Section: **Segmentierung, Registrierung**

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Abstract-Title:
3D PLANNING FOR TOTAL HIP REPLACEMENT SURGERY BASED ON 2D STANDARD X-RAYS

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Abstract-Text:
Purpose

We present a new method to allow 3D planning for total hip replacement surgery (THR) based on 2D standard X-rays.
Optimal implant placement is an essential factor to avoid postoperative complications after total hip replacement surgery. Cups placed within the “safe zone” defined by Lewinnek, which defines an angular orientation range of the cup relative to the pelvic bone, are expected to show a lower risk for postoperative luxation or loosening. Conventional THR planning is based on transparent implant templates which are placed manually on standard anterior-posterior (AP) X-rays of the patient’s hip. This method shows several known disadvantages: The magnification factors of the X-rays are not known exactly, leading to an error in size of up to 15%. The pelvic tilt in the AP X-rays can not be controlled exactly. Studies show a variation of the pelvic tilt in AP X-rays of up to 40°. Most important, the X-ray only shows a two-dimensional projection of the 3D bone. We therefore present and validate a method to approximately reconstruct orientation and shape of the 3D bone surface from the X-ray image and to allow virtual 3D implant placement within this bone surface model.

Method

The method is based on gender-specific statistical bone models (point distribution models) of the pelvic bone surface that have been created from CT data sets (20 male, 20 female) in previous studies. These 3D models are fitted into the given standard X-rays using the model silhouette and gray level information from the X-ray images. Fitting is initialized by a few manually marked landmarks. Additionally a calibration sphere connected to the patient’s hip during the X-ray is located in the images in order to exactly determine the unknown magnification factor. A prototypical planning station has been created which allows first to load a standard AP X-ray image as DICOM file, then to manually mark the landmarks and locate the calibration sphere. Subsequently the 3D model is automatically fitted into the image. Finally, the system allows to do the actual implant planning by virtually placing CAD implant models from an implant database into the 3D reconstruction of the bone shown in the image. During implant placement, the system provides exact measurements of the angular orientation of the implant relative to the pelvic bone as well as a 3D visualization of the plan within the 3D model.

Results

Validation of the method is based on digitally reconstructed radiographs from 23 CT data sets used for model creation and the corresponding leave-one-out models. Projection parameters and pelvic tilt of the 23 created images were varied randomly. Fitting results after manual processing of two different persons were directly compared to the CT segmentations as ground truth. First results show a very good reconstruction of the bone surface with a fitting error of only a few millimeters between corresponding points of the bone models. This approximation error involves differences in translation, rotation, size and shape. We could also show that the pelvic tilt of the bone relative to the X-ray projection plane can be reconstructed with an average error of less than 5°.

Conclusion

Thorough planning of THR surgeries is an essential precondition to avoid postoperative complications. Our method allows exact 3D planning of the implant placement relative to a 3D reconstructed bone model. The known problems of conventional 2D planning on X-rays, i.e. the unknown exact size, unknown bone orientation (pelvic tilt) and unknown exact 3D bone shape, can thus be avoided by applying our method.

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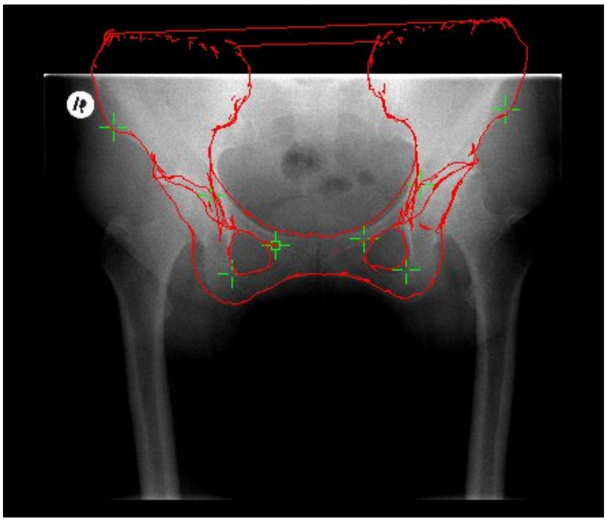

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