Determining Safe Screw Corridors: Efficacy of a Novel Numerical Approach on the Pelvis

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INTRODUCTION:

Orthopaedic surgeons employ a variety of methods to define bone screw insertion trajectories, yet there is no universally accepted standard. Some researchers determine safe screw paths based on the minimum and maximum allowable transverse and sagittal angles in relation to a given anatomical plane. Others adopt a geometric strategy, identifying the largest possible cylinder that can fit a screw within the bone corridor. In these geometric methods, the range of safe insertions is often represented as sagittal angle versus transverse angle, with the geometric center (GC) used as the nominal insertion direction. Although this technique is applicable in many scenarios, it falls short in cases where the safe region has a convex shape. To address this limitation, the present study introduces a new method—referred to as the "weighted central direction" (WCD)—designed to identify a suitable insertion direction even in convex configurations. This study aims to assess the effectiveness of the proposed method in comparison to the commonly used geometric center (GC) approach. We hypothesize that in cases where the GC falls outside the safe insertion region, the angular deviation between the GC and the weighted central direction (WCD) will be significantly larger than in cases where the GC lies within the safe zone.

METHODS:

Using CT scan data from 56 human hemipelves, we reconstructed 3D models to evaluate safe insertion angles through the iliac crest and supraacetabular region at a depth of 60 mm. Sagittal safe insertion ranges were plotted against transverse ranges in anatomical planes rotated in 5° sagittal increments. The WCD was calculated along a dorsal axis (τ) by averaging midpoints of safe transverse inclinations across sagittal angles and weighting them by the area of corresponding trapezoids. The weighted position, expressed by $\alpha = (\sum d_i W_i)/D$, was used to determine the WCD location and translate it into sagittal and transverse angles. The GC was then calculated as the centroid of the area in the sagittal-transverse angles plot. A t-test compared these distances between cases where the GC was inside versus outside the safe region. Significance was set at $p < 0.05$. Analyses were conducted using Octave.

RESULTS:

For the iliac crest, average sagittal inclinations were -42.3°±29.9 (GC) and -42.4°±30.3 (WCD), while transverse inclinations were 36.6°±5.5 (GC) and 37.6°±5.8 (WCD). In the supraacetabular region, average sagittal angles were 8.5°±5.4 (GC) and 9.7°±6.9 (WCD), with transverse angles of 24.4°±4.4 (GC) and 27.0°±4.6 (WCD). In the iliac crest region, the GC was located outside the safe zone in 14.3% of cases; in contrast, the WCD was always within bounds in the supraacetabular region. The average GC–WCD distance was 3.9°±2.9 (iliac crest) and 4.5°±1.7 (supraacetabular). For the iliac crest, this distance was significantly larger (8.1°±4.1) in cases where the GC was outside the safe zone, compared to 3.3°±2.3 when it was inside ($p < 0.001$).

DISCUSSION AND CONCLUSION:

The WCD method proved more reliable than the GC approach for determining safe screw trajectories, especially in convex insertion regions. Unlike GC, the WCD was consistently within the safe area. This makes WCD a valuable tool for surgical navigation, particularly in non-trauma applications. Limitations include the sample size, exclusive use of 3D CT models (rather than cadaveric validation), and the assumption of continuity in insertion regions. The WCD method may not be applicable where safe regions are discontinuous. The WCD method consistently identified a safe insertion direction across all subjects studied and could enhance accuracy during pelvic screw placement in surgical settings.
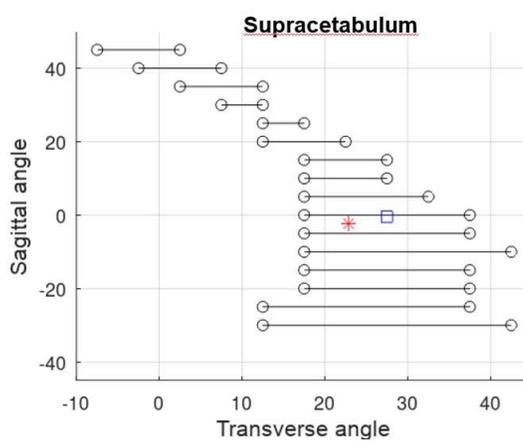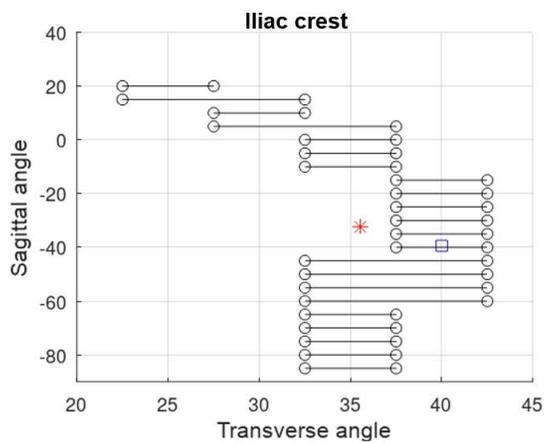
Figure 1: example of screw safe ranges for one subject: for the iliac crest, the corridor determined by the geometric center (GC,"*") lies outside the safe insertion range, while the weighted central direction (WCD,"□") remains within it.