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Evaluation of an Image Intensifier Supported Technique to Identify the Center of Rotation of the Humero-Ulnar Hinge Joint - An Anatomical Study

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Abstract

The use of a hinged elbow fixator has become a standard technique in traumatized and unstable elbow joints. It is still a challenge to identify the best fitting axis of rotation. A well described and frequently used technique uses the image intensifier. A K-wire is place into the center of capitulum and trochlea. There is yet no experimental proof that this technique does reliably allow to align the external fixator according to the natural center of rotation.

A total of 15 cadaver specimens were used. The center of rotation was identified according to the intraoperatively used technique. Afterwards the specimens were embedded in resin and cut into slices.

Evaluation of the geometry revealed a minor error of the K-wire position that was more prominent on the ulnar side. In summery the K-wire position was found in an area of 2 mm radius from the center of the slice. The center in each slice was directly determined by the shape of the cartilage surface.

The indirect technique is a valuable Method to determine the axis of rotation. Even if the technique is applied accurately, a minor error is unavoidable but may be neglected for surgical purposes.

Introduction

For the use of a hinged early motion fixator the movement axis must be identified intraoperatively. This can be managed by inserting a K-wire under image intensification into the center of the condyles (capitulum and trochlea). Precondition is a congruent radiological exposure of the circular shape of Capitulum and Trochlea from the lateral side. Whereas the lateral entry point can easily be addressed with the tip of the K-wire that is placed firmly on the bone surface in the middle of the radiologically visible circles drilling the K-wire further into the bone frequently leads to a false positioning of the K-wire. To avoid multiple attempts a simple answer to this problem is to bend the overhanging part of the K-wire at the base to achieve a dot like projection of the overhanging part of the wire under image intensification. The fixator is then mounted on the K-wire with its canulated central unit, trusting in a satisfactory congruence between K-wire and movement axis. An anatomical investigation was carried out to ascertain the reliability of this practical technique, to demonstrate potential errors and to propose control possibilities.

Materials and Methods

The upper extremity of fifteen formalin alcohol preserved human cadaver specimens was collected from the student's anatomy course and clinically inspected. Only specimens with no signs of previous injuries or other diseases were included. The examination was performed on the left side of the 15 specimens (Min 63y, Max 88y, Mean 77.9, Stdev 7.97) Joint capsule and collateral ligaments were left intact. All other soft tissues were subsequently removed. The surface of Capitulum and Trochlea was marked with a radio opaque copper wire to easy the recognition of their contour under image intensification (Figure 1). In accordance with the technique used intraoperatively a 2 mm K-wire was drilled into the center of the congruent circles of Trochlea and Capitulum with the aid of an image intensifier. Some effort was made to place the K-wire ideally in the center of the joint. The position of the wire after drilling it into the bone was again controlled by an image intensifier. If it did not represent the ideal axis of the joint. It was corrected by bending the part of the wire outside the bone until this part of the wire projected as a dot under image intensifier. Then the Fixator was mounted in the typical way with to bone screws in the humerus and to bone screws in the ulna thus exactly imitating the procedure as it is done during surgery (Figure 2). After removal of the K-wire the joint was moved to full extend of flexion and extension and the clinically free movement of the elbow joint with the fixator in place was observed putting particular attention to the tension of the collateral ligaments during movement.

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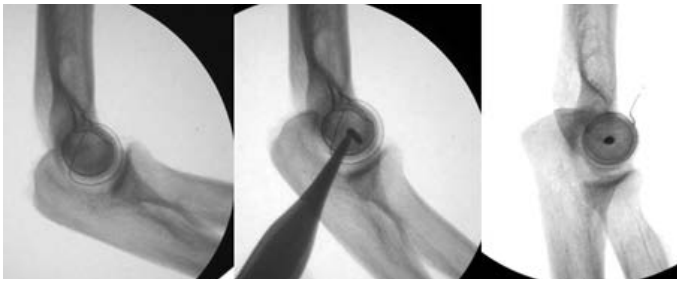

Figure 1: (a) Showing a lateral view (image intensifier) of the elbow joint. Die surface of the cartilage is marked with a thin copper wire. Therefor the center of rotation could be made visible reliably in each specimen. **(b)** The K-wire was drilled into the bone. Afterwards the center of the joint and the position and course of the inserted K-wire was controlled. Fig. b shows a minimal deviation of the K-wire. The part of the wire outside of the bone was bent until it presents as a dot, here indicated by the tip of the pincer that point to the end of the wire outside of the bone. The fixator was mounted using the K-wire outside of the bone as a guide for centering the canulated entral unit of the fixator. **(c)** After observing the movement of the joint, a new K-wire was inserted into the center of the bone using the canulated central unit of the fixator as a template. The position of the new wire was again controlled and proofed to be exactly in the center of the condyles.

Figure 2: Experimental setting. Capitulum and trochlea (central part) was marked with a thin copper wire that made the identification of the joint center easy. The fixator is mounted on the K-wire through the canulation of the hinge central unit.

After the clinical testing a new K-wire of 2 mm diameter was inserted through the cannulated hinge joint of the fixator and drilled into the condyle. This K-wire represented the center of rotation according to the hinged fixator.

The fixator was removed, and the wire left in place, cut plane with the bone surface. The Humerus and both forearm bones were sawn off close to the elbow joint. The Joint was then plastinated according to the technique of Gunther von Hagens et al. [1]. After curing of the resin. The cured blocks were cut into slices with 2 mm thickness. Three slices of the central part of each the capitulum and trochlea were collected and. Microradiographs of these slices were obtained and scanned. The analyses were carried out with a vector orientated graphic program (Corel Draw™)

A Cartesian coordinate system was built with the x-axis parallel to the ventral humeral cortex. The origin of the coordinate system represents the center of a circle that matches the contour of the cartilage. The deviations of the K-wire relative to the origin of the coordinate system (=joint center) are shown in Figure 3 a,b.

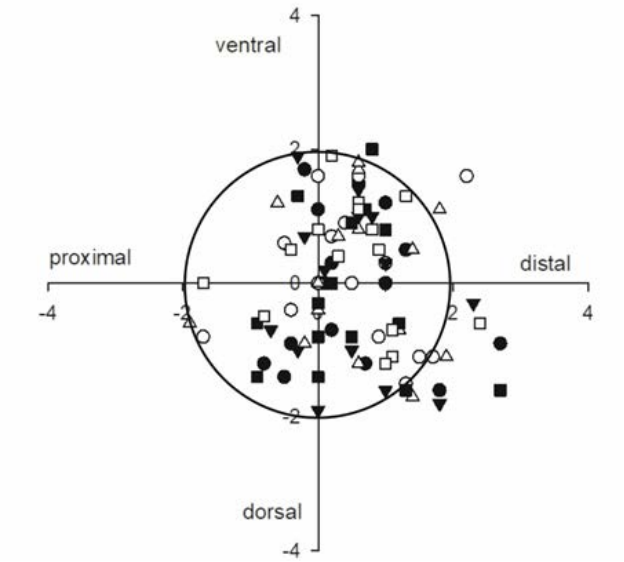

Figure 3a: Position of the K-wire relative to the center of the cartilage surface. Most of the data point are within a circle of 2 radius.
The filled black symbols are showing the ulnar slices: Circle = Slice in the middle position; Square and triangle = neighboring slices
The white symbols are showing the radial slices: Circle = Slice in the middle position; Square and triangle = neighboring slices

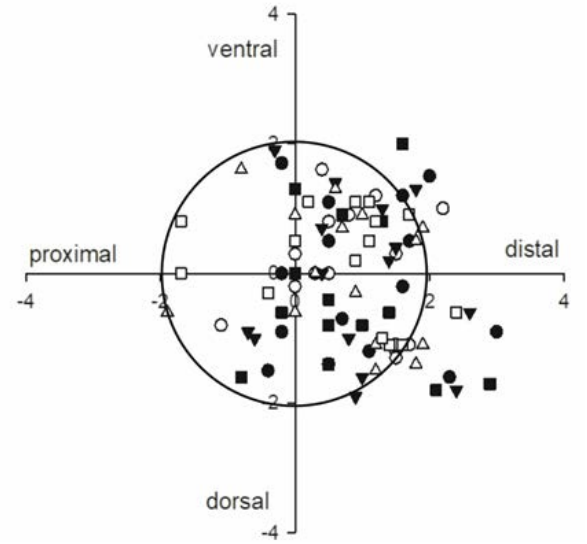

Figure 3b: Position of the K-wire relative to the center of the subchondral bone surface. Most of the data point are within a circle of 2 radius. There is a visible tendency toward a more distal position of the K-wire.
The filled black symbols are showing the ulnar slices: Circle = Slice in the middle position; Square and triangle = neighboring slices
The white symbols are showing the radial slices: Circle = Slice in the middle position; Square and triangle = neighboring slices

Results

The clinical tests after application of the fixator did not indicate a movement disorder. All specimen could be moved to a full extend. In the end position of flexion and extension a

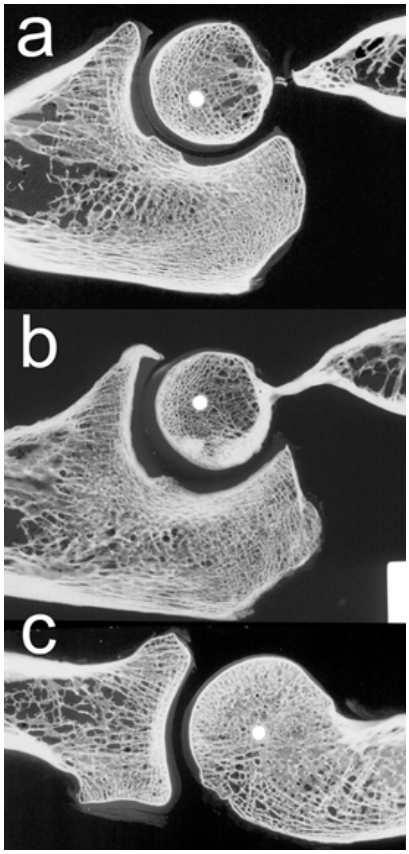

Figure 4: Microradiographs of typical slices. The position of the K-wire is clearly visible. The center of each slice was identified by drawing a circle with respect to the cartilage surface of the respective slice. The position of the K-wire relative to the joint center was determined. To make the results comparable a cartesian coordinate system was built with the x-axis parallel to the ventral cortex of the humerus.
Note the differences in the thickness of the cartilage.

slight increase in the tension of the ulnar collateral ligaments could be observed but did not hinder full movement.

A total of 90 microradiographs of the selected slices were scanned and evaluated with a vector-orientated graphic program (Corel Draw®). On each the slices the K-wire was clearly visible (Figure 1). The distance of the K-wire relative to the center of the cartilage surface was measured using a coordinate system according to the x-axis and the y-axis.

The results of the K-wire position compared to the center defined relative to the cartilage surface of the slices is shown in Figure 3a. The K-wire did not perfectly match the true center of rotation in most of the cases. The data points were found symmetrically around the origin of the coordinate system. The spreading was lesser in the Capitulum than in the Trochlea but the mean values of the distance between center of the cartilage surface and the K-wire were close to each other (mean value 1.3 mm at the Capitulum, mean value 1.4 mm at the Trochlea). In the Trochlea the maximum mismatch accounted for 3.2 mm (Min 0.2 mm), in the Capitulum the maximum was 2.2 mm (Min 0.2 mm).

In Figure 3b, the measurement was made using the center of a circle that matches the subchondral bone surface. Using this reference point there is a tendency of the K-wire position toward a more distal position.

In 60 cases the deviation of the K-wire was distal to the joint center, in only 30 cases the K-wire run proximally. The distribution of the mismatch to the ventral and dorsal side of the coordinate system did only show minor differences. With few exceptions most of the K-wires were in a central area of the condyle with a diameter of 2 mm.

Discussion

Hinged early motion fixators are already clinically used. Their use in unstable elbow joint is clear [2-4]. A preliminary of the use however is a correct placement of the joint axis. An indirect technique to identify the axis of rotation has been described earlier. For the intraoperative identification of the movement center of the elbow joint the patient is positioned supine on the table with the injured arm placed on a hand table. Using an indirect technique to place the K-wire into the center of the hinge joint an image intensifier is used. Until now it is not clear whether this indirect technique is accurate enough to allow for a sufficient centering of the fixator for a reliable clinical use of hinged fixator. The study presented here shows that the placement of the central K-wire can be reliable in between certain limits. In nearly all the 15 specimens the wire was close to the center in an area with a radius of 2 mm around the center based on the cartilage surface. The more distal position of the K-wire in Figure 3b can be explained by the uneven thickness of the cartilage layer. The question arises if the intraoperatively used reference (bone surface) can lead to a deviation of the center wire.

It is well known that the humero-ulnar hinge joint cannot be considered as a true hinge. The natural center varies in each individual during extension and flexion [5-10].

Conclusion

The distribution of the K-wire in this study seems to be within this natural movement of the ‘instant center’. This fact may allow the conclusion that the described techniques is accurate enough for the alignment of a hinged (technical) fixator.

In this study the measurements were all made using the cartilage surface as a reference for the center of rotation. This seems to be logical because the movement of the joint directly depends on the congruency of the cartilage between both joint partners. However, this technique does nor fully reflect the intraoperative situation as it is not possible to directly view the cartilage using an indirect technique as described above. In the examples shown here a difference in the thickness of the cartilage layer can be seen. This might have an impact on the exactness of the intraoperative used technique that is solely based on the subchondral bone layer. In a further study should be cleared whether this difference in shape is relevant for the definition of the joint center intraoperatively.

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