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Impact of robotic-assisted surgery on enhancing stability of stemless shoulder arthroplasty

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Introduction and Background

Bone mineral density (BMD) plays a crucial role in determining the stability of stemless total shoulder arthroplasty. Although preoperative CT-based BMD evaluation has been explored, discrepancies between planned and actual humeral head resection surfaces remain a concern with conventional guides. Robotic-assisted surgery has the potential to improve accuracy and consistency. This study aimed to assess whether robotic-assisted resection enhances precision and alignment with preoperative planning and whether improved accuracy impacts BMD at the implant site, contributing to stemless shoulder arthroplasty stability.

Material and Method

Study 1: A total of 69 matched fresh-frozen cadaveric shoulders (138 shoulders) underwent CT imaging and preoperative planning for anatomical (aTSA) and reverse (rTSA) shoulder arthroplasty. Fourteen experienced shoulder surgeons performed conventional guide-based resection on one side and robotic-assisted resection on the contralateral side. Postoperative CT analysis evaluated resection accuracy relative to preoperative planning.

Study 2: Forty-five humeral specimens were scanned with a BMD phantom (B-MAS200, Kyoto Kagaku). Resection simulations were conducted based on preoperative plans, introducing angular and positional variations replicating conventional and robotic-assisted techniques. A total of 100 resections were performed per method, and postoperative BMD measurements were compared to preoperative values to assess surgical error and BMD sensitivity.

Results

Robotic-assisted resection significantly improved accuracy in inclination, retroversion, and resection height compared to conventional methods ($P< 0.05$). BMD at the resection surface demonstrated strong correlation with preoperative values in both conventional ($R^2= 0.978$, $P< 0.001$) and robotic-assisted techniques ($R^2= 0.995$, $P< 0.001$), but the deviation was significantly smaller with robotic assistance ($P< 0.001$).

Conclusions

Robotic-assisted humeral head resection enhances accuracy and consistency with preoperative planning while maintaining reliable BMD measurements at the implant site. These improvements may contribute to greater stability in stemless shoulder arthroplasty. Further investigations should explore how robotic-assisted techniques influence implant fixation, particularly in less experienced surgeons, and inform future software development for optimizing implant placement.