Current Concepts Review

Three-dimensional printed models for surgery planning of post-traumatic stiff elbow: Current concepts

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ABSTRACT

The post-traumatic stiff elbow is a challenge for the surgeon, requiring expertise for the treatment choice and accurate planning. Stiffness can result from traumatic injury involving the periarticular soft tissues and the joint articular surfaces. In this article, we want to assess the impact of three-dimensional (3D) printed models in selecting the appropriate surgical strategy for this pathology.

Six cases of increasing complexity regarding post-traumatic stiff elbow were submitted to four expert elbow surgeons who had the possibility to evaluate videos and reports of clinical examination, plain radiograms and CT with 3D reconstruction for each case.

After a first treatment proposition given by the experts for each patient, a three-dimensional printed model of each elbow based on the CT was provided to the surgeons, asking them to evaluate again all the cases having the possibility to assess also the 3D models.

In the four most complex cases all surgeons found more beneficial the use of three-dimensional representation for treatment planning and rate the risk of complications than the sole CT imaging with 3D reconstruction and many of them changed surgical strategy after analysing the model.

3D printing technology is a useful tool in surgery planning for treating complex cases of post traumatic elbow stiffness, especially in the presence of joint deformity.

Level of Evidence: IV

Current Concepts

- Incidence of complex articular fractures of the distal humerus in adults have been increased and are likely going to grow up in the future due to the increasing rate of high energy traumas and to the raising percentage of elderly population.
- The distal humerus and the entire elbow joint have a complex anatomy (three joints in a small space) with high level of mechanical forces crossing the articular surfaces from the forearm to the shoulder.
- Stiffness and painful elbow instability can be considered two major complications which influence daily living activities.
- Despite the great accuracy of CT with 3D reconstruction, it faces the limits of human perception using only one sense (vision).

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INTRODUCTION

Three dimensional (3D) printing, a rapid prototyping technology that uses a digital model to build a physical object layer by layer, holds considerable promises and has been increasingly used for orthopaedic surgery applications during the last years [1–3]. Furthermore, the use of 3D printed models to support surgeons in fractures treatment [4] have displayed promisingly results particularly for elbow surgery, in terms of better recognition of the fracture pattern [5] and faster surgery [6] with better outcomes [7].

Post-traumatic elbow stiffness is characterized by various levels of severity, from simple retraction of periarticular soft tissues to extensive bone deformity. A wide range of therapeutic options, from simple rehabilitation to prosthetic implantation, are available to manage such widely different presentations [8]. In the preoperative planning stage it is important to identify the most suitable treatment strategy based on injury assessment.

We have examined a series of patients with post-traumatic elbow stiffness to evaluate in which cases 3D printing provides an advantage in preoperative planning and treatment choice.

METHODS

Were recruited six patients with stiffness of diverse severity who underwent clinical evaluation with x-rays and CT with 3D reconstruction. The cases were referred to four upper limb surgeons with at least 15 years of experience in elbow surgery who were not involved in the study. They evaluated every patient stating the extension of articular damage, the type of suggested surgical procedure and the expected functional outcome using a 49-items questionnaire. The experts reviewed then each case after obtaining 3D-printed models of the six stiff elbows.

To elaborate the 3D models used for this research was employed the software Inobitec Dicom Viewer Pro and the obtained reconstruction was 3D printed using mostly resins materials.

The time required to obtain a 3D-printed model after sending the CT scans to be processed was an average of 7 days.

RESULTS

Case 1 (Fig. 1).
Patient: 66-year-old right-handed woman.
Trauma: blunt trauma to the right elbow without fracture.
Treatment: half-cast for 15 days followed by physiotherapy.
ROM 12 months from the trauma: flexion-extension, 100°–40°; pronation-supination, 80°–80°.
Outcome: none of the surgeons changed surgical strategy after viewing the 3D-printed model; they found it useful only as a teaching aid with no advantage over CT with 3D reconstruction.

Case 2 (Fig. 2).
Patient: 33-year-old right-handed woman.
Trauma: undisplaced fracture of the right radial head without elbow dislocation.
Treatment: cast for 35 days followed by rehabilitation programme.
ROM 12 months from the trauma: flexion-extension, 100°–60°; pronation-supination, 45°–45°.
Outcome: none of the surgeons changed surgical strategy after viewing the 3D-printed model; they found it useful only as a teaching aid with no advantage over CT with 3D reconstruction.

Case 3 (Fig. 3).
Patient: 37-year-old right-handed man.
Trauma: undisplaced fracture of the left radial head with elbow dislocation.
Treatment: cast for 30 days followed by rehabilitation programme.
ROM 12 months from the trauma: flexion-extension, 100°–60°; pronation-supination, 80°–80°.
Outcome: one examiner changed surgical strategy after examination of the 3D-printed model. All surgeons found it more useful to choose the surgical strategy and rate the risk of complications than CT imaging with 3D reconstruction.

Case 4 (Fig. 4).
Patient: 36-year-old right-handed man.
Trauma: undisplaced fracture of the olecranon, left elbow.
Treatment: cast for 40 days followed by rehabilitation programme.
ROM 12 months from the trauma: flexion-extension, 120°–80°; pronation-supination, 80°–80°.
Outcome: two examiners changed surgical strategy after examination of the 3D-printed model. All surgeons found it more useful to choose the surgical strategy and rate the risk of complications than CT imaging with 3D reconstruction.

Case 5 (Fig. 5A–B).
Trauma: displaced distal humeral fracture, left elbow.
Treatment: open reduction and internal fixation with K-wires, cast for 40 days followed by rehabilitation programme.
ROM 12 months from the trauma: flexion-extension, 100°–80°; pronation-supination, 30°–30°.
Outcome: three examiners changed surgical strategy after examination of the 3D-printed model. All surgeons found it more useful to choose...
the surgical strategy and rate the risk of complications than CT imaging with 3D reconstruction.

Case 6 (Fig. 6A–B).
Patient: 26-year-old left-handed man.
Trauma: distal humeral fracture, left elbow.
Treatment: cast for 50 days followed by rehabilitation programme.
ROM 12 months from the trauma: flexion-extension, 90°–80°; pronation-supination, 20°–10°
Outcome: all examiners changed surgical strategy after examination of the 3D-printed model and all found it more useful to choose the surgical strategy and rate the risk of complications than CT imaging with 3D reconstruction.

For cases 3,4,5,6 the use of models was considered of clinical utility and led to a change of surgical strategy from one to all experts as the complexity was increasing.

DISCUSSION

In cases with more severe injury such as complex lesions involving the articular surface of the elbow or periarticular heterotopic ossifications, 3D-printed models were more informative than the traditional diagnostic approach in preoperative planning. 3D printing was of less use when joint stiffness was not associated with skeletal injury or joint deformity, where the main cause of loss of motion was soft-tissue retraction.

It was evaluated the sole utility of 3D-printed models in the preoperative planning of complex cases of elbow stiffness. It is clear that no clinical assessment and effectiveness of the planned treatment was investigated because it was not the aim of this study. Other articles in literature had shown extensively the clinical effectiveness of planning with 3D-printed models for elbow stiffness surgery [9,10] and this research focused on the aspect of the change of surgical strategy due to the use of models rather than on the surgical strategy itself, highlighting more the power of this useful tool than the clinical benefits.
Fig. 5. (A–B) Plain radiograms with CT three dimensional reconstruction (5A) and 3D-printed model (5B) of the fifth case.
Our report involved a small number of assessments and surgeons, though limited, its purpose was to preliminarily investigate the application of a new preoperative planning tool for treating post-traumatic elbow stiffness. Using a wider sample of expert surgeons and larger number of cases should lead further researches, using a similar protocol, to an improved knowledge upon the utility of 3D-printed models, providing a route to their systematic use.

In our opinion, 3D printing is going to be increasingly applied to help surgeons choose the most appropriate treatment strategy in post-traumatic stiff elbow surgery, especially in patients with malunion or non-union of joint surfaces. Further researches are needed and we believe are going to be encouraged by these preliminary results.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.
References


