Comparative Performance of Microscope and Exoscope in Simulated Skull Base Tasks: Evaluation of Dexterity and Accuracy

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Introduction

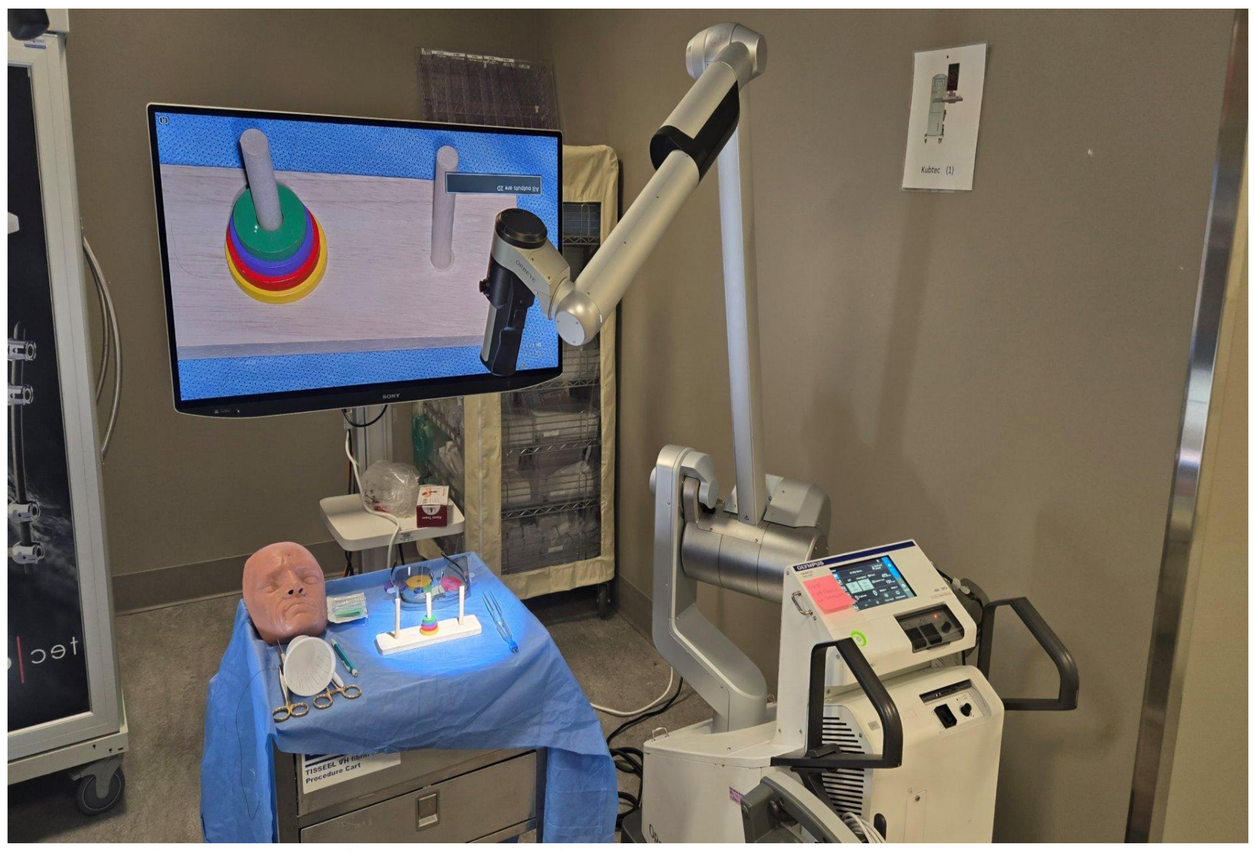
Adequate surgical visualization is a fundamental determinant of safety and precision in skull base surgery. While operative microscopes remain the standard visualization tool, high-definition exoscopes have emerged as potential alternatives, offering ergonomic benefits and improved shared visualization for the operative team. However, the effectiveness of exoscopic visualization in terms of manual dexterity, task accuracy, and error control has not been fully validated. This study aimed to compare performance between the exoscope and the surgical microscope using standardized simulated microsurgical tasks relevant to skull base surgery.

Methods

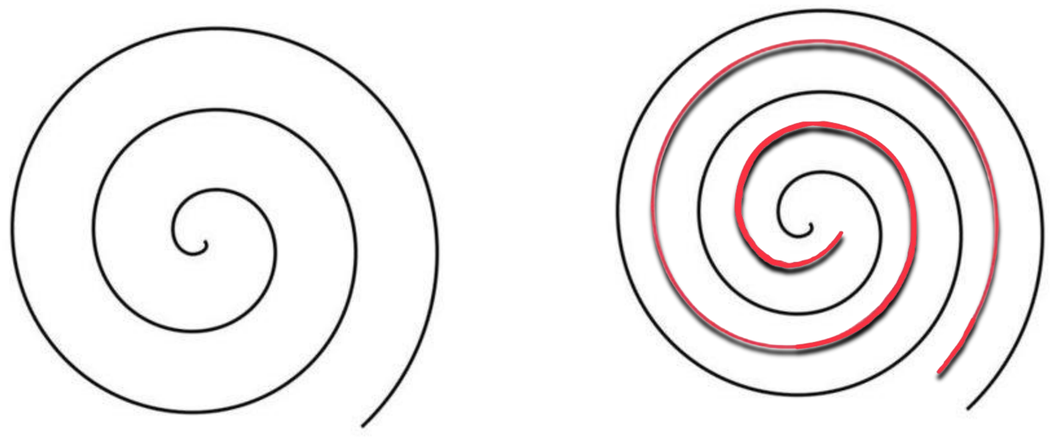
A prospective experimental study was conducted including 16 participants (3 medical students, 8 residents, and 5 skull base surgeons). Each participant completed four standardized microsurgical tasks: a Tower of Hanoi disk-moving task, spiral tracing, square tracing, and microsurgical needle insertion into a synthetic model. Each task was performed under three visualization modalities: naked-eye visualization, surgical microscope (Leica ARveo8), and high-definition exoscope (Olympus Orbeye). All testing was performed in a standardized laboratory environment. Primary outcomes included task completion time, error frequency (including critical errors), and accuracy. Performance was analyzed across visualization modalities and stratified by proficiency level (low versus high).

Results

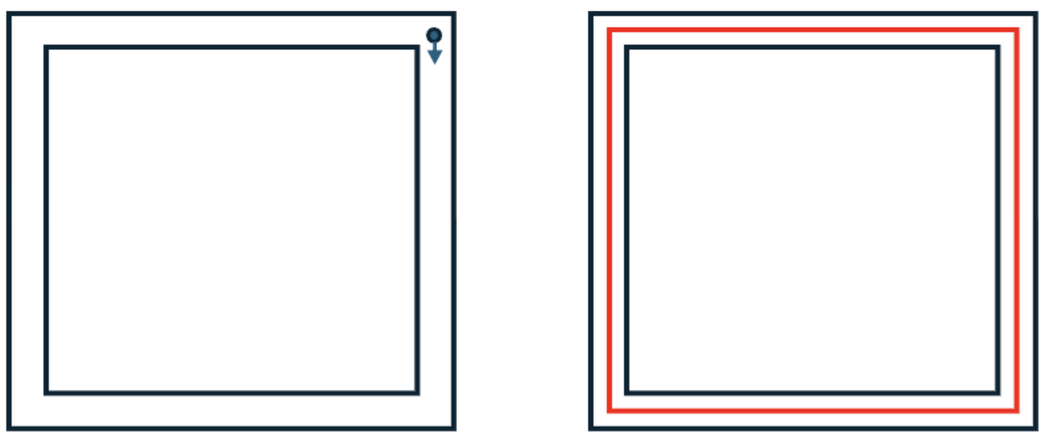
All 16 participants completed all four tasks under all visualization conditions, including 11 classified as low proficiency and 5 as high proficiency. In the disk-moving task, low-proficiency participants demonstrated no significant differences between modalities, whereas high-proficiency participants performed the task more rapidly under microscope visualization. Exoscope performance improved on repeat trials, suggesting the presence of a learning effect. In tracing tasks, completion times were generally similar across visualization modalities; however, low-proficiency participants demonstrated greater variability in performance. Critical errors increased with exoscope use, particularly during square tracing, whereas spiral tracing performance was less affected. Accuracy was reduced with the exoscope during square tracing in the low-proficiency group, while high-proficiency participants maintained comparable accuracy across all modalities. Notably, when using the exoscope, a negative relationship was observed between task time and critical errors, suggesting that slower movements may reduce error rates under exoscopic visualization.



Surgical Atmosphere simulation setting.



Spiral tracing test.



Square tracing test.

Conclusion

The exoscope demonstrated overall performance comparable to the surgical microscope in simulated skull base tasks. However, its use was associated with a higher frequency of critical errors, particularly among less experienced participants. With repeated exposure, performance improved, and experienced surgeons maintained stable outcomes across visualization modalities. The observed negative correlation between task time and critical errors suggests that slower, more deliberate movements may compensate for slight imaging delay, reflecting an adaptive learning curve that may enhance safety and precision during early exoscope adoption.