Surgical navigation for corrective osteotomy of cubitus deformites using augmented reality techniques

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Introduction: This study develops surgical navigation system for corrective osteotomy, which allows the surgeon to accurately perform surgery as preoperative surgical planning. By utilizing augmented reality techniques, we provide the surgeon with visual feedback of the target position for corrected bones. There have been a number of studies on surgical procedures and surgical planning for cubitus deformities. However, there have been few attempts to link between surgical planning and actual surgical procedures. For corrective osteotomy of cubitus deformites, internal rotation deformity should be considered, as well as varus or valgus deformity. [1)] Correction of the three-dimensional deformities is so complicate that it is difficult for the surgeon to carry out the operation as planned from preoperative surgical planning. To solve this problem, some studies used surgical template to improve the accuracy of the procedure by guiding the osteotomy as planned preoperatively. [2)] This approach, however, has shortcomings; the surgical templates do not fit well with the bone in some cases, and extra cost and time are required in fabricating the surgical templates. The outcome of the operation can be enhanced by providing the surgeon with intra-operative visual feedback of the target configuration of the bones and by monitoring the accuracy of the operation in real time. In this study, we propose a surgical navigation system to give visual feedback to the surgeon using augmented reality (AR) techniques. Using AR image, the developed system provides the superimposed image of target configuration of bones, which was calculated at preoperative surgical planning stage, and monitors the difference between the actual configuration and the planned configuration.

Hypothesis: The target configuration of bones can be calculated from preoperative surgical planning, and the difference between the surgical planning model and actual configuration during surgery can be estimated in real time. The difference can be visualized using AR images, and it can also be evaluated using an error index. The surgeon can use the error index as intra-operative feedback to monitor the accuracy of the procedure.

Methods: The navigation system consists of an optical tracking device, a camera, a saw bone model, a CAD model and optical markers. A saw bone model is a simplified humerus model with deformity. A total of nine markers are used: three markers for the camera that views the operation site, three markers for each side of humerus model that is divided by osteotomy. The optical tracking device reads position information from these three sets of three markers. One set of markers on the saw bone model is used for registration between the saw bone model and the 3D CAD model. After registration, the other set of markers on the saw bone model provides positional difference with reference to the CAD model. The position difference is calculated by using root mean square error (RMSE). Based on RMSE, a percentile gauge to indicate the accuracy of the correction is calculated and displayed on the computer screen as a visual feedback.

Results: The surgical navigation system was used to perform open-wedge osteotomy on the saw bone model. By monitoring the percentile gauge on the computer screen during the procedure, the humerus model was straightened as planned after wedge-shaped cutting from the saw bone model.

Conclusion: While the surgical planning can help improve the accuracy of surgical procedure, the outcome of the surgery heavily depends on how well the actual operation is carried out as planned. By providing the surgeon with AR image and index to monitor the difference between the target bone configuration and actual configuration, the outcome of the surgery can be greatly improved. This study

tests the feasibility of AR techniques for surgical navigation, and the results confirm the possibility of using AR image serving as helpful assistance for the surgeon during corrective osteotomy.

References

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