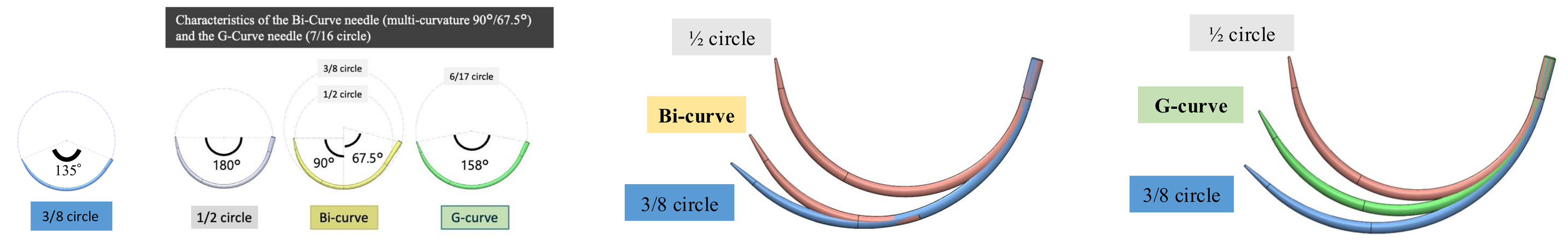
Novel Trajectory-Optimized Curvature Suture Needles Enhance Needle Passage and Suturing Efficiency in Robotic Surgery

Daiki Kimura [1], Susumu Shibasaki [1], Yusuke Watanabe [2], Tatsuhiko Harada [2], Yusuke Nakano [1], Shingo Akimoto [1], Masaya Nakauchi [2], Tsuyoshi Tanaka [1], Kazuki Inaba [2], Takeshi Takahara [1], Koki Otsuka [2], Ichiro Uyama [2], Koichi Suda [1]
1 Department of Surgery, Fujita Health University 2 Department of Advanced Robotic and Endoscopic Surgery, Fujita Health University

Background:

Suturing is one of the most fundamental and indispensable techniques in surgery; it is the cornerstone of both surgical education and clinical proficiency. Among the various technical aspects of suturing, needle handling affects the precision, efficiency, and safety of tissue approximation; proficiency in this skill is essential for optimal surgical outcomes. However, these traditional curvatures may not fully address the individual nuances encountered in diverse, technically demanding surgical scenarios, in which even subtle deviations in needle trajectory can markedly influence ease of manipulation, suturing accuracy, and overall ergonomics. In response to this gap, **Mani** Inc., Utsunomiya, Japan, and **Nitcho Kogyo** Co., Ltd., *Tokyo, Japan* developed the sutures equipped with the Bi-curve needle, composed of equal parts of half-circle and 3/8-circle arcs, and the G-curve needle, featuring an intermediate 7/16-circle curvature (Fig. 1).

(Fig. 1)

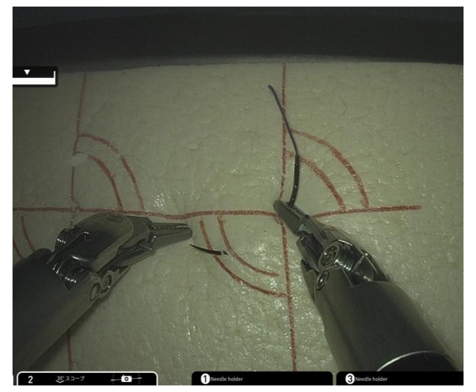


https://www.mani.co.jp/en/pdf/O2OphthalmicSutures.pdf

Methods:(1) Fundamental suturing task

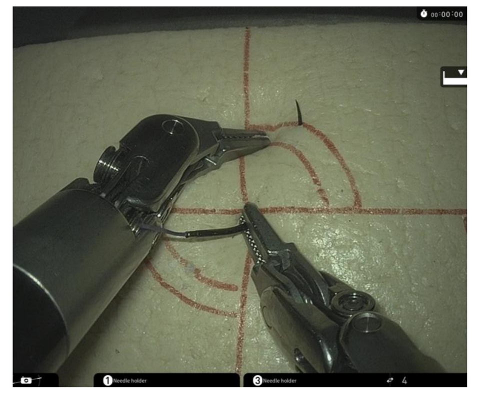
(Fig. 2A)

Forward suturing



(Fig. 2B)

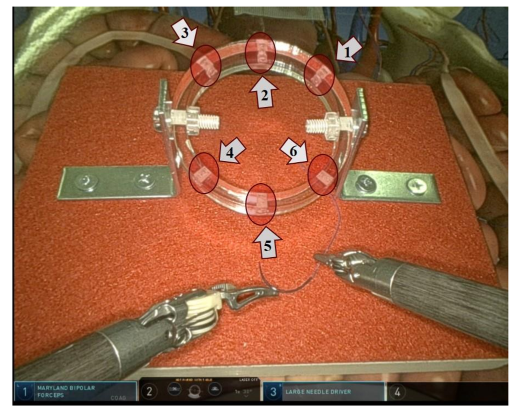
Backward suturing



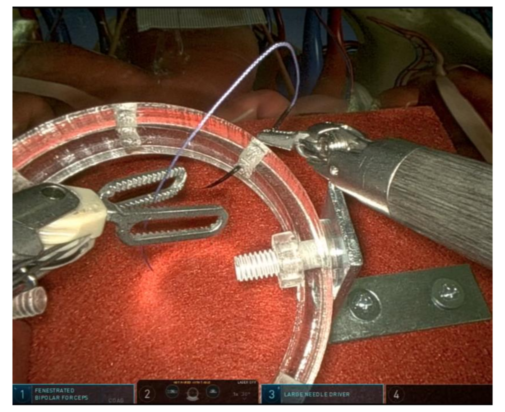
Five senior surgical residents (in postgraduate years 3–10) and five experienced surgeons (>10 years since postgraduate work) participated in this study. For each task, only minimal instructions on how to perform it were given, and the participants were not informed of the purpose of the study or evaluation items at all. Circles 8 and 10 mm in diameter were drawn on a suturing practice pad. The center of the circles was designated as the needle insertion point, and the area between the 8-mm and 10-mm circles was designated as the needle exit point. For the forward technique (Fig. 2A), the exit point was positioned between the 6 o'clock and 9 o'clock positions; for the backward technique (Fig. 2B), between the 12 o'clock and 3 o'clock positions, All procedures were recorded on video, and the time from needle insertion to complete withdrawal was measured. Each participant performed 10 repetitions of the tasks, and their performance was evaluated using the total suturing time. and the hinotori Surgical Robot System (Medicaroid Co., Kobe, Japan) was used for the robotic procedures.

Methods:(2) Advanced training in laparoscopic suturing (ATRAS) needle-handling task

(Fig. 3A)



(Fig. 3B)

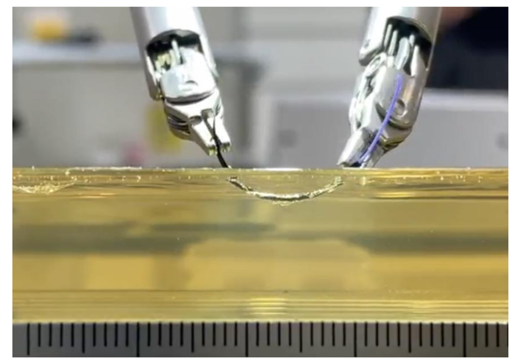


(Fig. 3C)

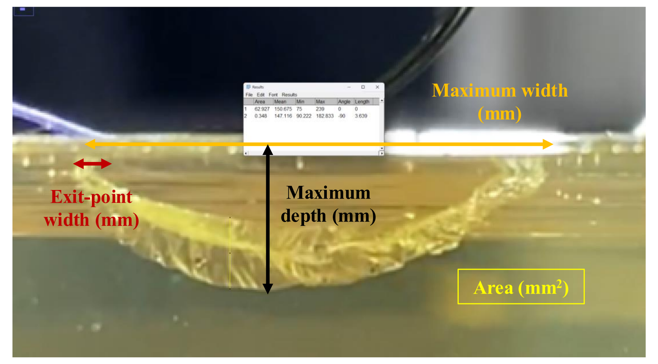
Suturing performance was assessed using the ATLAS needle-handling task (Fig. 3A~3C), which measures the quality of needle passage and manipulation. Performance outcomes included task completion time, needle-passage time, and needle-passage quality, scored on an ordinal 1–3 scale reflecting traversal smoothness and resistance encountered during passage. Each participant performed the task twice for each needle type , procedures were performed with the da Vinci Xi Surgical System equipped with a needle driver and fenestrated forceps, and all procedures were recorded on video.

Methods:(3) Needle trajectory characteristics

(Fig. 4A)



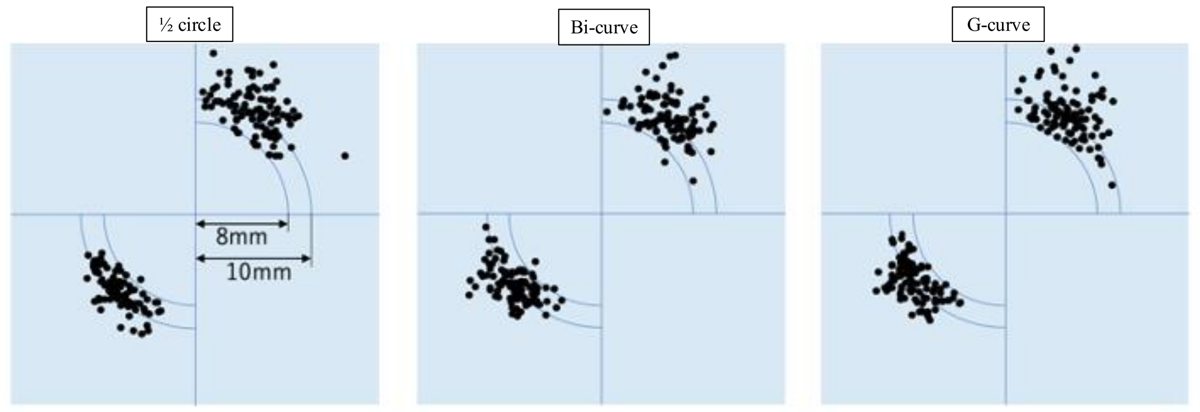
(Fig. 4B)



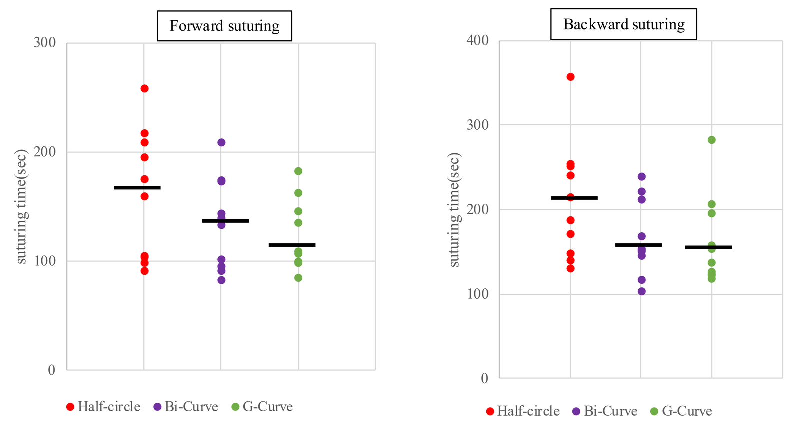
Surgeons of all training levels performed standardized suturing tasks using the da Vinci Xi robotic platform. Three needle geometries with a 22-mm, 3-0 suture were tested: the Bi-Curve needle (multi-curvature 90° /67.5°), the G-Curve needle (7/16 circle), and a conventional 1/2-circle needle. Needle trajectory characteristics were evaluated using a gelatin phantom model (Fig. 4A). Pathway depth, width of the needle exit-site disruption, and the cross-sectional area generated by needle passage were quantified to assess curvature-driven differences (Fig. 4B). The area calculation was generated by open-source software, the Fiji image processing package of ImageJ, developed by the National Institutes of Health (NIH) in the United States

Results:(1) Fundamental suturing task

(Fig. 5A)



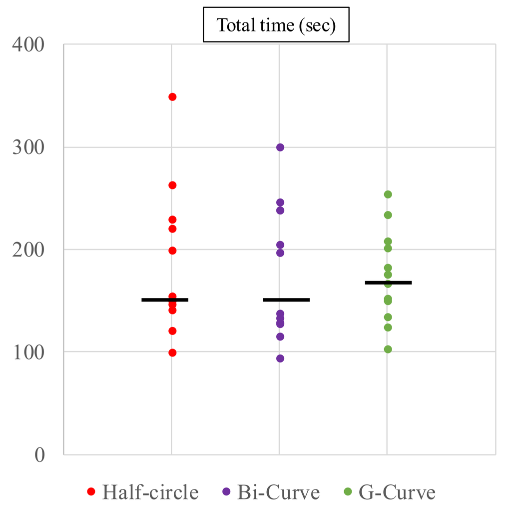
(Fig. 5B)



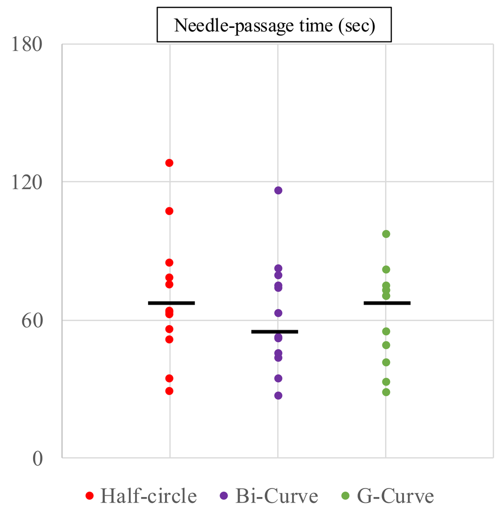
In the robotic needling techniques, both forward and backward, we observed no significant differences in suturing times among the needle types, although those with both the Bi-curve and G-curve needles were slightly shorter than that with the half-circle needle (Fig. 5A). Plots for each needle are shown(Fig. 5B).

Results:(2) Advanced training in laparoscopic suturing (ATRAS) needle-handling task

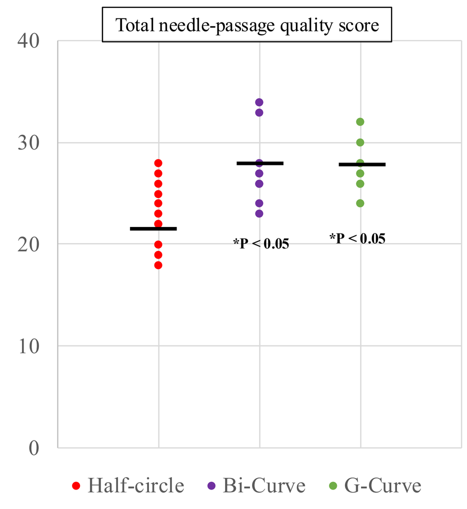
(Fig. 6A)



(Fig. 6B)



(Fig. 6C)

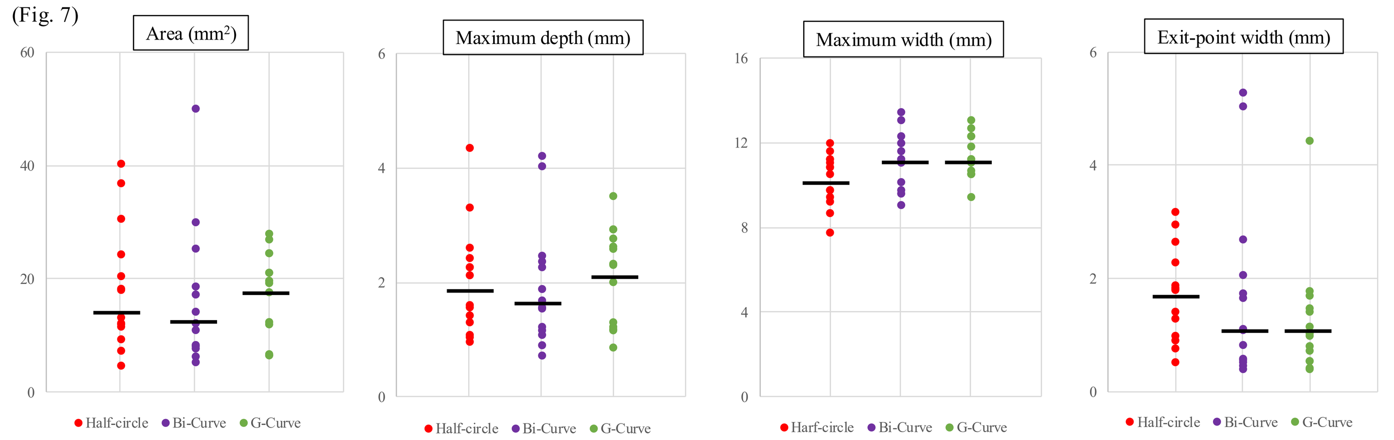


We found no significant differences in the total time necessary to complete the ATLAS-NH tasks with the three types of needles (Fig. 6A). This time included not only needle insertion and withdrawal but also needle handover maneuvers and even time lost when the needle was dropped. In an analysis limited to needle-passage time, we identified no significant differences among the three needle types (Fig. 6B). In contrast, video-based analysis of the total needle-passage quality score demonstrated significantly higher scores for the Bi-curve and G-curve needles than for the half-circle needle (Fig. 6C).

Results:(3) Needle trajectory characteristics

We found that with the half-circle needle, the median maximum depth was 2 mm; the median maximum width, 10mm; the median exit-point width, 2mm; and the median penetration area, 19mm². Those with the Bi-curve needle were 2mm, 10mm, 2mm, and 19mm², respectively, and those with the G-curve were 2mm, 10mm, 2mm, and 19mm², respectively. The differences between these measurements with the three needle types were not significant (Fig. 7).

(Fig. 7)



Summary

- ➢ **Suturing times of the Bi-curve and G-curve needles were slightly shorter than that with the half-circle needle.**
- ➢ **The total needle-passage quality score demonstrated significantly higher scores for the Bi-curve and G-curve needles than for the half-circle needle.**
- ➢ **The needle trajectory characteristics were almost comparable among three needle types.**

⇨ Bi-Curve and G-Curve, were at least equivalent quality compared with a standard 1/2-circle needle, or may be potentially useful.

Conclusion:

The Bi-curve and G-curve needles demonstrated the potential for improved handling in comparison with the conventional half-circle needle in settings that necessitated basic suturing skills. Their effects on tissue and the extent of tissue damage were also comparable with those of the conventional needle. Collectively, these findings suggest that these novel needles may contribute to improved surgical handling without compromising tissue safety and may support the development of surgical skills.

There are no conflicts of interests

FUJITA HEALTH UNIVERSITY

SURGERY FUJITA HEALTH UNIVERSITY

Association for Promotion Advanced Medical Technology APAMT