Assessment of bilateral symmetry of the radius and ulna: implications for optimal 3D planning of corrective procedures

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After a fracture of the distal radius, the bone segments may heal in a suboptimal position. This condition may lead to a reduced hand function, pain and finally osteoarthritis, sometimes requiring corrective surgery. The contralateral unaffected radius is often used as a reference in planning of a corrective osteotomy procedure of a malunited distal radius. In the conventional procedure, radiographs of both the affected radius and the contralateral radius have been used for planning. The 2D nature of radiographs renders them sub-optimal for planning due to overprojection of anatomical structures and the inability to plan all 6 degrees of freedom required for an adequate planning of the repositioning of the bone parts in 3D space. Therefore, computer-assisted 3D planning techniques have been developed recently based on CT images of both forearms.

Although these 3D techniques are currently being implemented in clinical practice, the contralateral forearm for planning arm and the optimal strategy for studied thoroughly.

To estimate the accuracy of the the contralateral forearm we metry of corresponding radii and imaging techniques. A total of 20 previous wrist injury underwent a graphy scan of both forearms, were segmented to create virtual these bones. We selected a distal part from these bones and mirrored CT-image of the contralateral side. This allowed estimation of the accuracy by calculation of relative displacements ($\Delta x, \Delta y, \Delta z$) and rotations ($\Delta \phi_x, \Delta \phi_y, \Delta \phi_z$) required for align the left bone with the right bone segments as a reference. We also investigated the relationship between longitudinal length differences in radius and ulna and utilized this relationship to arrive at an optimal planning of the length of the affected radius after surgery.

Relative differences in displacement and orientation parameters after planning based on the contralateral radius were ($\Delta x, \Delta y, \Delta z$): -0.81±1.22 mm, -0.01±0.64 mm, and 2.63±2.03 mm; and ($\Delta \phi_x, \Delta \phi_y, \Delta \phi_z$): 0.13±1.00°, -0.60±1.35°, and 0.53±5.00°. The same parameters for the ulna were ($\Delta x, \Delta y, \Delta z$): -0.22±0.82 mm, 0.52±0.99 mm, 2.08±2.33 mm; and ($\Delta \phi_x, \Delta \phi_y, \Delta \phi_z$): -0.56±0.96°, -0.71±1.51°, and -
2.61°±5.58°. The results also point out that there is a strong linear relationship between absolute length differences (Δz) of the radius and ulna among the individuals.

Since we observed substantial length difference of the longitudinal bone axes of both forearms in healthy individuals, planning of the length of the reconstructed radius using the unaffected radius as a reference may therefore not be as useful as previously assumed. However, including the length difference of the adjacent forearm bones turned out to be useful in improving length correction in computer-assisted planning of radius or ulna osteotomies. The improved planning including the linear relationship between length differences reduces absolute length deviations by a factor of two and markedly reduces length positioning variability, (from 2.9± 2.1 mm to 1.5 ± 0.6 mm). We expect this approach to be valuable for 3-D planning of a corrective distal radius osteotomy.

Awareness of the level of bilateral symmetry is important in reconstructive surgery procedures when the contralateral unaffected side is used as a reference for planning and evaluation. Bilateral asymmetry may introduce length errors into this type of preoperative planning that can be reduced by taking into account the concomitant ulnae asymmetry.