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Definition of the Elbow Axis for the use of a Hinged Early Motion Elbow Fixator Based on the Subchondral Cortex Compared to the Cartilage Covered Contour

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Abstract

The application of a hinged early motion fixator in the injured elbow joint requires a precise alignment of the technical fixator hinge joint with the flexion and extension axis of the elbow joint. The currently used approach defining the joint center is based on the subchondrale bone layer of Trochlea and Capitulum. While the intraoperatively use of an image intensifier allows to identify the circular shape of the joint line, the true, cartilage covered joint surface is invisible.

Fifteen specimens were used to investigate the potential differences between the joint center based on the cartilage surface compared to the center defined by the subchondrale bone layer. The joint centers was analysed on plastinated slices cut out of the center of Trochlea and Capitulum.

The clearly visible differences of the cartilage based versus bone based joint centers in the slices proved to be so small that they did not show a statistical significance. Compared to the movement of the joint axis during flexion and extension they do not play an important role and can be neglected.

The currently used operative technique based on the visible bone surface is therefore a reliable estimation of the true joint center

Introduction

The use of an early motion fixator for injuries in the elbow joint has gained popularity in recent years. Various models are currently on the market that allow for an alignment of the flexion and extension axis of the humeroulnar connection with a fixator inbuilt technical hinge joint.

For the success in the use of an early motion fixator it is crucial to define the center of the natural elbow joint on a reliable basis [1-3]. The joint line and accordingly its true center are defined by the cartilage covered outer contour of the condyle. However all available types of early motion fixators currently on the market use an image intensifier to identify the joint center. The identification of the joint center is therefore based on the visible subchondrale cortical layer of Trochlea and Capitulum. Caused by a potentially variable thickness of the cartilage layer the intraoperatively defined center of rotation might differ from the natural center of the joint.

The question arises whether a difference between a joint center defined on the basis of the cartilage layer versus the subchondrale bone layer does exist and if so to what extent and whether it may influence the current practice.

Materials and Methods

Fifteen formalin alcohol preserved human cadaver specimens of the upper extremity with no signs of previous injuries or other diseases were freed from all soft tissues except the elbow joint capsule and collateral ligaments. A total of 15 specimens were used for the study (Min 63y, Max 88y, Mean 77.9, Stdev 7.97).The movement (flexion and extension as well as forearm rotation) was tested in all used specimens and found to be normal.

The Humerus and both forearm bones were cut close to the elbow joint. The specimens were embedded in composite resin according to the method of plastination [4]. After curing slices of 2 mm thickness were sawn out of the center of the Capitulum and the Trochlea. Microradiographs were made from each slice to allow for a visibility of both cartilage and subchondrale cortex. The radiographs were scanned and the joint line and joint center was analysed using a vector orientated graphic program (Corel Draw®)

Results

The cartilage layer was found to vary remarkably in

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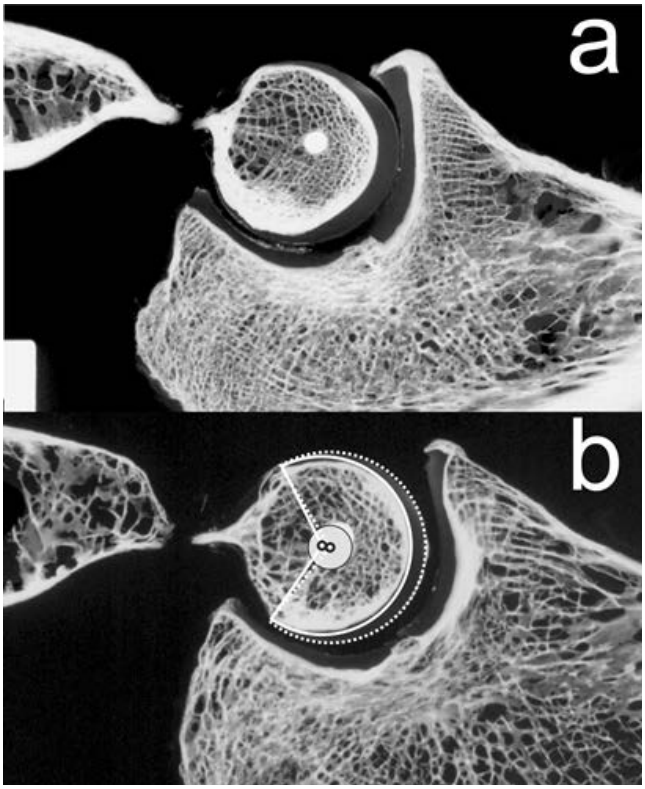

Figure 1: Microradiographs of 2 mm slices from the center of the Trochlea display both the cartilage and the strong subchondrale bone layer. Only a section of 223° (medium value) has a circular shape and is covered with cartilage

a) The subchondrale cortex different from the cartilage surface seems to be rather uneven. (The radio opaque dot in the middle of the condyle is a leftover from another experiment and is not related to this study)

b) The cartilage surface and the surface of the subchondrale cortex are contoured. The centers of the circles are close to each other with the center of the subchondrale cortex being a shade proximal (continuous white line). The grey circle indicates the area size of potential migration of the movement axis during flexion and extension (see text).

thickness among the specimens. Figure 1 shows two examples of slices (center of the Trochlea) demonstrating the variability in the appearance of the cartilage. It also gives the impression that the subchondrale cortical layer does not always display an ideal circle. At the Trochlea the cartilage shows to be thickest at the distal part of the condyle in all specimens of this study (Figure 1) whereas at the Capitulum the more dorsal part of the joint surface bears the thickest cartilage (Figure 2). Although there are clearly visible changes in thickness and distribution of the cartilage covering, the overall differences of the center based on the cartilage surface compared to the subchondrale bone surface are marginal. The distance of the center point was measured in all slices a) based on the subcondral bone cortex and b) based on the cartilage surface. The mean value for the distance between both center points was in the Trochlea slice 0.5 mm (min 0.1, max 1.4, standard deviation 0.3). The mean value for the Capitulum slices was 0.4 mm (min 0, max 0.6, standard deviation 0.2). The differences proofed to be not significant ($p>0.05$; Wilcoxon Whitney Man Test). As shown in Figure 1b the typical distribution of the cartilage thickness suggests that the center based on the cartilage surface is slightly more distally located but the differences are so small that they do not generate a statistical significance.

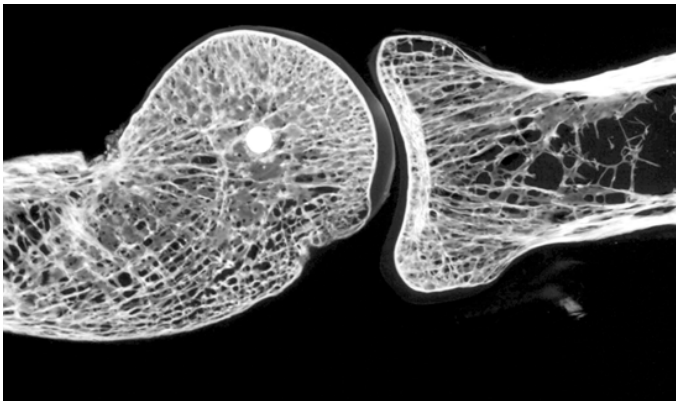

Figure 2: Slice from the central part of the Capitulum with the elbow joint in extension. Compared to the Trochlea the cartilage layer in the Capitulum is lesser. As a result of the inclination of the Capitulum in extension the dorsal part of the joint surface comes into contact with the radial head. (The radio opaque dot in the middle of the condyle is a leftover from another experiment and is not related to this study)

Discussion

Most of the authors concerned with the elbow joint understand the humero ulnar connection as a hinge joint. The movement axis however is migrating during flexion and extension within certain limits [8-10]. Studies have shown that the overall movement of the axis is minimal. It runs through the center of the Trochlea within an area of 2-3 mm in diameter [7,10]. London in accordance with the other authors found that the instant centers of rotation are located so close in the center of the Trochlea and the Capitulum that they are nearly superexposed to each other. He described an exception for the last 10 degree of extension and flexion where the axis is significantly moving proximally [8].

The analysis of the differences between the center of the Trochlea and Capitulum defined respectively on the basis of the cartilage surface and the subchondrale bone surface are far beyond the limits of the distribution of the instant centers of the movement axis (Figure 1b).

Conclusion

It therefore must be assumed that these differences do not play a significant role in defining the movement center of the flexion and extension axis of the elbow joint. As a result of this study the currently used technique to identify the hinge joint axis of the elbow based on the subchondrale bone layer visible in the image intensifier is found to be a reliable estimation of the true joint axis.

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