

Feasibility study of a new semi-automatic detection method of joint penetration during triple-screw internal fixation for femoral neck fracture

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Introduction

During a triple-screw internal fixation of femoral neck fracture, joint penetration is difficult to detect without imaging technologies and manual measurements. The screws may appear on the standard antero-posterior and lateral radiographs to be within the femoral head while they are actually penetrating the articular joint [1,2]. The objective of this paper is to study the feasibility of a new semi-automatic detection method of joint penetration during triple-screw internal fixation of femoral neck fractures.

Materials and methods

The proposed semi-automatic detection method of joint penetration requires the computation of the tip-to-surface distance (TSD) defined as the distance in mm between the tip of an inserted screw and the articular surface of the femoral joint.

A two-step process for the computation of TSD was implemented. First, the tip position of the inserted screw can be manually identified on intraoperative antero-posterior and lateral 2D radiographs. Second, the Euclidean coordinates of the identified screw tip can be reconstructed in 3D and expressed in the absolute reference frame of the intraoperative imaging system. These Euclidean coordinates enable the automatic computation of TSD. Negative values of TSD represent actual penetrations of the articular surface, while positive values represent no joint penetration.

To show the feasibility of this method, five cases of internal screw fixation of femoral neck fracture were simulated in a 3D Computer Aided Design (CAD) software using a virtual model of femur and screw. Three cases (cases #2, 4 and 5) were designed with the screw penetrating the articular joint, while two other cases (cases #1 and 3) had no joint penetration. The theoretical TSD corresponding to each simulated case was computed. For each case, two perpendicular 2D snapshots of the 3D CAD scenario with no visually detectable joint penetration, especially for the simulated cases #2, 4 and 5, were defined to simulate intraoperative antero-posterior and lateral radiographs.

For each case, two operators were asked to perform the manual identification of the screw tip on the simulated antero-posterior and lateral radiographs. TSD were computed from the manual identifications of the screw tips and the average value (called semi-automatic measurement) was compared to the corresponding theoretical TSD (reference measurement). Correlation coefficient between the two operators was computed.

Results

Correlation coefficient between the two operators who identified the screw tip for the five simulated cases was 0.96. All penetrating screws were detected by the operators (cases #2, 4 and 5; Table I). Maximum difference between reference and semi-automatic measurements was 1.2 mm for the simulated case #5. There was no negative difference between reference and automatic measurements. Moreover, no unpenetrating screw was considered as a penetrating screw.

Discussion

This study showed the feasibility to detect joint penetration during simulated internal screw fixation of femoral neck fracture by using 2D radiographs to identify the position of the inserted screw tip and compute the 3D distance relative to the articular surface of the hip joint.

Observed results showed positive semi-definite differences between reference and semi-automatic measurements of TSD. This suggests that the proposed method to detect joint penetration is conservative, by ensuring the recognition of actual joint penetration and reducing the risk to recognize false joint penetration.

Although these results clearly have to be validated clinically, they may be straightaway useful to assess the level of accuracy that the semi-automatic detection method needs to be provided with, particularly in terms of the screw tip identification performed intraoperatively by the operator.

Table I - Tip-to-surface distances (TSD)			
Simulated case	Reference measurements (mm)	Semi-automatic measurements (mm)	Difference (mm)
1	0.5	0.2	0.3
2	-5.5	-5.8	0.3
3	2.3	2.3	0.0
4	-3.0	-3.9	0.9
5	-1.5	-2.7	1.2

References

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2. Mao Y, Song J, Wei J, Wang M., “Prevention of unrecognized joint penetration during internal fixation of hip fractures: a geometric model based on Steinmetz Solid,” *Hip Int.* 2010;20(4):547-50.