

# Surgical Treatment of Displaced Mid-Shaft Clavicular Fractures with Precontoured Anatomical Locked Plates

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## ABSTRACT

**Background:** On the basis of clavicular fracture locations, they have classified as middle, lateral, and medial third fractures. Middle thirds account for approximately 80% of clavicle fractures, making them the most common region in terms of incidence.

**Objective:** This investigation was designed to evaluate the outcomes of open reduction and internal fixation for displaced fractures of the mid-shaft of the clavicle, with the assistance of a precontoured anatomical locked plate.

**Patients and Methods:** This investigation was conducted in the Orthopedic Department of Menofia University Hospital and New Cairo Hospital on thirty patients. The investigation was conducted with the informed consent of all patients. The t-test was employed to ascertain the significance of the data, with a p-value of less than 0.001.

**Results:** The patients in the study had a mean time of union of  $10.0 \pm 1.33$  weeks, with a range of 8-12 weeks. One case was an exception, as it presented with an infected non-union. In summary, the age was statistically significantly correlated with the final score. Excellent results had a mean age of  $53.33 \pm 4.16$  years, while exceptional results had a mean age of  $33.63 \pm 11.74$  years. **Conclusion:** In certain patients, a precontoured clavicular fixed plate is an effective treatment procedure for the internal fixation and open reduction of displaced fractures in the middle third of the clavicle. The procedure has exceptional overall results and a low rate of complications, despite its low morbidity rate.

**Keywords:** Clavicle, Fracture, Reduction, Fixation, Precontoured, Locked plate.

## INTRODUCTION

Clavicle fractures may manifest at any point along the clavicle. Nevertheless, the significant majority (69-82%) of the occurrences occur in the midshaft, at or near the intersection of the middle and outer third. The reason for this is twofold: firstly, it is the bone's narrowest section, and secondly, it is the sole bone segment that lacks reinforcement from the attached musculature and ligaments<sup>(1)</sup>.

Clavicle fractures are common among those who have fallen onto an extended arm or the point of the shoulder. They manifest in a disproportionate number of very young and very old patients. Historically, a splint or figure-of-8 bandage has been the go-to for treating clavicle fractures that occur in the middle of the shaft. Excellent outcomes have been achieved in most cases, with few complications, little functional impairment and low rates of non-union<sup>(1)</sup>.

Two of the most common surgical procedures for treating displaced midshaft clavicular fractures are open reduction and internal fixation by plate or intramedullary fixation<sup>(2)</sup>. Infection, implant loosening, nonunion, and refracture following implant removal are among the most common complications of plate fixation<sup>(3)</sup>. An anatomically precontoured clavicle plate is a plating system that aids in the restoration of the patient's original structure during surgery, requiring minimal or no plate deformation by the surgeon. Avoiding the necessity of bending a precontoured clavicle plate conserves valuable operating room time<sup>(4)</sup>. The necessity for hardware removal may be diminished by the recent introduction of anatomically contoured clavicle plates<sup>(5)</sup>.

This investigation was designed to evaluate the outcomes of open reduction and internal fixation for displaced fractures of the mid-shaft of the clavicle, with

the assistance of a precontoured anatomical locked plate.

## PATIENTS AND METHODS

This investigation was conducted in the Orthopedic Department of Menofia University Hospital and New Cairo Hospital on thirty patients. In the following fashion, all data pertaining to the patient under investigation were collected:

## METHODS

**Methods of examination:** The data was collected in accordance with the following spreadsheet:

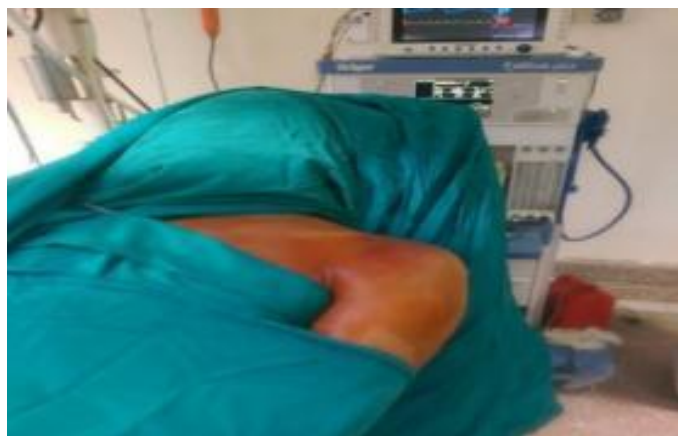
- A) **History:** Personal information: Name, age, sex, occupation, and the time passed prior to hospital presentation. History of the present symptoms: Injury mechanism and the presence of swelling and discomfort.
- B) **Clinical examination:** Associated vascular or neurological injuries, tenderness, skin condition overlying the fracture, tenting of skin overlying the fracture, dominant or non-dominant side, and other associated injuries.
- C) **Radiological evaluation:** In order to evaluate the fracture type in accordance with the Robinson classification<sup>(6)</sup>, an anteroposterior radiograph of the clavicle was obtained for each patient.

**Inclusion criteria:** Any patient who is 16 years of age or older and under 65 years of age, as well as those who have completed a minimum of six months of postoperative follow-up. Recommended surgical procedure for patients: The following conditions are frequently linked to significant displacement: distal clavicle type 2 fractures, complete displacement of the fracture, 2 cm of shortening, comminuted fractures with

a displaced transverse "zed" (or z-shaped) fragment, neurovascular compromise, and polytrauma (with multiple fractures). This results in skin tenting and an increased risk of puncture. In order to expedite rehabilitation, it may be necessary to address open fractures and an inability to tolerate confined treatment.

**Methods of treatment:** All patients were treated through open reduction and internal fixation, utilising a precontoured stainless steel locking plate.

**Anaesthesia and positioning:** The patient was placed under general anaesthesia during the surgical procedure. In order to induce anaesthesia, 1.5 g of cefuroxime was administered intravenously 30 to 60 minutes beforehand. The patient was positioned in a semi-elevated (beach-chair) position, with the afflicted upper extremity curved to the side and a square draped over it. A thin pad was positioned beneath the shoulder blade (Figure 1).



**Figure (1):** Position of the patient.

**Procedure:** After reduction, the left or right clavicle plate of the appropriate size was chosen. Two to three locking and/or non-locking apertures should be present both proximal and distal to the fracture fragments, as the fracture may be concealed by the two middle spaces. While it is feasible to achieve the most advantageous position by sliding the plate medially or laterally. Following the selection of the optimal position for the plate, bone anchors were employed to provisionally secure it to the clavicle. The fasteners that are not locked can be positioned in either a unicortical or bicortical configuration. Preventing over-penetration of the distal cortex is essential when using bicortical screws, as this could lead to neurovascular injury. The neurovascular structures should be protected from over-penetration of the drill bit by positioning a curved retractor or other protective device beneath the inferior surface of the clavicle. To ensure early stability, the first two fasteners should be placed medially and laterally adjacent to the fracture site. To determine the depth, use the offset drill guide in conjunction with the drill pit size that is suitable. Next, use the assembled driver to insert the screws into the channels. It is possible to remove the bone attachments that hold the plate to the clavicle after the two screws have been implanted. Using the locking drill guide, insert the 3.5 mm locking screws into the

threaded holes. If possible, insert at least three screws on each side of the fissure (Figure 2).



**Figure (2):** Precontoured locking plate applied to the fracture.

**Closure:** The field was liberally irrigated with standard saline after all fasteners were inserted and the construct's stability was guaranteed. Subsequently, a standard closure was implemented in layers, employing no.. One absorbable suture for the myofascia, one absorbable suture for the subcutaneous tissue (no. 2-0), and clips or subcuticular stitching for the epidermis is recommended.

**Methods of follow-up:** Cefuroxime 1.5 g was administered every 8 hours for 24 hours to the patient, who was placed in an arm splint. In certain carefully selected patients at risk, the duration of antibiotic therapy was extended to 48 hours or 72 hours. Pendulum range of motion exercises were initiated by the patients during the initial postoperative week. Initially, passive motion exercises were implemented for four weeks, and active assisted exercises were introduced for the subsequent four to six weeks. Radiographic healing was observed at six weeks postoperatively and active strengthening was subsequently implemented. Radiological follow-up should be continuous for a minimum of six months.

The initial two months should include a follow-up plain X-ray every two weeks, followed by one plain X-ray for each subsequent month. The results were evaluated at the conclusion of this period in accordance with as follows:

#### **Constant and Murley Shoulder Score<sup>(7)</sup> (CMS):**

The CMS system is widely implemented worldwide to determine the appropriate levels of shoulder function for a variety of age groups and to establish the definition of disability in healthy individuals. It has also been implemented to ascertain discrepancies in the rate of recovery following injury or treatment. The functional shoulder assessment instrument, the CMS, is scored on a scale of 100 points, with higher scores suggesting enhanced function. The four distinct components are subjective pain (15 points), Activity of Daily Living (ADL) (20 points), range of motion (40 points) as

determined by an objective clinical assessment, strength (25 points), and overall composite score.

**Pain:** For the first subjective parameter, we measure the worst pain we've ever had while going about our regular daily lives.

**Activity of daily living:** Other subjective parameters that are assessed include the individual's ability to participate in daily activities related to employment, recreation, and sleep.

**Range of motion:** Provides a neutral assessment of the patient's asymptomatic active mobility in the following planes: pure forward and lateral elevation, composite functional external and internal rotation.

**Strength:** Resistance against abduction is the basis for scoring, with a maximum of 25 points.

**Ethical approval:**

The Faculty of Medicine of Menoufia University's Local Ethics Committee gave its approval to the study. The investigation was conducted with the informed consent of all patients. We certify that none of the methods used in this study went outside the guidelines outlined in the most recent iteration of the Declaration of Helsinki.

**Statistical analysis:**

The gathered data were computerized and statistically analyzed using IBM SPSS software package Version 22.0. Mean ± SD, range, and median were used to express quantitative data, which were compared using independent t-test. Numbers and percentages were used to describe the qualitative data, which were compared using Pearson Chi-square (X<sup>2</sup>) test or Fisher's exact test. A significance level of P = 0.05 was used to evaluate the results.

**RESULTS**

According to the Constant and Murley Shoulder Score, the average score at the end of the six-month follow-up was 94.30 ± 12.81, ranging from 46 to 100. Out of the total number of patients, twenty-four (80%) had excellent outcomes, five (16.67%) had good outcomes, and one (3.33%) had bad outcomes (Table 1).

**Table (1): Distribution of the studied patients regarding the final score according to Constant and Murley Shoulder Score**

Final score	No.	%
Excellent (91 – 100)	24	80.0
Good (81 - 90)	5	16.67
Fair (71 – 80)	0	0.0
Adequate (61 - 70)	0	0.0
Poor (< 60)	1	3.33
<b>Total</b>	<b>30</b>	<b>100.0</b>
Min. – Max.	46.0 – 100.0	
Mean ± SD.	94.30 ± 12.81	
Median	100.0	

At the conclusion of the follow-up period, the mean final Constant and Murley Shoulder Score for pain, ranged from 5 to 15, was 14.0 ± 2.62 (Table 2).

**Table (2): Distribution of the studied patients regarding pain**

Pain	No.	%
None	24	80.0
Mild	5	16.67
Moderate	1	3.33
<b>Total</b>	<b>30</b>	<b>100.0</b>
Min. – Max.	5.0 – 15.0	
Mean ± SD.	14.0 ± 2.62	
Median	15.0	

The mean final Constant and Murley Shoulder Score for activity of daily living was 18.80 ± 3.38, with a range of 6 to 20, following the follow-up period (Table 3).

**Table (3): Distribution of the studied patients regarding activity of daily living**

Activity of daily living	No.	%
<b>Activity level:</b>		
Full work	28	93.33
Full recreation/sport	1	3.33
Unaffected sleep	1	3.33
<b>Total</b>	<b>30</b>	<b>100.0</b>
<b>Positioning</b>		
Up to neck	1	3.33
Above head	29	96.67
<b>Total</b>	<b>30</b>	<b>100.0</b>
Min. – Max.	6.0 – 20.0	
Mean ± SD.	18.80 ± 3.38	
Median	20.0	

The mean final Constant and Murley Shoulder Score for active forward flexion was 9.20 ± 1.20, with a range of 6 to 10, following the follow-up period (Table 4).

**Table (4): Distribution of the studied patients regarding active forward flexion**

Active external rotation	No.	%
61-90°	1	3.33
121-150°	1	3.33
151-180°	28	93.33
<b>Total</b>	<b>30</b>	<b>100.0</b>
Min. – Max.	6.0 – 10.0	
Mean ± SD.	9.20 ± 1.20	
Median	10.0	

On average, the patients in the study had a union duration of 10.0 ± 1.33 weeks, with the exception of one case that had an infected non-union. This time frame lasted between eight and twelve weeks (Table 5).

**Table (5): Distribution of the studied patients regarding the union**

Union (weeks)	No.	%
Non-union	1	3.33
Union	29	96.67
<b>Total</b>	<b>30</b>	<b>100.0</b>
Min. – Max. (n=29)	8.0 – 12.0	
Mean ± SD.	10.0 ± 1.33	
Median	10.0	

The final score was significantly correlated with age, according to statistical analysis. A mean age of  $53.33 \pm 4.16$  years was associated with excellent results, whereas a mean age of  $33.63 \pm 11.74$  years was associated with exceptional results (p-value = 0.001) (Table 6).

**Table (6): Relation between the final score and the age of the patients**

Age (years)	Final score						Test of significance	P
	Excellent (n = 24)		Good (n = 5)		Poor (n = 1)			
	No.	%	No.	%	No.	%		
≤30	12	50.0	0	0.0	1	100.0	X <sup>2</sup>	MC <sub>p</sub> =0.213*
>30	12	50.0	5	100.0	0	0.0		
<b>Total</b>	<b>24</b>	<b>100</b>	<b>5</b>	<b>100</b>	<b>1</b>	<b>100</b>		
Min. – Max.	20.0 – 56.0		50.0 – 58.0				t=3.658*	0.001**
Mean ± SD.	33.63 ± 11.74		53.33 ± 4.16		27.0 <sup>#</sup>			
Median	31.0		52.0					

X<sup>2</sup>: Value for Chi-square test, MC: Monte Carlo, t: Student t-test, \*: Statistically insignificant, \*\*: Statistically significant, #: excluded from the comparison

The final score and the time interval prior to surgery did not exhibit any statistically significant relation (p-value = 0.838) (Table 7).

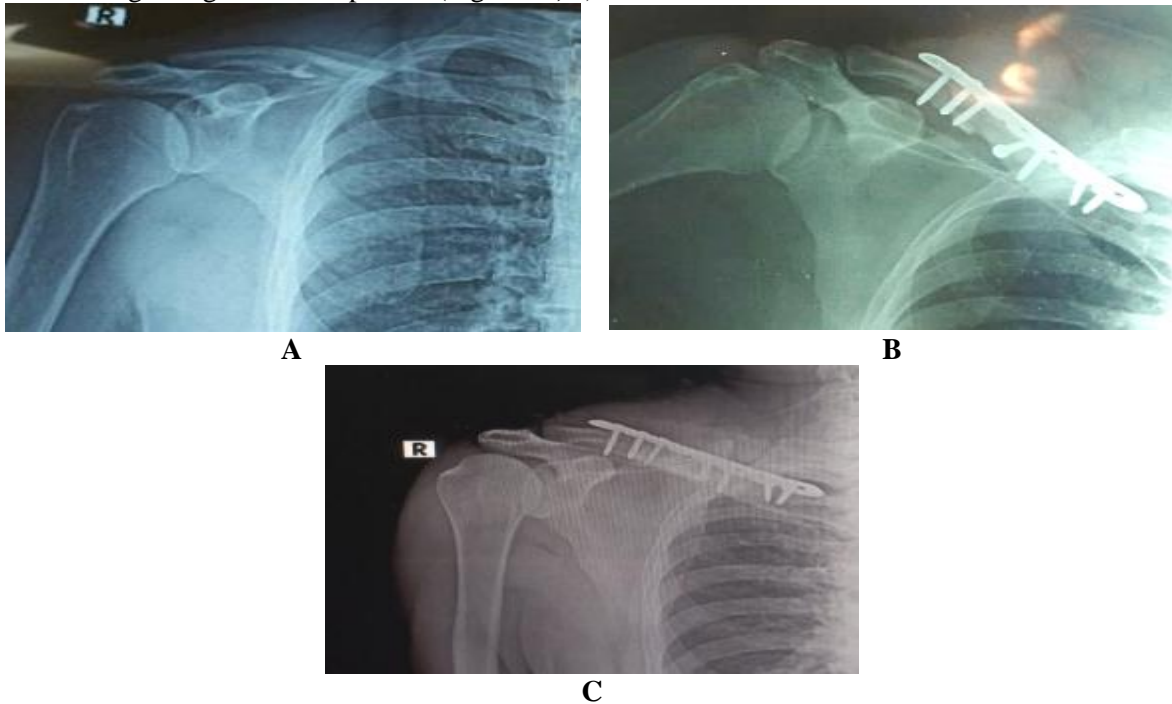
**Table (7): Relation between final score and time lapsed before surgery**

Time lapsed before surgery (days)	Final score			t-test	P
	Excellent (n = 24)	Good (n = 5)	Poor (n = 1)		
Min. – Max.	1.0 – 13.0	1.0 – 12.0		0.205	0.838
Mean ± SD.	4.58 ± 3.61	4.2 ± 4.54	1.0 <sup>#</sup>		
Median	3.5	3.0			
<b>Total</b>	<b>24</b>	<b>5</b>	<b>1</b>		

<sup>#</sup>: Excluded from the comparison

**CASE 1**

A thirty-three-year-old male who was medically independent and serves as a manual labourer, the middle third of his right clavicle (Robinson type 2 B1) was fractured from a direct impact on his right shoulder. Following a single day, a precontoured secured plate was implemented for fixation. All things considered, the total score of 100 included the following: activities of daily living: 20 pain-free exercises, including full-range forward elevation and abduction, external rotation, and internal rotation. By the end of the sixth month, the union had been effectively formed. An "excellent" rating was given to the patient (Figures 3, 4).



**Figure (3): Case. A: preoperative plain X-ray, B: Immediate postoperative, C: plain X-ray after six months shows complete union and the final score was excellent (final score 100).**



**Figure (4): Case. A:** complete active forward elevation. **B:** complete active abduction. **C:** complete external rotation where the hand is fully elevated above the cranium. **D:** The interscapular region was reached by the dorsum of the hand. There was a final tally of 100.

## DISCUSSION

Clavicle fractures are most common in the middle third of the body, accounting for around 80% of all cases. The displaced fracture site is hindered from union by the arm's weight, pectoralis major and minor, latissimus dorsi, trapezius, and scapular motions. Postponed or failed union is the outcome of nonoperative treatment <sup>(8)</sup>.

Precontoured plates may offer potential benefits due to their design characteristics. The natural clavicle's anatomical configuration and a high degree of modularity are initially present, with both right and left clavicle attachments being available. It is possible to treat all types of mid-shaft fractures with the help of surgical techniques. The second perk is that the rounded edges and low profile might make postoperative hardware intolerance less likely <sup>(9)</sup>.

In the first week following surgery, patients were to begin pendulum range of motion exercises while their arms were confined to splints as a part of our study's rehabilitation protocol. The patient was instructed to do passive motion exercises for four weeks after radiographic healing was confirmed, followed by active assisted exercises for four to six weeks, and active strengthening exercises for six weeks after surgery.

According to the Constant and Murley Shoulder Score, the average score at the end of the six-months follow-up was  $94.30 \pm 12.81$ , ranging from 46 to 100. Out of the total number of patients, twenty-four (80%) had excellent outcomes, five (16.67%) had good outcomes, and one (3.33%) had bad outcomes.

Two researches by **Böstman et al.** <sup>(10)</sup> and **VanBeek et al.** <sup>(11)</sup>, among others, are compared to the present literature on the surgical treatment of clavicular mid-shaft fractures using a locking plate. According to **Böstman et al.** <sup>(10)</sup>, traumas to the midline of the clavicle were the only ones studied. A total of 103 patients underwent early open reduction and internal fixation using a plate and fasteners techniques. The most significant complications were nonunion, plate fracturing, refracture after plate removal, and profound infection. Plate loosening was the cause of malunion, the most prevalent of the secondary complications. Three patients (15%) experienced plate prominence, three patients (2.91%) experienced delayed union, and two patients experienced persistent nonunion. In total, 14 reoperations were conducted as a consequence of the complications. The rate of infection was 7.8%. Cumulative complications were observed at a rate of 23%. Patient noncompliance with the postoperative regimen was the primary cause of failures.

According to **VanBeek et al.** <sup>(11)</sup>, we compared the outcomes of 24 patients given precontoured plates versus 14 patients given noncontoured plates. Regardless of the small sample size, the hardware

removal rate was higher with non-contoured plates (21.4%) than with precontoured plates (10.7%). In the postoperative non-contoured group, 9 out of 14 patients (64.3%) and in the precontoured group 9 out of 28 (52.1%) reported plate prominence. One patient had non-union following bone grafting during revision surgery, which was a major setback. The overall complication rate was 64.3% for the non-contoured patients and 39.3% for the precontoured patients.

In our study, the mean final Constant and Murley Shoulder Score for activity of daily living was  $18.80 \pm 3.38$ , with a range of 6 to 20, following the follow-up period. The mean final Constant and Murley Shoulder Score for active forward flexion was  $9.20 \pm 1.20$ , with a range of 6 to 10, following the follow-up period. On average, the patients in the study had a union duration of  $10.0 \pm 1.33$  weeks, with the exception of one case that had an infected non-union. This time frame lasted between eight and twelve weeks.

**Chandrasenan et al.** <sup>(12)</sup> cleared fifteen patients got precontoured plating and fifteen got non-contoured plating for their displaced mid-shaft clavicle fractures. No one in the precontoured group had their hardware removed 18 months after surgery, on average. Two patients in the non-contoured group had broken plates, five had irritation to soft tissues, and two had severe non-union; these six patients had their plates removed for a variety of reasons.

**Houwert et al.** <sup>(13)</sup> in a retrospective analysis conducted on 90 patients who underwent intramedullary nail or plate fixation for displaced midshaft clavicle fractures. The complications were subsequently assessed and contrasted between the two treatment groups. Upon the implant's removal, the plate group experienced four refractures (7%), whereas the EIN group did not. Within two months of the implant's removal, all refractures have transpired. On the other hand, patients who were treated with a plate required implant removal less frequently than those who were treated with an EIN.

Following plating for displaced clavicle fractures, 122 patients were observed by **Poigenfürst et al.** <sup>(14)</sup>, for refractures followed the plate removal. Because of the rigidity of plate fixation, which aids primary bone recovery, the plating group experienced a higher rate of refracture following implant removal. The reduced mechanical strength of the fracture site after healing is the direct cause of the elevated refracture rates.

**Ferran et al.** <sup>(15)</sup> studied seventeen patients with displaced mid-shaft clavicle fractures who underwent Rockwood pin fixation and fifteen patients who underwent non-contoured low contact dynamic compression plate (LCDCP) treatment were compared. After a year of participation, the study found no statistically significant changes in functional outcomes.

They achieved a 100% union rate in all cases treated with either plating or Rockwood Pin without major complications. However, irritation to the soft tissues necessitated the removal of 53% of the plates.

**Tarng *et al.***<sup>(16)</sup> compared 32 patients who were treated with a 3.5 mm reconstruction plate and 25 patients who were treated with EIN. In contrast to fixation with reconstruction plates, the research demonstrated that the use of intramedullary nails can provide adequate stability, effectively mitigate pain, and expedite the functional recovery of the afflicted limb. Both techniques experienced comparable rates of complications. In contrast to the 37.5% in the plate group, the investigation also identified that the removal of the implant was necessary in 16% of cases treated by EIN.

In our study, the final score and the time interval prior to surgery did not exhibit any statistically significant relation. Decent received an average of 4.2 days, while excellent received an average of 4.58 days. The average total number of days received by the poor was one. We obtained a p-value of 0.603.

**Campochiaro *et al.***<sup>(17)</sup> found just 14.3% of the plates needing removal after fracture consolidation, retrospective evaluations of 68 patients treated with precontoured plates demonstrated outstanding functional outcomes.

**Kalamaras *et al.***<sup>(18)</sup> found their patients were immobilised in a sling for six weeks, following which they began a progressive physiotherapy regimen. The mean Constant and Murley Shoulder Score was 96, with a range of 96-100, despite the extended period of immobilisation and the delayed return to normal activities. In contrast to this study, we initiated pendulum exercises immediately in the first postoperative week, as our fixation was secured by locked screws.

## CONCLUSION

In certain patients, a recontoured clavicular fixed plate is an effective treatment procedure for the internal fixation and open reduction of displaced breaks in the middle third of the clavicle. The procedure has a low morbidity rate, exceptional overall results, and a low rate of complications.

**Conflict of interest:** None.

**Competing of interest:** None.

**Financial disclosures:** None.

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