Original Article

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# Medial Open Reduction via Anteromedial Approach in Developmental Hip Dysplasia: Long-term Clinical and Radiological Outcomes

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## Abstract

**Aim:** The anteromedial approach in medial open reduction techniques is rarely used to treat developmental dysplasia of the hip (DDH). The objective of this study was to present the clinical and radiological outcomes of DDH patients treated with the anteromedial approach.

**Methods:** Fifty-nine hips of 52 patients aged between 6 and 18 months who underwent medial open reduction between 2009 and 2017 through an anteromedial approach and who had at least 5 years of follow-up were retrospectively evaluated. Results were reviewed in terms of avascular necrosis (AVN) rates and the need for further surgery.

**Results:** At the last follow-up, the rate of clinically significant AVN was 11.9%. Additional corrective surgery was performed on 20.3% of the patients. According to the modified McKay classification, 91.5% of the patients had excellent results. Radiologically, 93.2% of the patients were classified as Severin type 1. The mean age at operation time and initial Tönnis type of patients were significantly higher in patients who required advanced corrective surgery than in those who did not (p=0.042 and p=0.018, respectively).

**Conclusion:** The anteromedial approach is safe and practical for improving radiological outcomes and reducing the need for further surgery. Long-term studies focusing on the period after bone formation are required.

**Keywords:** Anteromedial approach, avascular necrosis, developmental dysplasia of the hip, medial open reduction, further surgery

## Introduction

The primary goal of developmental dysplasia of the hip (DDH) treatment is to enable healthy joint development to provide a functionally congruent hip joint (1). Further goals of treatment are to prevent avascular necrosis (AVN) of the femoral head and to avoid the need for further corrective surgery (FCS) (1). In the first 6 months of infancy, closed reduction of the hip using an abduction othosis such as the Pavlik harness is considered to be the primary treatment modality (2). When nonsurgical treatment fails to achieve sustained reduction, the surgeon may proceed with open reduction. In this age group, soft tissue procedures are preferred for the surgical treatment of DDH. The surgical approach for reduction, however, is contentious (3). Anterior and medial approaches have been defined, with some advantages and disadvantages compared with each other. Smaller incision, shorter operation time, less soft tissue dissection, less blood loss, and direct visualization of anatomic structures such as the contracted inferior joint capsule, transverse acetabular ligament, and thickened and elongated ligamentum teres are the major advantages of the medial approach; however,there is an ongoing debate on the relatively longer learning curve and a higher rate of AVN of the femoral head (4).

The anterior approach is generally reserved for older children after the walking age and has the advantage of capsular plication when an elongated capsule leads to joint instability after reduction of the femoral head. In addition, acetabular procedures may be enclosed with an open reduction procedure through the same approach (5). Avascular necrosis is a well-known complication of both anterior and medial approaches (6).

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Ludloff was the first to describe the medial approach for open reduction of the hip joint (7). Ferguson refined this method by crossing the space posterior to the adductor longus (8). Weinstein and Ponseti modified the anteromedial method (9). The rates of AVN and FCS associated with open reduction of the hip joint vary widely in the literature, with the medial approach being more commonly associated with AVN and FCS (2).

The purpose of this study was to compare the mid-term clinical and radiographic results of the anteromedial Weinstein approach in children with DDH aged between 6 and 18 months.

## Methods

### Compliance with Ethical Standards

This study was conducted retrospectively in accordance with the standards of the University of Health Sciences Turkey, Istanbul Haseki Training and Research Hospital Clinical Research Ethics Committee (date: 11.05.2022, and approval number: 06-2022) and the 1975 Declaration of Helsinki, which was revised in 2013. Between May and October 2022, from the date of ethical committee permission, the study was conducted using a retrospective data collection. Parents who agreed to participate in the study were informed that the data would only be used in scientific research, and a written informed consent form was signed during the final visit.

### Study Design

A total of 89 consecutive patients who underwent medial open reduction for DDH from 2009 to 2017 were retrospectively reviewed. The inclusion criteria for this study were patients who had Weinstein anteromedial open reduction for DDH with a minimum follow-up of 5 years. The exclusion criteria for this study were patients with a diagnosis of neuromuscular disease, teratologic hip dislocation, or skeletal dysplasia, and those who had undergone postomedial Ferguson or Ludloff medial open reductions. The remaining 59 hips of 52 children were enrolled in the trial after 37 children were excluded based on the inclusion criteria.

### Surgical Technique

All procedures were performed by a single senior surgeon. Before open reduction, an arthrogram was performed. All patients with insufficient consentic reduction were operated on using the anteromedial approach described by Weinstein (Figure 1) (6). Bilateral dislocations were treated simultaneously.

Following transverse incision and adductor longus release, the iliopsoas tendon and medial joint capsule were identified between the pectineus muscle and the neurovascular bundle, as described by Weinstein (Figure 2). After careful release of the iliopsoas tendon (Figure 3), the medial cicumflex artery (Figure 4) was identified and saved before opening the joint capsule. We believe that the medial circumflex artery and medial joint capsule can be better identified, and thus, a possible insult to the artery, which may facilitate vascular necrosis, may

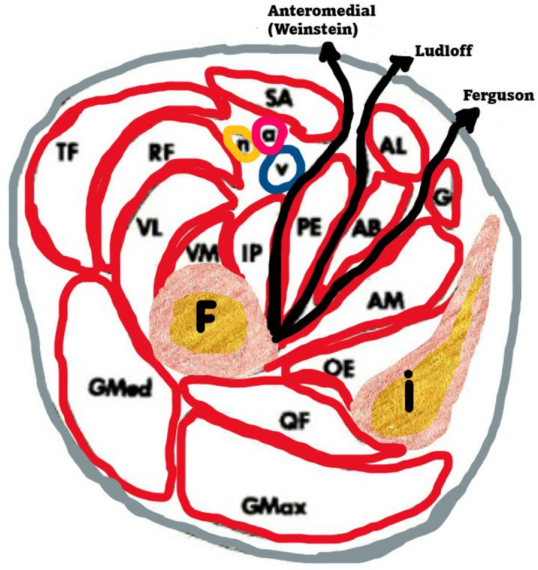


**Figure 1.** The various intervals used for medial open reduction are shown in this illustration

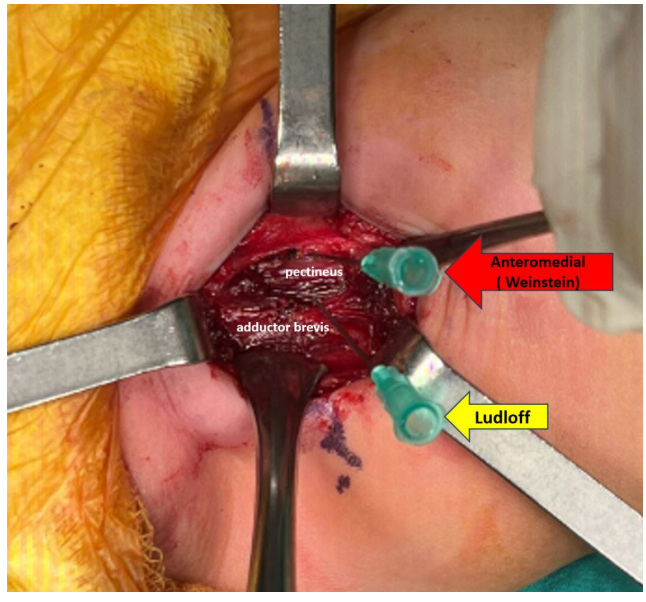


**Figure 2.** Intraoperative imaging of the anteromedial and Ludloff intervals relative to the pectineus and adductor brevis muscles

be better avoided by this approach. After opening the medial capsule, the ligamentum trees and pulvinar were identified and excised, the transverse acetabular ligament was released, and concentric reduction of the femoral head was achieved. The capsule was closed with loose sutures, and a hip spica cast was applied in the human position.


**Figure 3.** The iliopsoas tendon is identified in the intraoperative picture

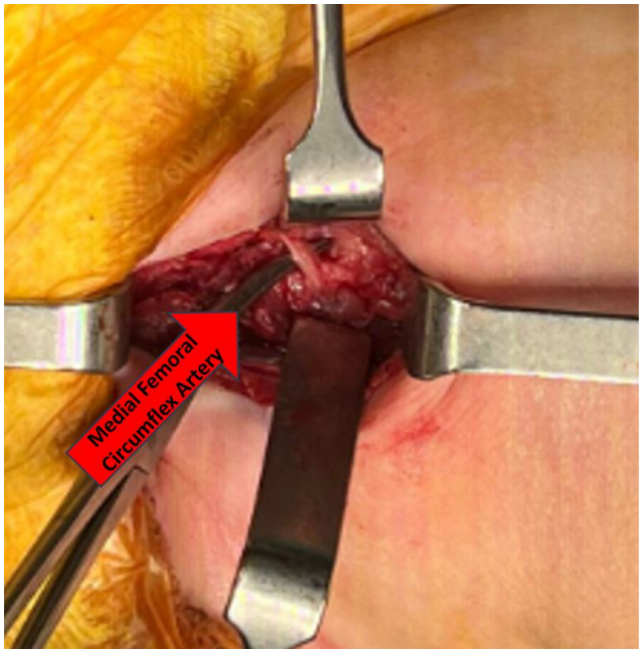


**Figure 4.** Intraoperative image identifies the medial femoral circumflex artery

At the sixth week postoperatively, the spica cast was removed in the operating room, and a new spica cast was applied after gentle manipulation of the hip joints. The total time in the spica cast was 3 months for all patients. If there was any doubt regarding concentric reduction after postoperative pelvic X-rays, a computed tomography scan was used to assess reduction, but it was not performed routinely. Following removal of the spica cast, an abduction brace was administered for an additional 3 months to treat residual acetabular dysplasia.

### Clinical Evaluation

After taking a detailed patient history, a physical examination was performed to assess active symptoms, hip range of motion, pain and limping status, functional status, motion restriction, and gait pattern. Clinical and functional results of the patients were evaluated according to the modified Mckay clinical scoring system. The Iowa hip score questionnaire was filled out by the patient's parents for patients aged ten years or younger; for patients aged 11 to 18, the questionnaire was filled out by the patient.

### Radiological Evaluation

Preoperative radiological evaluation of pelvic radiographs was performed according to the Tönnis classification. The Kalamchi and MacEwen classification was used to assess AVN at one year and at the latest follow-up. The center-edge (CE) angle was measured five years after surgery and at the most recent follow-up to allow Severin classification of the hips. Severin types I and II were considered to represent a good result, and types III, IV, V, and VI were considered to represent a poor result.

Patients who underwent FCS were identified by examination of their surgical records. Patients who required additional open reduction, pelvic osteotomy, and femoral osteotomy were recorded.

### Statistical Analysis

Statistical analysis was performed using SPSS 21.0 for Windows (IBM Corp., Armonk, New York). Descriptive statistics were provided, including the mean, standard deviation, minimum and maximum values for numerical variables, and numbers and percentages for categorical variables. When the normal distribution condition was satisfied, the Student's t-test was used to compare numerical variables between two independent groups. When the condition was not satisfied, the Mann-Whitney U test was used. Two dependent group analyses were analyzed using the paired t-test because the differences in numerical variables provided the normal distribution condition. The relationships between numerical variables

were analyzed by Pearson correlation analysis when the parametric test condition was met and by Spearman correlation analysis when the condition was not met. The rates in the groups were compared using the chi-square test. P≤0.05 were considered statistically significant.

## Results

The patient's baseline characteristics are shown in Table 1. The mean follow-up of the patients was 86.9±30.7 months. The mean age of the patients at the last follow-up was 97.7±31.3 months. In 66% of the patients, there was no initial hip screening with ultrasonography. The average age at the time of surgery was 10.4 months.

A total of 17 children (32%) had previously failed conservative treatment that included a Pavlik harness in eleven cases, a double diaper in two cases, and a closed reduction in four cases; 35 children had no previous treatment.

Preoperative radiological evaluation findings are demonstrated in Table 2. Prior to surgery, the mean AI of the affected hip was 37.4°±6.7° (19-50°) and remained significantly higher than that of the unaffected side five years later (p<0.001). At the final follow-up, the mean CE angle was 27.1°±7°, significantly lower on the affected side (p<0.05), and within normal ranges.

Final follow-up clinical and radiological evaluation findings are presented in Table 3. The overall final follow-up revealed excellent or good results in 57 hips (96.6%), of which Severin type I was found in 55 hips (93.2%) and type II in 2 hips (3.4%). A total of two hips (3.4%) were Severin type III, which had a poor outcome; no type IV, type V, or type VI hips existed.

Clinically significant (Type 2 and above) AVN rates were determined to be Type 2 in 5 (8.5%) hips, Type 3 in 1 (1.7%) hip, and Type 4 in 1 (1.7%) hip. According to the Kalamchi and MacEwen classification, the clinically significant AVN rate in this study was 11.9%.

**Table 1. Baseline characteristics of patients in the study**

| Characteristic | Total n=52 (hips, n=59) |
|---|---|
| Female gender, n (%) | 41 (79) |
| Side, n (%) | |
| Left | 28 (54) |
| Right | 17 (32) |
| Bilateral | 7 (14) |
| Mean age at surgery, months (SD) | 10.4±4.2 |
| Mean age at final follow-up, maths (SD) | 97.7±31.3 |
| Mean follow-up time, ms (SD) | 86.9±30.7 |

SD: Standard deviation

**Table 2. Preoperative radiological evaluation findings**

| Characteristic | Hips, n |
|---|---|
| Tonnis classification | |
| Grade II | 1 |
| Grade III | 32 |
| Grade IV | 26 |
| Mean AI degree (°) (range) | |
| Affected hip | 37° (19 to 50) |
| Contralateral stable hip | 25° (13 to 40) |

AI: Acetabular index

**Table 3. Latest follow-up clinical and radiological evaluation findings**

| Characteristic | | | |
|---|---|---|---|
| AI at the final follow-up* degree (°) | | 19.4±6.7 (6,7-40) | |
| Final CEA** degree (°) | | 27.1±7.0 (2-42) | |
| Modified Mc-Kay Criteria; n (%) | Excellent<br>Good<br>Fair<br>Poor | 54 (91)<br>4 (6)<br>1 (2)<br>0 | |
| Severin's Radiographic Classification Class; n (%) | I<br>II<br>III<br>IV | 55 (93)<br>2 (3.5)<br>2 (3.5)<br>0 | |
| Presence of AVN n (%) | Yes<br>No | 7 (12)<br>52 (88) | |
| Kalamchi and MacEwen Criteria**** Type I-IV; n (%) | II<br>III<br>IV | 5 (8)<br>1 (2)<br>1 (2) | |
| Further corrective surgery n (%) | Yes<br>No | 12 (20)<br>47 (80) | |
| Type of revision surgery n (%) | Salter osteotomy<br>Femoral osteotomy | 11(18)<br>1 (2) | |

*AI acetabular index, **CEA center-edge angle, ***The presence of clinically significant AVN based on the Kalamchi and MacEwen criteria, ****Severity of AVN according to Kalamchi and MacEwen criteria

At the final follow-up, patients clinical status was assessed using the McKay functional classification system. Fifty (91.5%) hips were classified as Type 1 (excellent), four (7%) hips were classified as Type 2 (good), and one (1.7%) hip was classified as Type 3 (poor) (moderate).

Further corrective surgery was administered to 12 (20%) hips. Figure 5 shows normal anatomical development of the hip after MAR, and Figure 6 includes examples of patients who underwent Salter osteotomies for residual dysplasia after MAR. Salter osteotomies were performed in 11 hips, and femoral valgization and derotation osteotomies were performed in one patient (Figure 7).

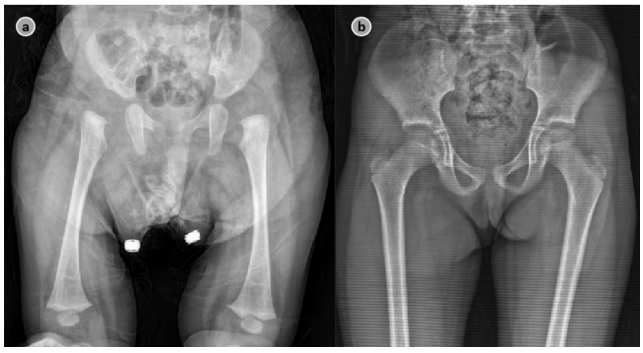


**Figure 5.** Radiographic views of bilateral hips undergoing MOR. AP radiographs of a 10-month-old female with bilateral DDH before and 9 years following anteromedial open reduction
*DDH: Developmental dysplasia of the hip, AP: Anterior posterior*


**Figure 6.** Radiographic views of a hip undergoing MOR and Salter osteotomy. Anteroposterior radiographs of a 14-month-old male with left DDH before (a), 2 years after MOR with left residual dysplasia of the hip (b), 3 years after MOR undergoing Salter osteotomy (c), 11 years following MOR (d)
*DDH: Developmental dysplasia of the hipç*

At the last follow-up, CE angle was found to be negatively correlated with age at the time and stage of preoperative Tönnis classification (p=0.015 and p=0.033, respectively) (Table 4). The preoperative Tönnis Type 4 ratio of hips requiring FCS was significantly higher (p=0.018) (Table 5).

In this study, wound complications related to casting occurred in two patients. Debridement and recasting were performed on these patients. All patients were discharged on the second day after surgery.

## Discussion

During early childhood, open reduction of DDH via the medial approach is an effective surgical treatment method. Two main medial intervention methods are currently being applied: Ludloff's method (anteromedial) and Ferguson's method (posteromedical) (10). Ludloff described an interval between the pectineus and adductor brevis called the anteromedial approach.

Weinstein and Ponseti reported a method similar to that described by Ludloff. They used the interval via the pectineus and femoral vessel nerve bundles to reach the capsule. To protect the medial circumflex artery, which crosses the operative field, the femoral vessel nerve pack


**Figure 7.** Radiographic views of a hip that developed AVN after MOR and is undergoing valgization osteotomy. Anteroposterior radiographs of a 7-month-old female with left DDH (a), AVN development in the left hip in the first year postoperatively (b), 2 years following MOR (c), and 4 years after MOR, valgisation osteotomy was performed (d)
*AVN: Avascular necrosis, DDH: Developmental dysplasia of the hip*

| Table 4. Relationship between age at the time of surgery and preoperative hip stage in patients final AI and final CEAs | | | | |
|---|---|---|---|---|
| | Mean age at surgery, months (SD) | | Preoperative Tönnis Hip Classification | |
| | r | p | r | p |
| Final AI | 0.123 | 0.366 | 0.091 | 0.505 |
| Final CEA | -0.322 | 0.015 | -0.286 | 0.033 |
| AI: Acetabular index, CEA: Center-edge angle, SD: Standard deviation | | | | |

| Table 5. Association between age at the time of surgery and preoperative hip stage in patients requiring FCS | | | | |
|---|---|---|---|---|
| | | Mean age at surgery, months (SD) | Preoperative Tönnis Hip Classification | |
| | | | Grade 3 | Grade 4 |
| | | Mean ± SD | n (%) | n (%) |
| FCS | No | 10.2±4.1 | 29 (63.0) | 17 (37.0) |
| | Yes | 12.7±4.5 | 3 (25.0) | 9 (75.0) |
| | p | 0.067 | 0.059 | 0.018 |
| FCS: Further corrective surgery, SD: Standard deviation | | | | |

must be gently identified and laterally retracted with an elevator. The medial circumflex artery provides the major blood supply to the femoral head, and any insult during the intervention may lead to AVN.

The literature reports an upper age limit of 18 months for open reduction with the medial approach. Ferguson increased this limit to 24 months (8). Weinstein stated that it can be used until the age of 3 years, while Herring set the upper age limit at 12 months (9,10). There have been studies published in Turkey in which the authors claim that it can be used safely for up to 24 months (11). In this study, we found a statistically significant increase in poor results due to residual dysplasia as the patients got older at the time of surgery. We also found a statistically significant decrease in the CE angle with increasing patient age at the last follow-up. Similar articles have found that a greater age at the time of reduction has a significant adverse effect on radiological outcomes (6). Okano et al. (12) also demonstrated the importance of a younger age for medial open reduction in their research.

Avascular necrosis and residual dysplasia are two important complications for treating DDH. Damage to the medial circumflex artery, in particular, may result in AVN, one of the most feared complications during treatment. Dysplasia of the hip appears to be the leading cause of adult hip arthroplasty. Clinically significant AVN rates of up to 67% have been reported in studies, with an intensity of 10-30% in medial open reduction (4). In a recent meta-analysis, the rates of AVN in open reduction alone in patients younger than three years of age were 94.4%; however, this meta-analysis included transient AVN results as well as permanent AVN findings (13). Transient AVN findings in the early stages of DDH may regress over time. There have been studies that show the need for advanced corrective surgery after MOR ranges from 23 to 54%, but the reported rates are variable. Medial approaches are preferred because they provide direct access to structures, resulting in less blood loss, no damage to the iliac apophysis and abductor muscles, and better cosmetic results.

Among the medial approaches, the Ludloff and Ferguson approaches are frequently preferred, according to the literature. In different studies, it is stated that successful results were obtained with various modifications of limited postermedical and medial approaches (11,14).

We prefer the anteromedial Weinstein approach in our practice, which is less popular than the other medial approaches. We believe that this approach allows for more direct access to the hip joint and allows us to identify and protect the medial femoral circumflex artery more easily compared with the Ludloff and Ferguson approaches. According to our hypothesis, lower AVN rates are expected.

In this study, we found a clinically significant AVN rate of 12%, and the rate of further advanced corrective surgery was 20%. Cummings et al. (15) found a 1/3 requirement for corrective surgery in patients following open reduction in a recent study. It was discovered that the rate of postoperative AVN increased with the stage of hip dislocation. Similarly, we discovered that the rate of AVN increased with the stage of preoperative tennis hip dislocation in our study.

Koizumi et al. (16), in their study of 35 hips in 1996, reported a 42% incidence of AVN. Further corrective surgery rates were %46. They had 19.4 years of follow-up. In 1997, Morcuende et al. (17) revealed a 41% AVN rate in their series of 93 hips who had anteromedial open reduction, a mean follow-up of 11 years, and a FCS rate of 17%. Okano et al. (18), in their series of 45 hips with 16.4 years of follow-up in 2009, reported 29% AVN, and Yamada in 2013, reported 28% AVN and 64% FCS in their series of 115 hips with 20.3 years of follow-up.

Pollet et al. (6) reported 19% AVN and 22% FCS in their series of 58 hips with 12.7 years of follow-up. Ozkut et al. (19) performed postermedial limited surgery on 62 hips in 47 patients and found the clinically significant AVN rate to be 1% and the need for corrective surgery to be 3.2%.

Erturk et al. (20) published the results of 35 hips from 24 patients operated on using the Weinstein approach, which is similar to our study. The author reported a 14.2% need for advanced hip surgery and a 17.1% incidence of AVN (20).

### Study Limitations

The most important limitation of studies on DDH is that most are retrospective. Kiani et al. (21) found an AVN rate of 44% and residual dysplasia of 55% in short-term follow-up in a large and prospective study. These results are higher than those of other studies. Transient AVN and residual dysplasia can be seen at a high rate in the early period of DDH treatment, but the development of the hip continues, and more moderate results can be obtained in long-term follow-ups.

The major limitations of this study are that it is a retrospective study and some patients have not yet reached skeletal maturity at the final evaluation. It should be considered that the development of the acetabulum will continue until it reaches skeletal maturity, and the results may vary after skeletal maturation. A relatively smaller study group and shorter mean follow-up compared with the literature are other limitations. The fact that all patients are operated on by a single surgeon with experience in pediatric orthopedics is advantageous in terms of consistency in results. This study is one of the few in the literature that examines the outcomes of Weinstein's anteromedial open reduction in DDH, despite its limitations.

## Conclusion

In this study, one in every five children required additional corrective surgery, and one in every eight children developed clinically significant AVN. Medial open reduction via the anteromedial approach yields excellent clinical and radiological outcomes for treating DDH. Anteromedial open reduction for conservatively irreducible hips in young children is a safe and feasible intervention to achieve better radiological results and reduce the need for additional corrective surgery. To achieve better results without AVN and the need for FSC, medical open reduction should be performed early in the appropriate indication and age group. Long-term studies focusing on the period after bone formation are required.

### Ethics

**Ethics Committee Approval:** Ethical approval was obtained from the University of Health Sciences Turkey, Istanbul Haseki Training and Research Hospital Clinical Research Ethics Committee (date: 11.05.2022, and approval number: 06-2022).

**Informed Consent:** Written informed consent form was signed during the final visit.

**Peer-review:** Externally and internally peer-reviewed.

### Authorship Contributions

Surgical and Medical Practices: I.S., Concept: E.G., Design: E.G., I.S., Data Collection or Processing: E.G., Analysis or Interpretation: E.G., I.S., Literature Search: E.G., I.S., Writing: E.G., I.S.

**Conflict of Interest:** The authors have no conflicts of interest to declare.

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