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Comparative study of proficiency improvement in ArtiSential[®] according to conventional laparoscopic surgery experiences

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ABSTRACT

Background: This pilot study investigates the adaptability of the articulating instrument (ArtiSential) among surgeons with different levels of experience in conventional laparoscopic surgery.

Methods: From June to November 2023, 18 laparoscopic surgeons participated in peg transfer and suture training using ArtiSential instruments. Participants were categorized into novice, intermediate, and expert groups. Peg transfer was repeated three times, comparing dominant and non-dominant hand. Suture training was conducted at four directional positions (1, 12, 3, and 5 o'clock) and analyzed across three trials.

Results: In terms of peg transfer timing analysis, there are significant differences between the three groups in the first ($p < 0.001$) and second trials ($p = 0.011$). However, in the third trial, the gap between the three groups decreased. In all three groups, the suture times at 3 o'clock and 5 o'clock were consistently lower compared to the 1 o'clock and 12 o'clock directions. As the trials progressed, the time decreased for suturing in all directions. Among them, the novice group had reduced suture times at 3 o'clock and 5 o'clock direction.

Conclusions: The ArtiSential instrument is adaptable even for novices. Its articulating features facilitate suturing in traditionally difficult directions (3 o'clock and 5 o'clock) for right-handed users.

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ArtiSential; peg transfer
training; suture training

Introduction

The advent of laparoscopy brought revolutionary changes to all kinds of surgery. However, the laparoscopic instrument has been maintained for decades without major changes from its initial development form. The typical linear movements of conventional laparoscopic instruments inevitably require multi-port access. To overcome this problem and reproduce ergonomic and delicate movements, a robotic system capable of articulation has been developed and is now widely used. However, compared to conventional laparoscopic surgery, the robotic system clearly has the disadvantage of being more expensive [1]. In response to this, an articulating laparoscopic instrument was developed, and various types of products were introduced to the

market. However, many of these products were eventually discontinued due to the challenges associated with user adaptation and the difficulty of operation.

The ArtiSential instrument (LIVSMED Inc., Seongnam-si, South Korea) was developed as a pistol-type handheld articulating tool and started to be used after receiving commercial approval from the Food and Drug Administration (FDA) in 2020 [2]. It is currently used across various clinical surgical fields. However, it is acknowledged to be less ergonomic than a robotic system in terms of instrument manipulation, requiring a significant amount of time to acclimate to its use [3].

We investigated how proficiency in operating the ArtiSential instrument varies with conventional

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laparoscopy experience in clinical surgeons and how it improves over time.

Methods and materials

Artisential instrument

ArtiSential[®] is a novel articulating laparoscopic instrument designed to provide enhanced dexterity through a double-jointed end-effector with seven degrees of freedom. The device enables intuitive and synchronized movement by mechanically translating the surgeon's hand, wrist, and finger motions to the distal tip, thereby preserving tactile feedback without the need for robotic assistance. It is available in shaft lengths of 25 cm, 38 cm, and 45 cm, with a standard outer diameter of 8 mm. Recently, a miniaturized version compatible with 5 mm trocars has also been developed to facilitate access in reduced-port and pediatric laparoscopic procedures. A variety of instrument types are available, including needle holders, fenestrated and Maryland dissectors, bipolar and monopolar energy devices, and laparoscopic scissors. The instrument requires no dedicated capital equipment and is fully compatible with conventional laparoscopic platforms. Optional features include articulation locking mechanisms and adjustable jaw control rings to optimize ergonomics for individual users.

Study design and participant's enrollment

This study was designed as a prospective comparative study to evaluate the improvement in proficiency when performing repeated simple (peg transfer training) and complex (suture training) motions using an ArtiSential instruments, according to a group of clinical surgeons with experience in conventional laparoscopic surgery. The applicant publicly recruited clinicians with experience in laparoscopic surgery within the hospital through an announcement, and the study was conducted after obtaining voluntary written consent. From January to September 2023, participants were recruited from clinical surgeons at the Severance Hospital, the Yongin Severance Hospital, and the Samsung Medical Center, all of whom had experience in general surgery, obstetrics, and gynecology surgery using conventional laparoscopic instruments. The surgeon group with one to fewer than 50 conventional laparoscopic surgery experiences was classified as novice, the group with 50 to fewer than 100 experiences was classified as intermediate, and the group with more than 100 experiences was classified as expert. Among all participants, 11 (61.1%) were from general surgery and seven (38.9%)

were from obstetrics and gynecology. Regarding academic position, seven participants (38.9%) were professors, six (33.3%) were fellows, and five (27.8%) were residents. Among them, six surgeons (33.3%) had prior experience with high-complexity procedures or robotic surgery. This study was approved by Institutional review board of Yongin Severance Hospital (9-2023-0123).

Peg transfer training

Peg transfer training is a program designed to assess the ability to manipulate the Artisential fenestrated forceps freely using the ArtiSential training kit (Figure 1A). Participants learn the basic articulating mechanics and aim to synchronize their movements with their hands, ultimately enabling them to perform traction and counter-traction during surgery. Using their dominant hand, participants move 12 pegs from the upper block to the lower block and then use the same hand to move 10 pegs from the lower block to the left-side block. These steps are then repeated with the non-dominant hand, and the time taken to complete this course is measured, with the process repeated three times.

Suture training

The suture training program measures the time it takes to make stitches and tie knots with 3-0 silk on the suture pad of the training kit using the ArtiSential needle holder and fenestrated forceps (Figure 1B). Suturing and tying are performed at 12 o'clock, 1 o'clock, 3 o'clock, and 5 o'clock, and this process is repeated three times.

Statistical analysis

Descriptive analyses of clinical characteristics were conducted using Mann-Whitney U test and Kruskal-Wallis test. The time required for peg transfer and suture training was described as the mean and standard deviation, with the minimum and maximum times also noted. For each graph analysis, the average time per trial was calculated, and linear regression analysis was performed. Statistical significance was set as $p < 0.05$. All statistical analyses were performed using IBM SPSS Statistics for Windows v 22.0 (IBM Corp., Armonk, NY, USA) and R v. 3.3.1 (R Foundation for Statistical Computing, Vienna, Austria).

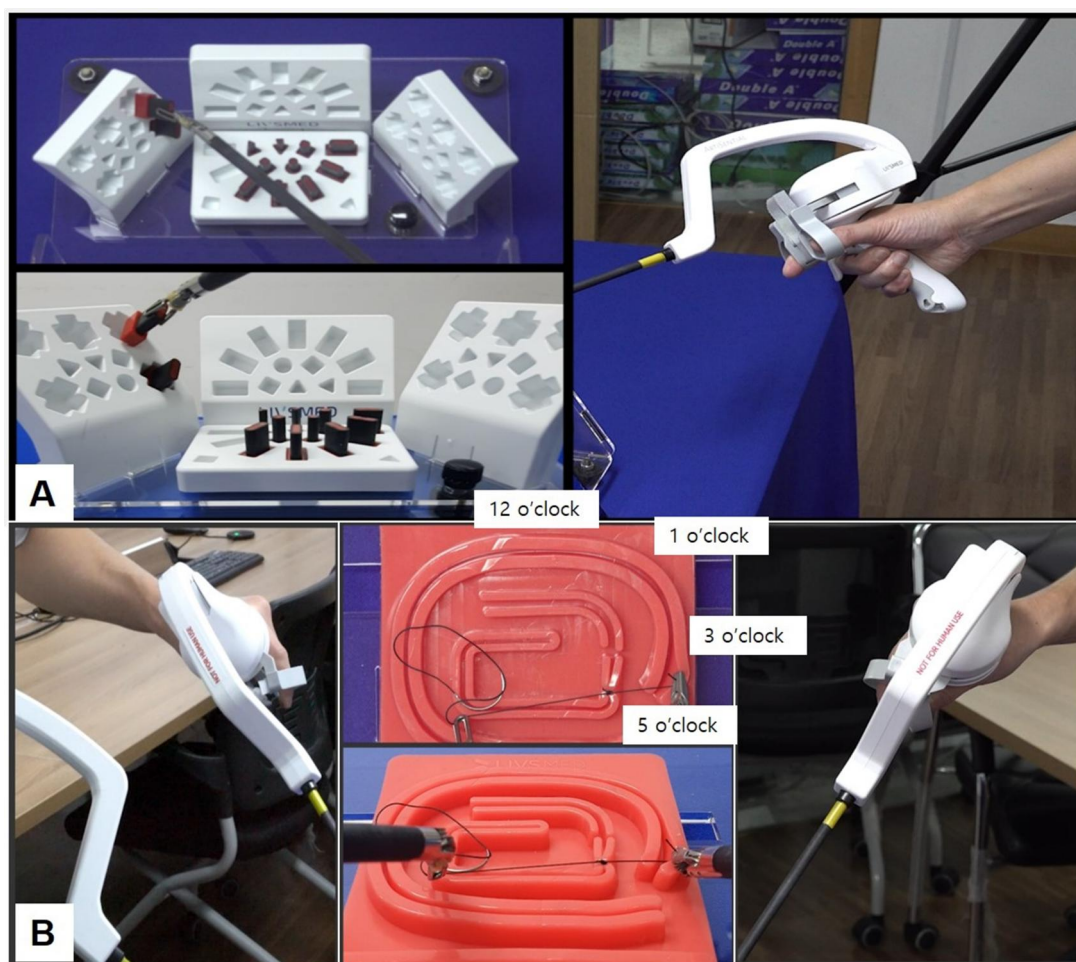


Figure 1. Scheme of peg transfer and suture training (A) peg transfer kit and instrument hand grip; (B) Suture training program.

Table 1. Comparisons of peg transfer training time for each group.

Mean $\pm$ SD, seconds [min, max]	Novice (N = 6)	Intermediate (N = 6)	Expert (N = 6)	p
1 st Trial	1023.3 $\pm$ 184.3 [795, 1273]	739.0 $\pm$ 242.5 [525, 1163]	273.2 $\pm$ 114.3 [144, 450]	< 0.001
2 nd Trial	644.8 $\pm$ 330.0 [160, 1142]	533.3 $\pm$ 204.7 [297, 833]	202.8 $\pm$ 48.7 [149, 265]	0.011
3 rd Trial	483.7 $\pm$ 292.5 [120, 956]	416.7 $\pm$ 183.2 [256, 753]	188.7 $\pm$ 68.0 [112, 274]	0.057
P	0.002	<0.001	0.012	

Results

Comparison of peg transfer training time

At the first trial, mean time of peg transfer in the novice group was 1023.3 ± 184.3 s (mean $\pm$ SD). In the intermediate group, mean time was 739.0 ± 242.5 s, compared with 273.2 ± 114.3 s in expert group ($p < 0.001$). In the second trial, mean time decreased in each group, 644.8 ± 330.0 , 533.3 ± 204.7 , and 202.8 ± 48.7 s ($p = 0.011$), respectively. In the third trial, mean time was 483.7 ± 292.5 s in the novice group, 416.7 ± 183.2 s in intermediate group, and 188.7 ± 68.0 s in expert group. As trials proceeded, significant differences became attenuated between the three groups (Table 1).

When comparing the mean time for peg transfer training across groups as trials progressed, the novice group showed a more rapid improvement compared to the other groups (Figure 2).

In the subgroup analysis according to dominant hand, peg transfer performance improved more rapidly for the non-dominant hand than the dominant hand across all groups as the trials progressed.

Comparison of suture training time

The time to complete suturing performances for oblique direction, such as 1 o'clock, and 5 o'clock was found to be longer than those for tangential direction,



Figure 2. Comparison of mean peg transfer training time according to groups.

Table 2. Comparisons of suture training time for each group.

Mean $\pm$ SD, seconds [min, max]		Novice (N = 5)	Intermediate (N = 4)	Expert (N = 6)	p
1 st Trial	1 o'clock suture	810.6 $\pm$ 239.8 [542,1062]	820.0 $\pm$ 284.7 [428,1065]	425.2 $\pm$ 189.4 [242,653]	0.026
	12 o'clock suture	723.6 $\pm$ 182.6 [465,870]	662.8 $\pm$ 218.7 [375,866]	381.0 $\pm$ 221.5 [168,715]	0.041
	3 o'clock suture	595.0 $\pm$ 149.1 [390,797]	501.8 $\pm$ 64.7 [436,591]	322.7 $\pm$ 125.1 [173,505]	0.009
	5 o'clock suture	668.6 $\pm$ 192.2 [410,887]	606.0 $\pm$ 123.4 [486,776]	288.8 $\pm$ 88.3 [178,402]	0.001
2 nd Trial	1 o'clock suture	674.2 $\pm$ 212.6 [460,966]	416.5 $\pm$ 199.6 [288,714]	320.2 $\pm$ 191.6 [137,620]	0.037
	12 o'clock suture	650.2 $\pm$ 232.2 [391,973]	475.0 $\pm$ 71.8 [394,564]	315.7 $\pm$ 176.6 [125,600]	0.031
	3 o'clock suture	471.2 $\pm$ 72.5 [348,525]	378.0 $\pm$ 73.9 [313,442]	293.2 $\pm$ 110.4 [190,461]	0.023
	5 o'clock suture	572.8 $\pm$ 165.7 [361,751]	460.8 $\pm$ 83.9 [336,518]	244.3 $\pm$ 72.4 [154,360]	0.002
3 rd Trial	1 o'clock suture	557.4 $\pm$ 160.6 [415,799]	461.0 $\pm$ 172.5 [300,646]	289.5 $\pm$ 186.0 [101,595]	0.071
	12 o'clock suture	554.2 $\pm$ 191.5 [309,818]	376.2 $\pm$ 89.3 [301,504]	301.0 $\pm$ 158.5 [167,575]	0.058
	3 o'clock suture	395.6 $\pm$ 84.9 [261,468]	366.8 $\pm$ 74.5 [262,438]	275.5 $\pm$ 120.9 [135,445]	0.155
	5 o'clock suture	457.2 $\pm$ 131.9 [265,603]	376.2 $\pm$ 112.6 [258,477]	230.5 $\pm$ 81.6 [114,367]	0.014

such as 12 o'clock and 3 o'clock. The difference between the mean suture times at 1 o'clock and 12 o'clock, as well as the mean suture times at 3 o'clock and 5 o'clock, was larger in the novice group than in the expert group. In all trials and groups, mean suture times at 3 o'clock and 5 o'clock were shorter than those at 1 o'clock and 12 o'clock, except for the 1 o'clock and 12 o'clock times in the third trial.

However, this difference became also attenuated as the trial progressed. In the first trial, the expert group showed less mean time in all directions than the other novice and intermediate groups. In the third trial, the

difference in mean suture time between each direction in the expert group was smaller than the difference in mean time between sutures in each direction in the novice group (Table 2).

Mostly, suturing performance was shown to increase as trials proceeded. When comparing the reduction in suture time in each direction as trials progressed for each group, it was observed that the novice group showed a consistent and stable decrease in suture time with each successive trials in all directions (Figure 3). The change in mean suture time for each participant in the novice group decreased in all

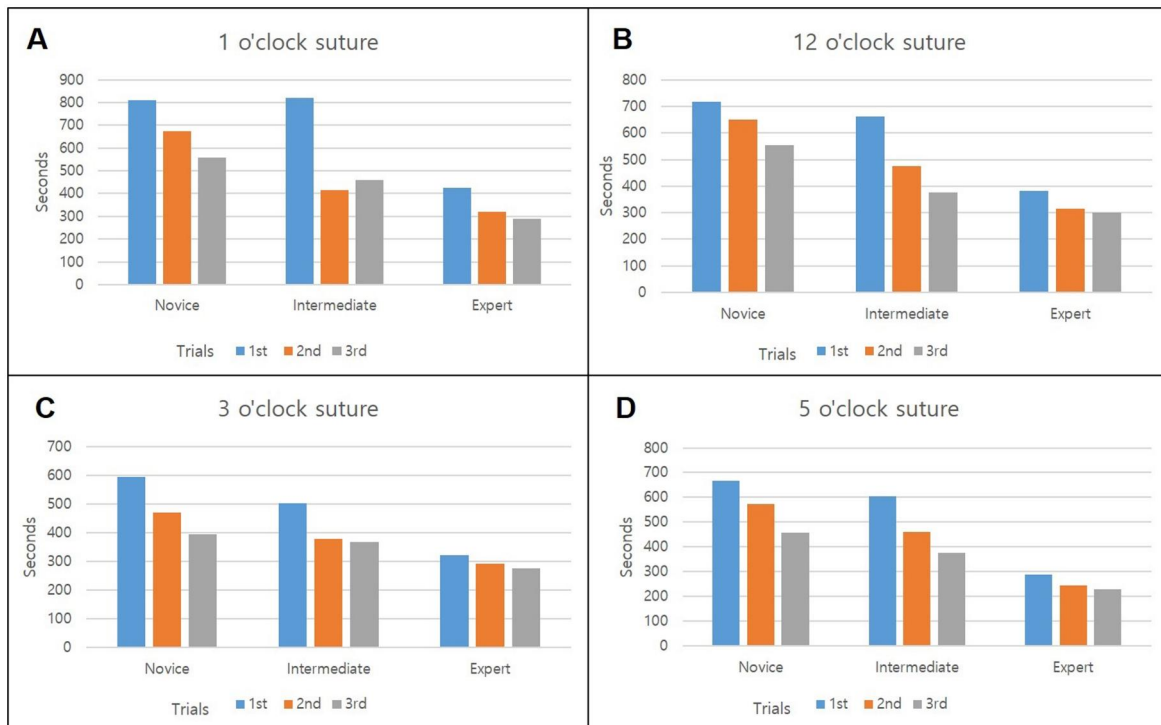


Figure 3. Comparison of mean suture time each groups according to trials.

cases except for the 12 o'clock direction. At 5 o'clock, all participants experienced a relatively even decrease. In the intermediate group, two participants experienced an increase in mean time during the third trial at the 1 o'clock and 3 o'clock directions. In the expert group, the range of change in mean time was not significant as the trial progressed (Figure 4).

Discussion

Many instruments have been developed to facilitate faster and more efficient procedures while ensuring clinical safety and feasibility. Recently, robotic platforms have emerged as a valuable alternative. However, the high cost remains the most significant barrier to their widespread adoption in surgical systems. The ArtiSential instrument was developed to provide articulating movement similar to that of robotic platforms, while being offered at a more affordable price and remaining compatible with conventional laparoscopic systems. In addition to allowing angulation motion, its ergonomic configuration has enabled its application in various surgical fields, including prostatectomy, hysterectomy, cardiovascular surgery, hernia repair, gastrectomy, renal surgery, thoracic surgery and colectomy [4–9]. The ArtiSential instrument, an advanced pistol-type laparoscopic tool providing seven degrees of freedom, was designed to

serve as a potentially more affordable alternative to robotic platforms. However, its specific manipulating system may pose a challenge for beginner surgeons, as it requires familiarity for effective use [10].

While recent clinical data on surgeries using the ArtiSential instrument have been published, there is limited dry lab proficiency data available. Furthermore, most clinical studies on the feasibility and safety of the ArtiSential instrument have been conducted by experienced surgeons familiar with minimally invasive surgery. Our institution has continuously implemented minimally invasive approaches for hepatopancreatobiliary surgery and has reported on the clinical feasibility of cholecystectomy and pancreaticoduodenectomy using the ArtiSential instrument [11–13]. In previous studies comparing peg transfer times, significant improvements in dexterity were observed in novice surgeons [14]. A recent dry-lab based study investigating proficiency with the ArtiSential instrument reported that medical students with no prior experience using laparoscopic instruments, after a brief period of training, performed a peg transfer task using the ArtiSential instrument. Although the task completion time was longer compared to the group using conventional instruments, the ArtiSential group demonstrated a significantly lower error rate [15]. In a previous study involving five expert surgeons with no prior experience using

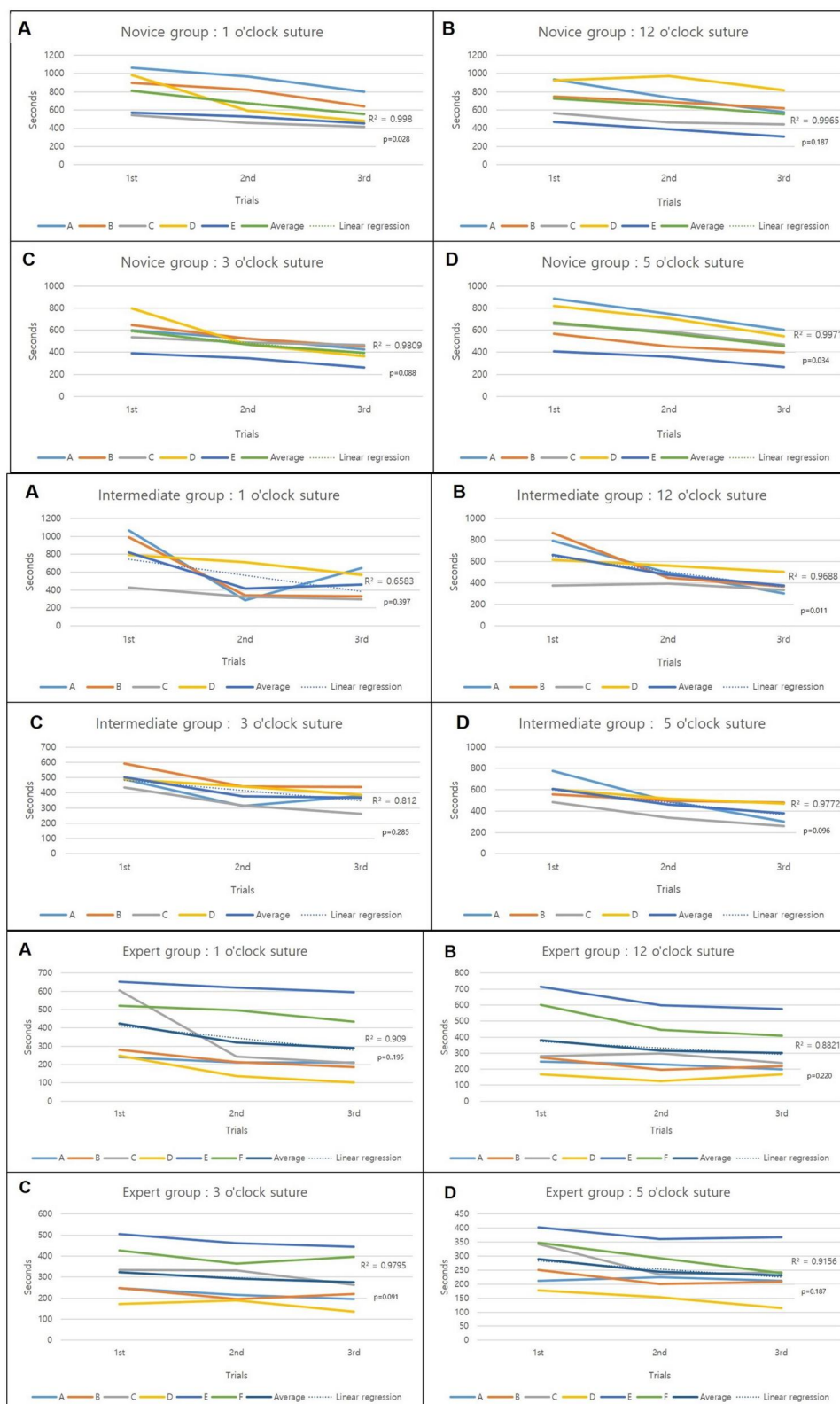


Figure 4. Suture training analysis according to direction in novice, intermediate, and expert groups.

robotic or other articulating instruments, all of whom had performed over 100 laparoscopic procedures, suture tasks using the ArtiSential[®] instrument and the da Vinci[®] robotic system were compared. The results

showed no statistically significant difference in total completion time or knotting intervals between the two instruments in both downward and upward suturing directions [16]. Additionally, in a porcine

model, when the renal pedicle clamping using ArtiSential instrument was compared to conventional laparoscopic instruments and robotic platform, favorable results were demonstrated [17]. Unlike previous studies, this study is designed to evaluate the proficiency of surgeons using the ArtiSential instrument prospectively. Through this study, we aimed to assess the initial discomfort and task failures that surgeons may experience when first using the instrument, by measuring the degree of time reduction through repeated trials. Furthermore, it investigated the improvement in operating efficiency and fidelity based on prior experience with conventional laparoscopic surgery.

In the peg transfer training, the first trial demonstrated a statistically significant difference in performance between the novice, intermediate, and expert groups. However, by the second trial, this gap was significantly reduced. Among the groups, the novice group showed the greatest reduction in transfer time, while the expert group exhibited the least. By the third trial, although the expert group still required the least amount of time, there was no statistically significant difference between the three groups. Additionally, as the trials progressed, the novice group exhibited the most rapid reduction in mean time. The expert group not only showed a reduction in mean peg transfer time as the trials progressed, but also demonstrated decreased variability among participants, suggesting that experienced surgeons may be able to use the ArtiSential instrument with stable performance over repeated trials. When comparing suture times, the 3 o'clock and 5 o'clock directions required less time than the 1 o'clock and 12 o'clock directions. This finding highlights the distinct advantage of the instrument's articulating motion. For right-handed surgeons, laparoscopic suturing in the relatively challenging 3 o'clock and 5 o'clock directions is made easier with the use of the ArtiSential instrument. These findings suggest that even novice surgeons with limited laparoscopic experience may show measurable improvement with the ArtiSential instrument through repeated trials in a simulated environment. However, caution is warranted when extrapolating these results to real-world clinical settings, given the limitations of the simulator-based design and small sample size. Although the articulating motion of the instrument appeared to support more efficient suturing in certain directions, further validation in clinical contexts is necessary to confirm its practical benefits.

The ArtiSential instrument, capable of articulating movement, has demonstrated potential for application in various clinical surgical procedures, particularly in areas requiring enhanced dexterity. It overcomes the primary drawback of robotic surgery platforms—high cost—while enabling ergonomic motion similar to that of robotic arms. Additionally, it provides tactile feedback, which is currently unavailable in most robotic platforms, and may enhance tactile awareness during manual control. Despite these strong advantages, the unfamiliar instrument operating system has been considered a barrier to widespread adoption among new users. Nevertheless, based on the results observed in this study, both expert surgeons familiar with conventional laparoscopic techniques and novice surgeons with limited experience may be able to adapt to the system through repeated use in a simulated environment.

However, this study has several limitations. First, although the participants were divided into groups, the sample size was small, and the study included a heterogeneous group of surgeons from different specialties. In addition, no a priori power analysis was conducted due to the pilot nature of the study; therefore, the potential risk of both Type I and Type II errors cannot be completely excluded. Second, the transfer and suturing movements used for comparison were relatively simple, making it challenging to fully assess the clinical benefits in real-world applications. Third, the limited number of trials made it impossible to observe long-term trends. Fourth, as this study assessed only task completion time—a purely quantitative metric—no qualitative measurements such as peg drop rate, knot security, needle placement accuracy, or efficiency of motion were included. Therefore, the observed improvement may not fully represent overall proficiency gains. Future large cohort prospective studies are necessary to evaluate the learning curve more accurately and to incorporate comprehensive qualitative assessments.

In conclusion, the articulating movement of the ArtiSential instrument facilitates suturing in the 3 o'clock and 5 o'clock directions, which are typically challenging for right-handed surgeons. This pilot study suggests that the ArtiSential instrument may be adopted by both experienced and novice surgeons, with observable improvements through repeated use in a simulated setting. However, due to the small sample size and dry-lab environment, these findings should be interpreted with caution. Further large-scale prospective studies are needed to evaluate the

learning curve in real clinical scenarios and to validate the instrument's usability and performance.

Author contributions

CRediT: **Seoung Yoon Rho**: Investigation, Writing – original draft; **Munseok Choi**: Investigation, Methodology; **Sung Hyun Kim**: Investigation, Validation; **Seung Soo Hong**: Methodology, Project administration, Validation; **Hyung-il Kim**: Formal analysis, Validation; **Yoo-Young Lee**: Investigation, Resources; **Brian Goh Kim**: Validation; **Yuichi Nagakawa**: Supervision, Validation; **Minoru Tanabe**: Supervision, Validation; **Daisuke Asano**: Supervision, Validation; **Chang Moo Kang**: Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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