Computer Navigated Total Hip Arthroplasty Via The Direct Superior Approach: A Retrospective Study of The First 30 Consecutive Cases

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Abstract

Background

The direct superior approach (DSA), which is one of the muscle-sparing approaches for total hip arthroplasty (THA), has been recently reported with positive outcomes. However, in minimally invasive THA, it has been reported that the visual intraoperative estimation of the cup position is not reliable. Therefore, those minimally invasive approaches are associated with the increased risk of acetabular cup malposition due to the limited exposure. Although the positive effects of computer navigation system on the accuracy of cup positioning have been reported in many studies, those are not unknown in THA via the DSA. In the current study, we investigated the accuracy of acetabular cup positioning in navigated THA via the DSA in the first 30 consecutive cases.

Methods

We have retroactively included the first 30 consecutive cases of navigated DSA, and the consecutive control cases using conventional posterior approach (PA) were included retroactively up to 30 cases. This retrospective study divided the cases of navigated DSA into 15 initial and 15 recent cases. The postoperative data were assessed on plain computed tomography to measure the radiographic inclination and anteversion of the acetabular component. Statistical analyses were performed using Mann-Whiteney U test for comparison of the mean, and Levene's tests for equality of standard deviations (SD).

Results

We found no significant differences in the means between navigated DSA and conventional PA for anteversion and inclination. For anteversion, the accuracy of acetabular cup positioning in navigated DSA (SD, 6.9°), including the recent 15 cases (SD, 4.1°), was significantly improved than in conventional PA (SD, 11.7°). For inclination, there were no significant differences in the accuracy of the acetabular cup positioning between navigated DSA (SD, 5.3°) and conventional PA (SD, 6.5°).

Conclusions

The increased variances of cup anteversion would be due to the frequency of pelvic malposition and the wide variation in pelvic orientation with the patient in the lateral decubitus position. Navigated THA via the DSA could be performed with good accuracy of cup placement in the first 30 cases. The results suggest that computer navigated THA via the DSA as a suitable option for hip replacement.

Introduction

The muscle-sparing approaches still have been prioritized in primary total hip arthroplasty (THA), although dislocations following primary THA has declined over time [1]. The direct superior approach (DSA) preserves the iliotibial band and short external rotators [2], and emerged as the postero-superior muscle-sparing THA which modified the conventional posterior approaches for THA. Because the posterior capsule and short external rotators are the static and dynamic stabilizers in flexion and internal rotation of the hip joint [3, 4], the adequate strength of the posterior structures greatly decreases the future risk of hip instability and the complications such as recurrent dislocation [5]. The positive outcomes of THA using DSA have been recently reported, for example less inadvertent muscle and tendon damage during DSA than during direct anterior approach (DAA) has been demonstrated in a cadaveric study [6].

Meanwhile, the limited exposure of muscle-sparing THA could have deteriorating effects on precise acetabular component orientation, although it has many positives in reducing pain, blood loss, rehabilitation time, and hospital stay by preserving muscles and tendons [7]. Acetabular cup orientation based on a surgeon's visual assessment often results in an inaccurate placement [8]. Especially in minimally invasive THA, it has been reported that the visual intraoperative estimation of the cup and stem position is not reliable [9]. In another previous study, the minimally invasive surgical approach, low volume surgeons, and obese patients were reported to be associated with increased risks of malpositioning [7, 8]. Malpositioning of the acetabular cup increases the risk of impingement, recurrent dislocation, pelvic osteolysis, acetabular migration, polyethylene wear, and early revision and failure [7]. Because positive effects and relevancies of computer navigation systems in THA for accurate cup positioning have been reported [10], the CT navigation system would be the key to resolving the risk for malpositioning in minimally invasive THA.

Without computer navigation system, the retrospective study about DSA has been recently reported that the learning curve is no more than 20 cases for surgeons trained in the posterior approach due to the decrease in operating time of the first 40 primary THA cases [11]. However, the effects of computer navigation system on DSA remains unknown. Therefore, in the current study, we investigated the effects of computer navigation system to improve the accuracy of cup orientation in DSA, considering the proficiency of DSA with navigation in the first 30 consecutive cases

Materials And Methods

We have included the first 30 consecutive cases of THA at our hospital retroactively using the direct superior approach (DSA) with navigation from December 2018 to May 2020, and the consecutive control cases using conventional posterior approach (PA) were included retroactively up to 30 cases before December 2018 (**Table 1**). Plain radiographs and medical records were reviewed to compare radiological and clinical outcomes. The cup inclination and anteversion angles were measured on three-dimensional computed tomography reconstructions postoperatively for each patient by two independent observers. The intraclass correlation coefficients (ICCs) for inter-observer and intra-observer reliability for the measurements were calculated. This research has been approved by the IRB of the authors' affiliated institutions.

Preoperative Planning

We obtained CT images from the anterior iliac spine to the femoral condyle using a helical CT scanner (GE Medical Systems, Milwaukee, WI, USA). The slice thickness was 1.0 mm and the pitch was 2 mm. Preoperative planning was performed for all THA procedures with the use of CT-based 3- dimensional (3D) templating and navigation software (CT-based hip, version 1.1; Stryker Navigation, Freiburg, Germany). The supine functional pelvic plane was used as a reference plane, for which patients were placed parallel to the CT table in the supine position, as a modification to the anterior pelvic plane defined by both the bilateral anterior superior iliac spine and pubic tubercle considering the pelvic tilt in the sagittal plane. In the navigated DSA for THA, our target position of the acetabular component was set as 40° abduction and 20° anteversion (radiographic). The target zone for the acetabular cup was defined as 30°–50° abduction and 10°–30° anteversion in the radiographic manner.

Surgical Information

Conventional posterior approach was performed with a patient placed in a lateral decubitus position. The short external rotators of the hip, including the piriformis and conjoined tendon, were released and the capsulotomy began at the proximal to the lesser trochanter of the femur and extended proximally in a L-shaped manner. With the hip dislocation, the femoral neck osteotomy was performed, and the piriformis and conjoined tendon were repaired at the wound closure.

DSA was performed with a patient placed in a lateral decubitus position according to the original method [2]. The leg was placed in 40° flexion, 40° internal rotation, and 40° adduction, using a padded Mayo stand. An incision of approximately 8 cm in length was made from the posterior corner of the greater trochanter extending proximally and posteriorly by 45° to the line from the top to the bottom. The piriformis tendon was preserved, and the conjoined tendon was released and tagged for later repair upon closure of the capsule. With the posterior hip capsule completely exposed, the capsulotomy began at the proximal to the lesser trochanter of the femur and extended proximally and posteromedially towards the superior acetabular margin in a straight line along the surgical incision line. Without the hip dislocation, the femoral neck osteotomy was performed in situ, and the femoral component was implanted without a navigation system.

Intraoperative surface registration was performed after placing the pelvic tracker onto the iliac crest with two pins using an external fixator (Hoffmann II Compact External fixation system; Stryker Orthopaedics, Mahwah, New Jersey). The previously registered five points prepared for surface matching, which included the anterior superior iliac spine, the center of the acetabular fossa, the anterior horn of the lunate surface, the posterior horn of the lunate surface, and the greater sciatic notch, were routinely completed. After component implantation and soaking in the diluted 0.3% povidone-iodine solution, direct side-to-side repair of the posterior capsule was performed, and the conjoined tendon was attached to the posterior aspect of the capsule.

All THA procedures were performed using cementless, titanium, proximally coated, and tapered stems (Accolade II; Stryker Orthopaedics, Mahwah, New Jersey) with cementless, hemispherical acetabular fixations (Trident Acetabular Cup System; Stryker Orthopaedics), and utilizing either a 28- (PA) or a 32- (DSA) mm femoral head and a highly cross-linked polyethylene-bearing couple.

Postoperative Records

We obtained postoperative CT images until discharge in all cases and these images were uploaded to the 3D templating software, and calculated (Synapse Vincent Ver 5.2; Fujifilm Medical, Tokyo, Japan). In this study, the following aspects were investigated: (1) accuracy of the acetabular component positioning; (2) the mean deviation of the radiographic cup inclination and anteversion angle among each group; (3) correlation coefficients of the operating time; (4) intraclass correlation coefficients (ICCs) of the intraobserver and interobserver measurements for the acetabular component alignment; and (5) patient demographics and perioperative complications.

Statistical Analysis

Pairwise comparison tests were performed using Levene's tests for equality of variances. Correlations were assessed by Spearman's rank correlation analysis. A p value less than 0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 19 (IBM Corp., Armonk, NY). A priori sample size calculation was performed. The significance criteria was adjusted for multiple comparisons using the Bonferroni correction. This sample size analysis revealed that 22 subjects were required in each group (66 subjects in total) to obtain a power of 80%.

Results

We found no significant difference in the means between navigated DSA and conventional PA for anteversion (p = 0.841) and inclination (p = 0.787). For anteversion, the accuracy of acetabular cup positioning in navigated DSA (SD, 6.9°), including the recent 15 cases (SD, 4.1°) was significantly better than in conventional PA (SD, 11.7°) (p = 0.010 and 0.003, respectively), meanwhile no significant difference was found between the initial 15 navigated DSA cases (SD, 8.1°) and conventional PA (SD, 11.7°) (p = 0.379) (**Table 2**). For inclination, there were no significant differences in the accuracy of the acetabular cup positioning between navigated DSA (SD, 5.3°), including the initial 15 cases (SD, 6.3°) and the recent 15 cases (SD, 4.5°), and conventional PA (SD, 6.5°) (p = 0.680, 1.000, 0.328, respectively) (**Table 2**). The operative time of DSA with navigation revealed a significant R2 value and negative trend (Spearman's rank correlation coefficient: R = -0.51, p = 0.004) (Fig. 2). In DSA with navigation group, there was one intraoperative calcar fracture, which required plating of the femur and revision surgery with restricted weightbearing postoperatively (the complication rate: 3%). In conventional PA group, there was one case of sciatic nerve palsy (the complication rate: 3%). No dislocations occurred in either group during a mean follow-up of 2 years. The ICCs for inter-observer and intra-observer reliability for the measurements were excellent (ICC > 0.9), indicating that the methods were highly reliable in the present study.

Discussion

The most important finding of the present study is that THA using DSA and computer navigation could be performed safely in the first 30 cases with good accuracy of cup placement. In addition, the recent 15 cases were performed with far better precision of cup placement compared to the initial 15 cases, suggesting that the proficiency of DSA with navigation continued beyond the 15 initial cases. As seen in Fig. 2, the curve of the operative time followed a substantially negative trend (Fig. 2). The excellent results of the current study could represent one of the effects of the CT navigation system, although a previous study of DSA reported that the cup abduction angle was highly variable [2]. Our results suggest that the learning curve plateau was achieved after the 15th surgery, meanwhile our study included the use of the CT navigation system by an adult reconstructive surgeon computer navigation system with experiences of conventional PA (Fig. 1a, b). Considering the previous study reporting that THA with DAA results in higher complication rates, during the learning-curve period, the low complication rate in the current study (3%) would be another positive aspect of navigated DSA [12].

Previously, it has been reported that performing a greater volume of surgeries can increase the accuracy of cup placement in abduction but not in anteversion [13]. The variances of cup anteversion would be a result of wide variation in pelvic orientation in the lateral decubitus position. The difficulty of pelvic positioning with the patient in the lateral decubitus position lead to the frequency of pelvic malposition [14]. Moreover, another study reported that the safe zone range for cup anteversion was narrower than that for inclination in THA [15]. In the current study, the precision of the cup anteversion was significantly improved in DSA with navigation group, and we considered that this would be the positive effect of the CT navigation system in THA to fix the cup at a suitable angle.

Although no consensus regarding the optimum orientation of the acetabular component in THA has been demonstrated previously [16], in the current study the preoperative plan was set to 40 degrees of radiographic inclination and 20 degrees of radiographic anteversion regarding the functional pelvic plane in the supine position, in accordance with various studies. To date, the Lewinnek safe zone (30°-50° inclination, 5°-25° anteversion, radiographical) has been dominantly used [17], however it has been recently known that the Lewinnek's safe zone does not confirm the stability of the operated hip joint [18, 19], and furthermore, many other proposed safe zones have been reported [20]. Matching native anteversion (20°-25°) was reported to achieve optimal stability [21], and another study proposed a safe zone comprising 43°±12° of operative inclination and 31°±8° of tilt-adjusted operative anteversion [15]. Moreover, a suitable acetabular cup orientation should be determined regarding the femoral situation, since the appropriate target angle of the cup is influenced by the anteversion and neck angle of the stem to prevent the mechanical impingement [22]. Widmer's concept of combined anteversion calculates the safe zone of cup inclination and anteversion, which is suitable for stems with anteversion angles of 15° and neck angles of 130° using a 28 mm diameter head [22]. Additionally, they calculated the variations in the safe zones on various stem neck angles in a biomechanical study [23]. Regarding the Widmer's report, the suitable combined anteversion in the current study was 41.3° due to the stem neck angle of 132° (Accolade II; Stryker. Orthopaedics, Mahwah, NJ) [23]. Previously, native femoral anteversion was reported to be 14.3° in control patients, and 22.1° in DDH patients [24]. If the equation of combined anteversion (cup Anteversion + 0.7*stem anteversion = 35°) was used and the stem anteversion was 20°, the appropriate cup anteversion would be 21.0° [25]. According to these findings, we set the 40° inclination and 20° anteversion (radiographic) in the preoperative plan for DSA with navigation in the current study. In all cases, with a mean 2-yaer follow-up, no postoperative hip dislocations were found, and the results of postoperative range of motion were excellent.

Furthermore, the release and repair of the conjoined tendon and the preservation of the piriformis tendon might be appropriate for balancing the suitable tension of the hip joint, considering the increase or decrease in postoperative lateral offset. In fact, the footprint of the conjoined tendon attachment is often overlaps with the canal of the femoral stem, and therefore the conjoined tendon is at a risk of being damaged during the femoral canal rasping in all approaches [3]. In addition, it has been reported that the iliofemoral ligament contributes to hip joint stability as the main dynamic and static stabilizer [26], as the thickest area of the capsule has been reported to correspond to the location of the iliofemoral ligament [27].

There are several limitations to our study. First, the measurement accuracy and reproducibility are limitations. The surface matching and registration of CT navigation contain some errors. Second, the study was restricted by the numbers of cases. Although it may be underpowered due to the relatively small sample size, the improving tendency of DSA with navigation in accuracy of cup anteversion was evident in the current study.

Conclusions

In conclusion, navigated THA via the DSA could be performed in the first 30 cases with good accuracy of cup placement with a low incidence of complications. This will have significant implications for the provision of DSA with navigation as a suitable option for hip replacement surgeons.

Abbreviations

DSA, directsuperior approach; THA, total hip arthroplasty; DAA, direct anterior approach; PA, posterior approach

Declarations

Ethics approval and consent to participate: This study was performed in line with the principles of the Declaration of Helsinki. The current study was conducted after authorization by the Institutional Ethics Review Board (approval number 834).

Consent for publication: The written informed consent for publication was obtained in all the patients in the consent form from their own institution

Availability of data and materials: The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests

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Authors' contributions

H. Watanabe: study concept and design, data collection, data analysis, performing operations, writing the paper.

T. Uematsu: study concept and design

Y. Tabata: study concept and design

Y. Mizuno: data analysis and data collection

Y. Akashi: editing the paper and data analysis

G. Gondo: editing the paper and data analysis

Y. Yasushi: study concept and design

T. Majima: study concept and design

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Tables

Table 1. Patient demographics of the study

	DSA with navigation	Conventional PA	*P*
Number of patients	30	30	-
Gender (male, female)	5, 25	4, 26	0.9
Age (yrs old)	68.7 ± 8.8	66.2 ± 9.4	.400
Height (cm)	154.6 ± 6.9	152.0 ± 8.9	.188
Weight (kg)	57.5 ± 10.0	56.6 ± 9.7	.863
BMI (kg/m^2)	24.0 ± 3.7	24.5 ± 3.8	.607
Follow-up (yrs.)	2.0 ± 0.4	3.8 ± 0.7	< .01
Complication			
Intraoperative fracture	1	0	
Sciatic nerve palsy	0	1	
Dislocation	0	0	
Infection	0	0	

Table 2. Cup inclination and anteversion values

Approach	Inclination			Anteversion		
	Mean	SD	Range	Mean	SD	Range
Conventional PA (N=30)	41.8°	6.5°	31° - 56°	22.3°	11.7°	2° - 52°
Navigated DSA (N=30)	42.1°	5.3°	30° - 53°	21.9°	6.9°	6° - 35°
Navigated DSA initial (N=15)	41.5°	6.3°	30° - 53°	18.7°	8.1°	6° - 35°
Navigated DSA recent (N=15)	42.6°	4.5°	35° - 53°	24.9°	4.1°	18° - 30°

Figures

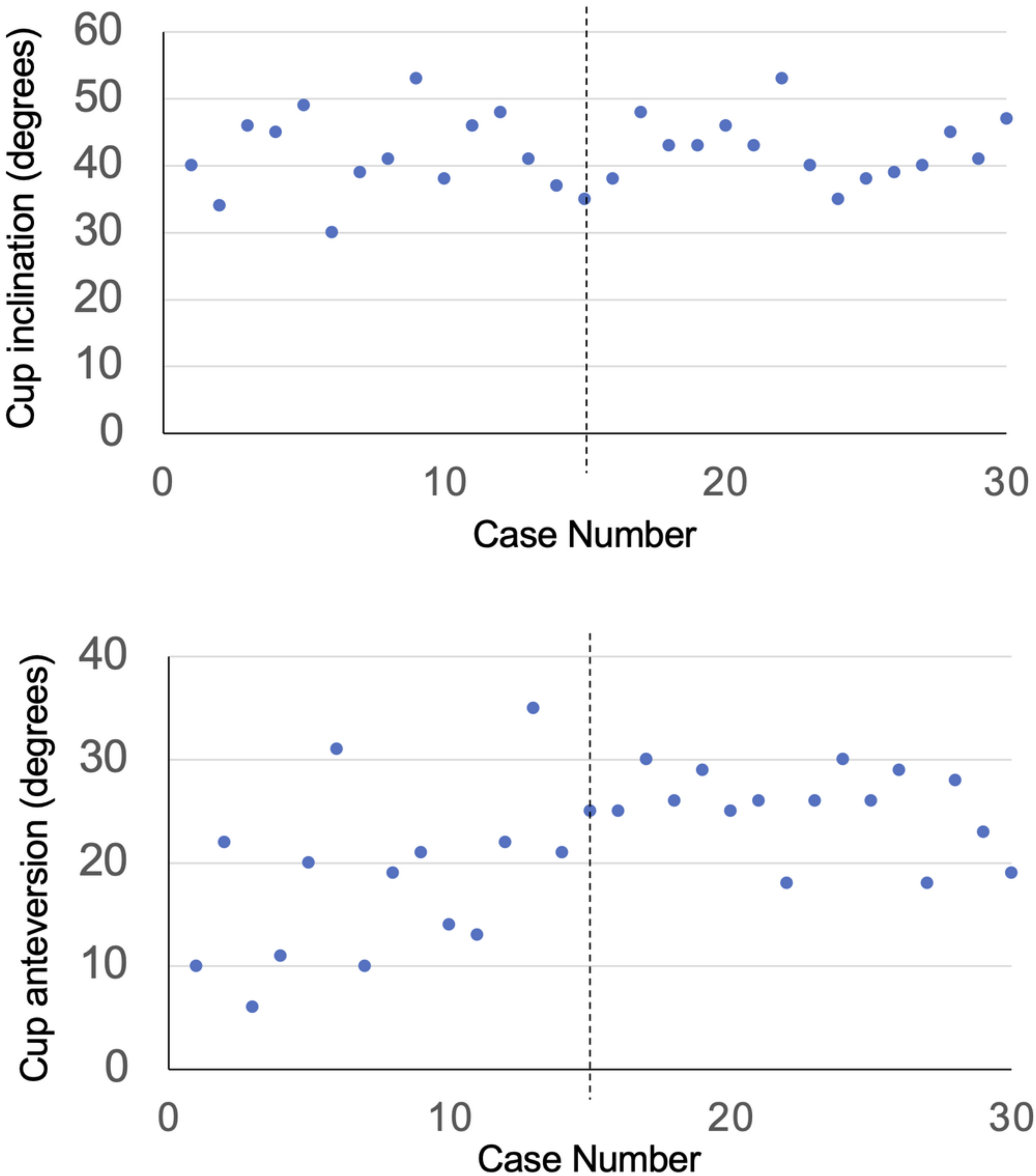

Figure 1

Scatterplot depicting case number and radiographic inclination (a) and anteversion (b) of the cup positions (degrees). The vertical dashed line indicates the transition from the initial 15 cases to the recent 15 cases.

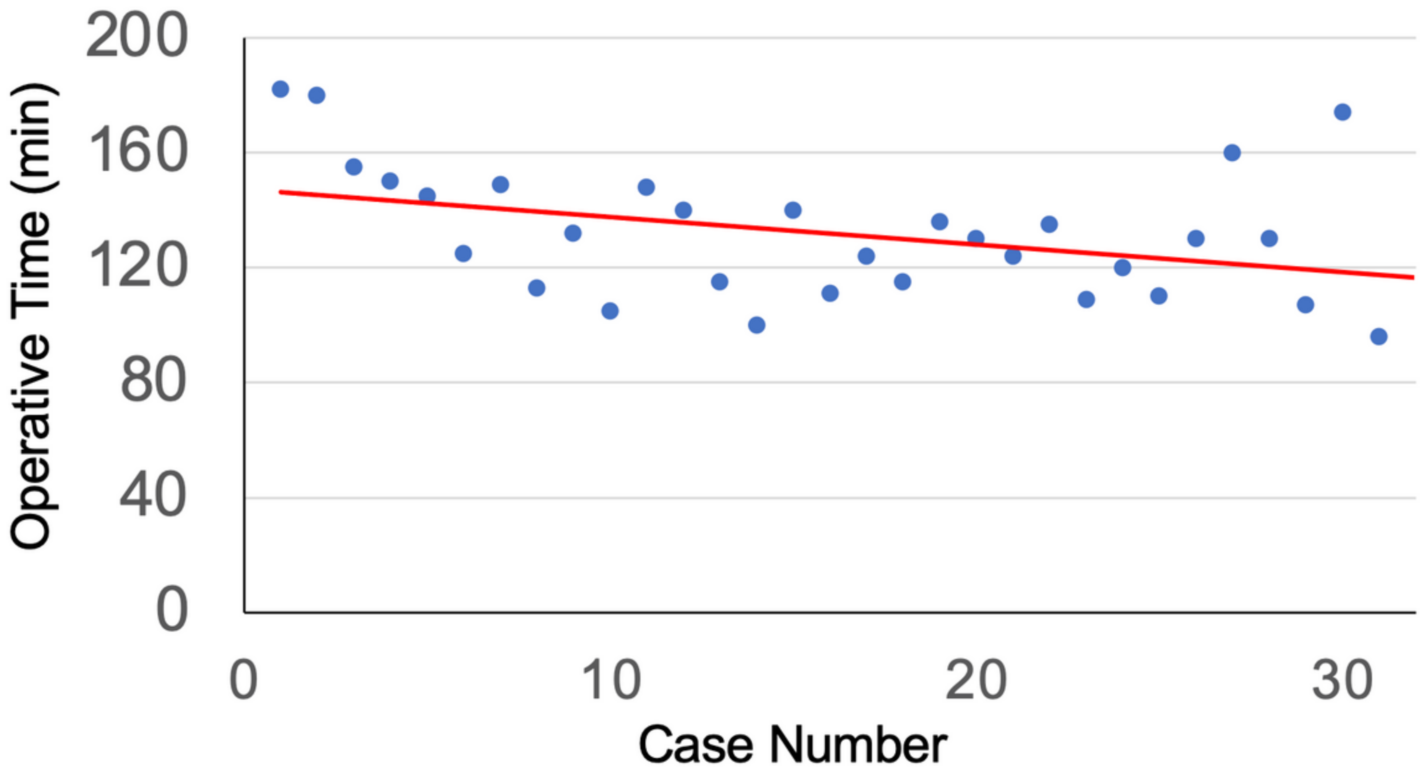

Figure 2

Correlation between case number and operative time in DSA using navigation systems. The panel includes a linear regression line (Spearman's correlation coefficient: R = -0.51, p = 0.004).