR fishing wires ran proximally through tunnels drilled into the humerus at the level of the related muscle origin to approximate the physiological muscle lines of action (Fig. 1B).

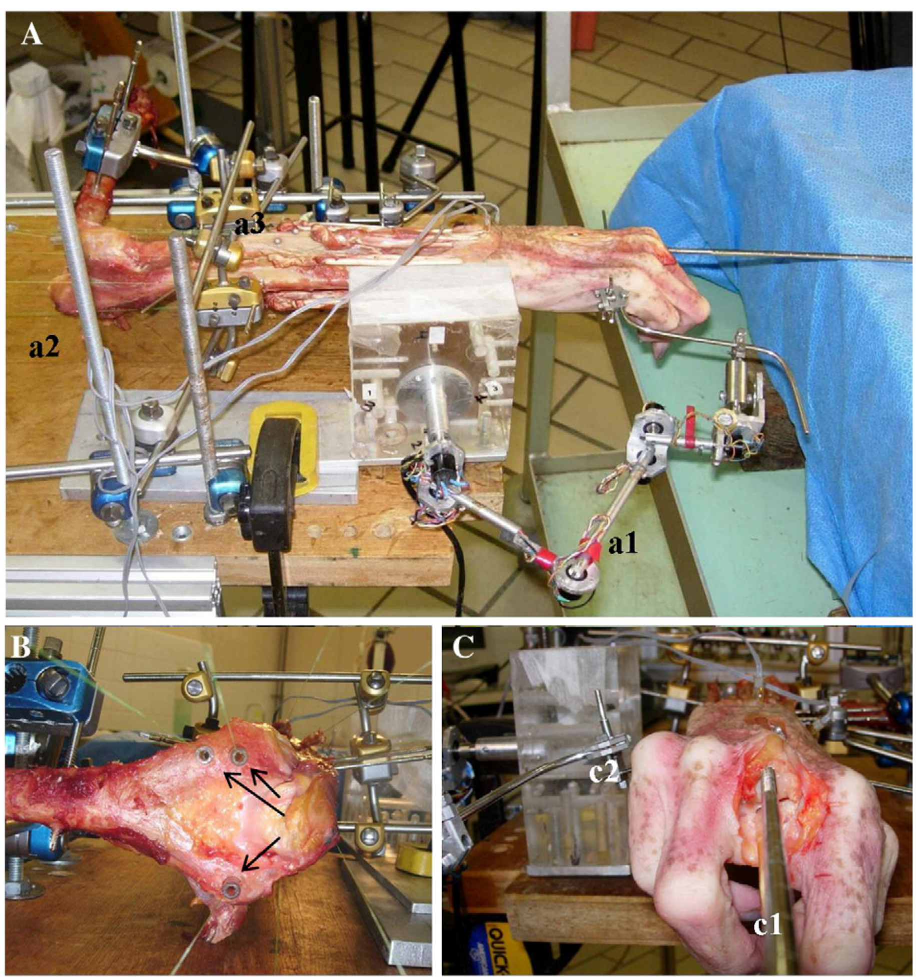

Fig. 1. Loading jig with specimen fixed with Schanz screw pins in neutral radiological position. A — Global setting; a1: 6 degrees of freedom-instrumented spatial linkage; a2: experimental jig; and a3: specimen fixations. B — Visualisation of bone tunnels (arrows). C — c1: Schanz screw pin in metacarpal III to allow motion guiding; and c2: fixation of 6 degrees of freedom-instrumented spatial linkage on the 5th metacarpal.