DETERMINATION OF THE INTERNAL LOADS OF THE PROXIMAL PHALANX DURING REHABILITATION EXERCISES

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Introduction

In proximal phalanx fractures, plate fixation has grown in popularity due to their greater construct rigidity [1]. To effectively evaluate any novel osteosynthesis device in this growing application, the biomechanical environment in which it will function must first be understood. While some studies have investigated the loading on the bones in the hand [2, 3], to our knowledge, there has yet to be an investigation that measured the internal forces on the proximal phalanx during rehabilitation exercises. These values are crucial because an osteosynthesis device must be able to sustain these loads over the course of healing; however, they are not readily measured in non-load bearing activities. In this study we developed a method to determine the internal forces on the proximal phalanx during common rehabilitation exercises of fingertip to palm articulation.

Methods

The internal loads in the phalanx were estimated by measuring the displacement of a plastic plate with known material properties and calculating the resultant bending moments in finite element (FE) models. Three human cadaver arm specimens were used in this study. A pre-op high-resolution CT scan (XtremeCT, Scanco) was performed for each hand with a voxel size of 82 µm. The second, third, and fourth proximal phalanx of each specimen was osteotomized with a 3 mm gap at the mid diaphysis. A custom PEEK (Polyether ether ketone) plate was then used to fix the osteotomy with two 1.5 mm cortex screws (DePuy Synthes) on either side of the fracture. Next, the flexion tendons for each digit were isolated and securely fixed to steel cables with sutures. All surgical operations were performed by an orthopedic surgeon. A post-op CT scan was performed with the hardware in place for each phalanx with identical settings as above. After the surgical procedures, the hand was fixed to the base of an electrodynamic testing machine (MTS, Acumen) with the palm oriented upwards. Rehabilitation exercises were simulated by fully extending the hand and then individually flexing each digit until the fingertip touched the palm by pulling on the flexor tendons with the actuator of the testing machine. This test was repeated three times for each finger. The displacements of the bone fragments were measured using a stereographic camera system (Aramis SRX, GOM GmbH) over the course of flexion. FE models of each phalanx were created from the CT scans to achieve accurate bone geometry and hardware placement. The reaction moments at the center of the PEEK plate were calculated by imposing the displacement data measured by the camera tracking system on the FE models as boundary conditions. Descriptive statistics and One-Way ANOVA testing were performed in SPSS 27 (IBM Corp.).

Results

The maximum bending moment calculated in the second, third, and fourth phalanges were 7.24 ± 1.56, 8.02 ± 1.13, and 6.04 ± 1.12 Nmm respectively. The third and fourth phalanx groups were significantly different from each other ($p = 0.009$), while the other groups were not significantly different.

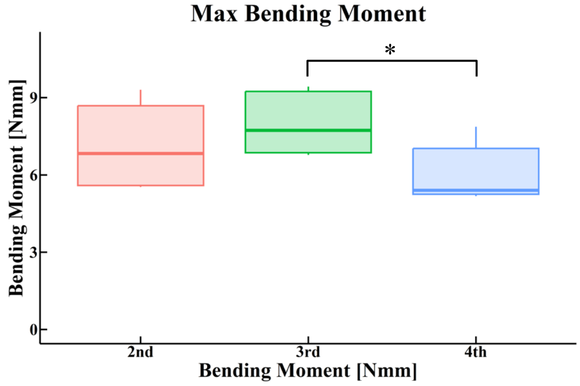

Figure 1: Box plots of the maximum bending moment of each group. Bars show statistical significance (p = 0.009).

Discussion

This work demonstrated that the internal loads in the proximal phalanx can be calculated during non-load bearing rehabilitation exercises. These calculated loads are important for the evaluation of new osteosynthesis devices for the proximal phalanx. The non-contact methods developed here could be applied in a similar manner to other regions of the body to better understand the internal forces during non- and low-load bearing activities.

References

1. Logters et al., Hand, 2018
2. Purves and Berme, J Biomed Eng, 1980
3. Fowler and Nicol, Clin Biomech 1999

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