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Robot-assisted versus dynamic navigation in endodontic microsurgery: Strengths, weaknesses and future directions

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The development of image-guided technology in the field of oral and maxillofacial surgery represents a leap in precision-guided treatment.[1] In these, robot-assisted (RA) and dynamic navigation (DN) systems are currently the most promising methods for guided osteotomy and root-end resection in endodontic microsurgery.[2–5] Based on available comparative studies, we intend to summarize recent evidence on the strengths and weaknesses of both two techniques and discuss potential future directions (Table 1).

Both robotic and dynamic navigation computer-assisted navigation systems have proven clinically viable in terms of accuracy and efficiency of treatment. Nevertheless, RA always have better surgical accuracy numbers, compared to those of DN.[2–5] Research also found that the angular deflection, platform deviation, and apical deviation of the RA system were significantly less than those of the DN system.[2–5] This increased precision is especially an advantage in posterior teeth or deep apices where manual access and visual control are difficult. However, robots are not without limitations. Extended setups and registration times, higher procedural cost, and complex requirements for calibration process make widespread clinical adoption difficult. In contrast, DN systems have shorter preparation times and interoperative flexibility, and may be better suited for time and resource-constrained practices.

A key trade-off between the two is control versus automation. Although the DN enables the operator to keep a sensation and real-time adjusting, this mild human factor may be variable. RA systems remove hand tremor from the operator and make the procedure reproducible, but these devices can potentially constrain the real-time adjustability and impose a large preoperative planning.

Prospects are promising and future directions are seen to be several. Improving the RA system's user friendliness and shortening setup time may increase the clinical potential of RA. Furthermore, the implementation of adaptive algorithms and the intraoperative feedback in robotic workflows might narrow the flexibility difference between RA and DN platforms. Additional in vivo experiments and cost-effectiveness analyses are required to justify wider use of such systems in everyday endodontic practice.

In summary, in-house robotics are more accurate and standardizable, while dynamic navigation is somewhere between precise and maneuverable. Upcoming work will need to concentrate on streamlining workflow integration, reducing procedural time, and broadening clinical validation to achieve safe, efficient, and accessible technology-assisted endodontic microsurgery.

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Table 1 Comparison of robot-assisted and dynamic navigation systems in endodontic microsurgery.

	Robot-assisted	Dynamic navigation
Strengths	- Highest surgical accuracy (less angular deflection, platform & apical deviation) - Eliminates hand tremor - Standardized, reproducible execution - Particularly advantageous in posterior or deep root apices	- Shorter setup and registration time - Real-time flexibility - Maintains tactile feedback - More accessible in resource-limited settings
Weaknesses	- Long setup and calibration time - Higher cost - Reduced real-time adjustability - Heavy reliance on preoperative planning	- Operator-dependent variability - Lower precision in complex anatomy - Manual control may be less reproducible
Future directions	- Improve user-friendliness and reduce registration time - Incorporate adaptive algorithms and intraoperative feedback to enhance flexibility - Conduct more in vivo studies and cost-effectiveness analyses	- Enhance instrument stability and reduce operator variability - Optimize interface for improved control accuracy - Further validation in complex clinical cases

Declaration of competing interest

The authors have no conflicts of interest relevant to this article to declare.

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