Clinical Biomechanics 30 (2015) 444–447

Contents lists available at ScienceDirect

Clinical Biomechanics

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

Radial head implant diameter: A biomechanical assessment of the forgotten dimension

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ARTICLE INFO

Article history:
Received 20 January 2014
Accepted 9 March 2015

Keywords:
Radial head arthroplasty
Radial head fracture
Diameter
Interosseous membrane
Implant size
Over-stuffing
Over-lengthening

ABSTRACT

Background: The effect of radial head implant length has been a subject of controversy, with the impact on clinical outcomes and forearm biomechanics being extensively studied. However, the impact of radial head diameter on forearm load transfer has not been examined. This study examined the influence of radial head implant diameter on forearm load transfer as measured by interosseous membrane tension and radiocapitellar joint contact characteristics.

Methods: An upper extremity simulator was utilized to study five cadaveric specimens with three different radial head implant diameters (−2 mm, anatomically sized, +2 mm). A load sensing device was woven into the fibers of the central band of the interosseous membrane to quantify its tension. An inter-positional pressure measurement sensor was used to quantify radiocapitellar joint contact force and area. Axial loads of 160 N were applied to the forearm during forearm rotation with the elbow at 90° of flexion.

Findings: Changes to the radial head diameter did not change radiocapitellar contact force or area ($P = 0.4$ and $P = 0.5$ respectively). There was a linear relationship between radial head diameter and interosseous membrane tension; increasing radial head diameter increases the interosseous membrane tension ($P = 0.01$).

Interpretation: Although radial head diameter was not found to alter radiocapitellar contact area or force, the interosseous membrane tension was impacted. After radial head arthroplasty, an increase in radial head implant diameter increases the interosseous membrane tension, with a potential for increased pain and stiffness. There is also a potential for increased proximal radioulnar joint contact pressures; resulting in stem loosening or radio-ulnar pain.

1. Introduction

Radial head arthroplasty for comminuted radial head fractures results in high patient satisfaction, and therefore has become increasingly utilized (Grewal et al., 2006). However, comminuted radial head fractures have a high incidence of associated soft tissue injuries, of which the interosseous membrane (IOM) is of notable concern (Hausmann et al., 2009). A number of studies have emerged about the importance of establishing the correct length of a radial head implant (Doornberg et al., 2006; Frank et al., 2009; VanGlabbeek et al., 2004). The concept of insertion of a radial head implant that is too thick has been termed 'over-lengthening' (VanGlabbeek et al., 2004). It has been demonstrated that increasing the length of the radial head changes the biomechanics of the forearm, with primary impact at the radiocapitellar joint (VanGlabbeek et al., 2004). This has led to the understanding that the relationship between the radius and the ulna is complex and the forearm itself can be considered a complex articulation (Tang et al., 1999). Little consideration, however, has been given to understanding the impact of changes of the radial head diameter on forearm biomechanics. The influence of diameter on the magnitude and position of IOM tension is unknown. Moreover, how the radial head diameter impacts the radiocapitellar joint contact area and forces is also unknown. Therefore, the purpose of this study was to examine the impact of radial head implant diameter on radiocapitellar contact area and force as well as the tension within the IOM. Hypothesis was that increasing radial head diameter would increase IOM tension, and decrease radiocapitellar contact area and force.

2. Methods

A novel *in vitro* elbow and forearm simulator was used to enable biomechanic testing in a physiologic manner (Fig. 1). The simulator allowed load application to the extremity with a minimum of external constraint. Axial loading was applied in line with the third metacarpal using a pneumatic actuator (Model FOD-094-S, Bimba®, University Park, IL). The forearm was rotated through a full range of supination and pronation in 6 s by using a servomotor (Model SM2315-DT,

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http://dx.doi.org/10.1016/j.clinbiomech.2015.03.012
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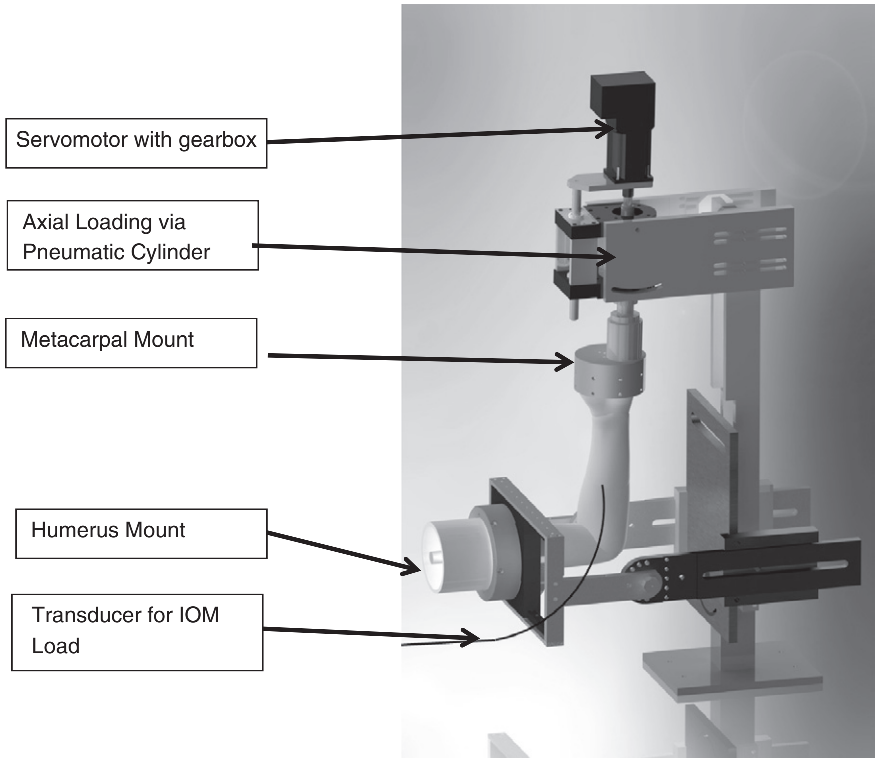

Fig. 1. The dynamic elbow and forearm simulator, modeled with a specimen mounted in the metacarpal and humeral pots.

Animatics®, Santa Clara, CA). Axial loading was controlled using computerized control *via* closed-loop feedback from a load cell (Futek® Model MBA 600, Irvine, CA) to within an accuracy of 8 N, and rotational position of the forearm was controlled using position control. The ability to constrain specific degrees of freedom allowed focused testing. The simulator also allowed the testing through a range of axial loads both dynamically as well as statically.

The IOM tension was measured using a custom load cell. This load cell was made by applying a pair of strain gauges (Vishay Micro-Measurements®, 120 Ω, 90° rosette, Raleigh, NC) to a strip of spring steel 9.5 × 6.5 × 0.32 mm. Based on a three point bending principle, the strain gauge was woven into the central band of the IOM (Fig. 2). The load cell was placed through two small parallel cuts made 4 mm apart in line with the fibers of the central band of the IOM, and affixed there by 5.0 silk suture (Ethicon, San Antonio, TX). The sensor was calibrated by weaving the device through synthetic material and hanging weights on it. Accuracy of the load cell was demonstrated *ex-vivo* by comparing readings to known weights, with a Pearson correlation of 0.94.

The radiocapitellar joint properties were measured utilizing flexible, thin pressure sensor array (K-Scan system, Model 4201, I-Scan 5.761 software, Tekscan®, South Boston, MA). The radiocapitellar contact area and force were measured *in situ*. The space available for the sensor was limited; resulting in some deformity of the sensor when in place. It was found in trial specimens that the calibration outside of the arm was not possible due to an inability to accurately recreate the areas of deformity. For each specimen, the position of the sensor within the radiocapitellar joint was carefully marked, and this position used for all future tests. To minimize the effect of the deformity, the data was normalized to the optimal radial head implant diameter and then statistically analyzed.

Five male cadaveric specimens (mean age is 65 years, range of 52–72 years) were thawed at room temperature. Specimens were excluded

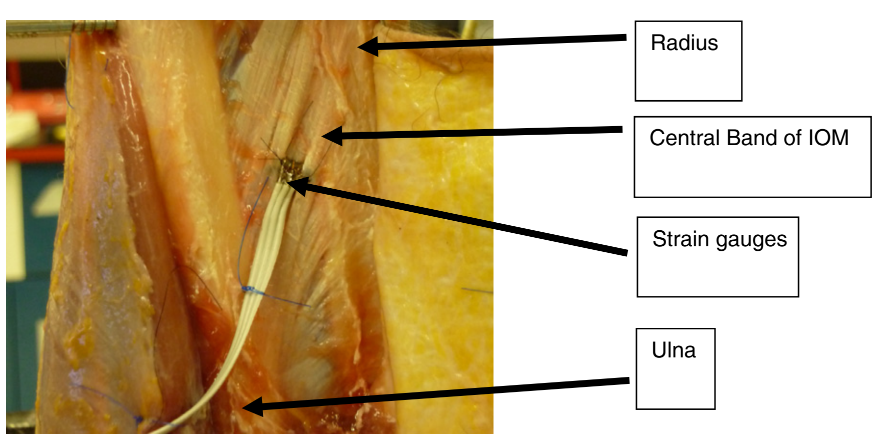

Fig. 2. The load transducer, woven into the central band of the IOM.