"Quantitative accuracy assessment of pedicle screw insertion in spine surgery: initial study using Artis Zeego II intraoperative imaging robotic system"

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ABSTRACT

Introduction In spine surgery, intraoperative computed tomography (CT) and fluoroscopy-based navigation systems have demonstrated significant improvements in accuracy and safety of pedicle screw placement when compared to freehand technique [1]. Evaluation of pedicle screw placement is assessed in terms of pedicle breaches typically detected through visual inspection of the CT and fluoroscopic images [2,3]. However, it is not yet possible to use intraoperative images to quantitatively assess the accuracy of pedicle screw insertion by comparing with a predefined insertion planning. This study aims to demonstrate the feasibility to quantitatively assess the accuracy of pedicle screw insertion using intraoperative fluoroscopic images and compare the achieved screw placement with a predefined insertion planning.

Materials and methods The study was conducted using a synthetic model of a lumbar spine. The testbed consisted of a clamping device and a reference block (Figure 1a). The clamping device consisted of five template supports, produced by additive manufacturing, to rigidly fix the lumbar spine by means of fastening screws. A global reference frame (R0) was defined fixed to the reference block. The testbed was scanned using a CT-scanner and a virtual 3D CT model of the test bed was reconstructed for the planning of the pedicle screw insertion. The insertion planning consisted of ten sets of desired entry point, desired orientation axis and desired target point, defining the ten desired placement of screws in the pedicles of the five lumbar vertebrae. The insertion planni...
Quantitative accuracy assessment of pedicle screw insertion in spine surgery
Initial study using Artis Zeego II intraoperative imaging robotic system

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Introduction

In spine surgery, intraoperative computed tomography (CT) and fluoroscopy-based navigation systems have demonstrated significant improvements in accuracy and safety of pedicle screw placement when compared to freehand technique [1]. Evaluation of pedicle screw placement is assessed in terms of pedicle breaches typically detected through visual inspection of the CT and fluoroscopic images [2,3]. However, it is not yet possible to use intraoperative images to quantitatively assess the accuracy of pedicle screw insertion by comparing with a predefined insertion planning.

Objectives

This study aims to demonstrate the feasibility to quantitatively assess the accuracy of pedicle screw insertion using intraoperative 3D fluoroscopic images and compare the achieved screw placement with a predefined insertion planning.

Materials and methods

The study was conducted using a synthetic lumbar spine rigidly fixed on a testbed made up of a clamping device and a reference block which defined a global reference frame (R0).

A testbed virtual 3D model was reconstructed using a CT-scan for the screw insertion planning. Ten sets of desired orientation axis, entry and target points of pedicle screws were planned and their coordinates expressed in R0 were stored.

One operator freehandly performed the screws insertions, in respect of printed frontal, axial and lateral views from the planning.

Another operator measured numerically inserted screws coordinates in R0, and compared errors to reference mechanical measurements digitized using highly accurate Microscribe 3D coordinate measuring machine.

Results

The difference between errors computed numerically and mechanically, averaged -0.8 mm for entry points, -0.1° for orientation axes and -0.3 mm for target points of inserted screws.

Three parameters were used to evaluate the insertion accuracy. Errors in the entry and target points were computed as linear difference between desired and achieved points. Error in orientation axis was computed as angular difference between desired and achieved insertion axes.

Test bed fluoroscopic images with inserted screws were acquired and reconstructed in 3D using Siemens Artis Zeego intraoperative imaging system.

Conclusion

This study showed the feasibility to compute achieved errors on a predefined pedicle screw insertion planning using intraoperative 3D fluoroscopic images with very good accuracy when compared to reference mechanical measurements. The results observed here are currently undergoing clinical validation with complementary in vivo studies. Once completed, the quantitative accuracy measurement methodology using intraoperative 3D fluoroscopic images that has been developed for the present study may be useful to investigate further pedicle screw insertion performed with computer-assisted technologies such as navigation and robotic systems.

References