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Original Research Article

A prospective functional outcome study of Volar locking plates versus K-wire fixation of dorsally displaced distal radius fractures

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Abstract

Introduction: Fractures of the distal end radius are the most common fractures of the upper extremity, encountered in practice and constitute 17% of all fractures and 75% of all forearm fractures. The fundamental principle of fracture treatment is to obtain accurate fracture reduction and then use an immobilization method that will maintain and hold that reduction. The most common surgical treatment of closed distal radius fractures is by Kirschner-wires (K-wires) or volar locking plates, with the latter gaining popularity these days. In this study, we compared functional outcomes of K-wires with those of volar locking plates.
Methods: A prospective comparative study of 50 patients with dorsally displaced distal radius fractures treated with K-wiring and volar locking plates (25 cases in each group) was performed. An initial clinical evaluation was done pre-operatively followed by fracture fixation and was further evaluated functionally and radiologically post-operatively. Functional results were analyzed by the modified Demerit point system of Gartland and Werley, anatomical results were analyzed by Sarmiento's modification of Lindstrom criteria, and radiological assessment was done as per criteria given by NANA *et al*.
Results: Radiologically and anatomically volar plate had better results as compared to k-wire, during the initial follow-up of fractures of the distal radius. The volar plate also dominated over k-wires in terms of functional results but at 6 months there was very little difference seen functionally. Both techniques provide great clinical results, without a clear superiority of either fixation method for the surgical management of distal radius fractures.
Conclusion: We conclude that locking plates offer no functional advantage over the older and economical method of Kirschner wire fixation for patients with displaced fractures of the distal radius.

Keywords: Distal radius, fixation, fracture, Kirschner, plate, volar, wrist, K-wire

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1. Introduction

Fractures of the distal end radius are the most common fractures of the upper extremity, encountered in practice and constitute 17% of all fractures and 75% of all forearm fractures [1]. These injuries have a bimodal distribution, affecting young adults through high-energy mechanisms and the elderly through low-energy falls due to osteoporosis.

The distal radius has been conceptualized as a three-column model (Figure 1). Restoration of radial length, radial tilt angle, and congruity of articular surfaces (Figure 2) is important for good functional results [2, 3].

Classifying the distal radius fractures and suggesting the best treatment protocols has been a major task as evidenced by the number of classification systems like Frykman classification [4], Gartland and Werley classification [5], Melone [6], Fernandez classification [7].

The fundamental principle of fracture treatment is to obtain accurate fracture reduction and then use an immobilization method that will maintain and hold that reduction. Several options for treatment are available like closed reduction and casting, Pins and plaster technique, percutaneous pinning, external fixation, Limited open reduction, Open reduction, internal fixation, and intramedullary nailing.

Percutaneous pinning of the fracture fragments and the use of a plaster cast are options for extra-articular fractures of the distal end of the radius that have substantial comminution or fractures with no more than two articular pieces that can be reduced anatomically.

Volar fixed-angle plates are indicated for unstable intra- or extra-articular apex dorsal (Smith) or apex volar (Colles) fractures, as well as volar shear fractures (Barton). Volar plates have been successfully utilized in the fixation of osteopenic distal radius fracture in elderly patients [8]. Pediatric patients with open physis, open fractures with inadequate soft tissue coverage, and distal articular shear fractures (commonly seen in carpal dislocation) where there is insufficient bone distally for screw capture are contraindications to volar plating of the distal radius.

By placing the plate on the volar aspect of the distal radius one can avoid the close contact between the plate and tendons because on the volar side the distance between the flexor tendons and volar cortex is longer and the plate can be completely covered by repairing the pronator quadratus muscle. Complications of the volar plating are injury to the palmar cutaneous branch of the median nerve, postoperative carpal tunnel syndrome, flexor pollicis longus, extensor tendon tenosynovitis, or rupture, complex regional pain syndrome (CRPS), delayed union, and loosening of screws. Placement of the plate distal to the edge of the pronator quadratus muscle (watershed line) increases the risk of flexor pollicis longus tendinitis or rupture [9].

The goal of the current study was to compare the effectiveness of closed reduction and internal fixation with K-wires against open reduction and internal fixation with a volar locking plate in treating distal end radius fractures. A comparison has been made based on functional, anatomical, and radiological parameters.

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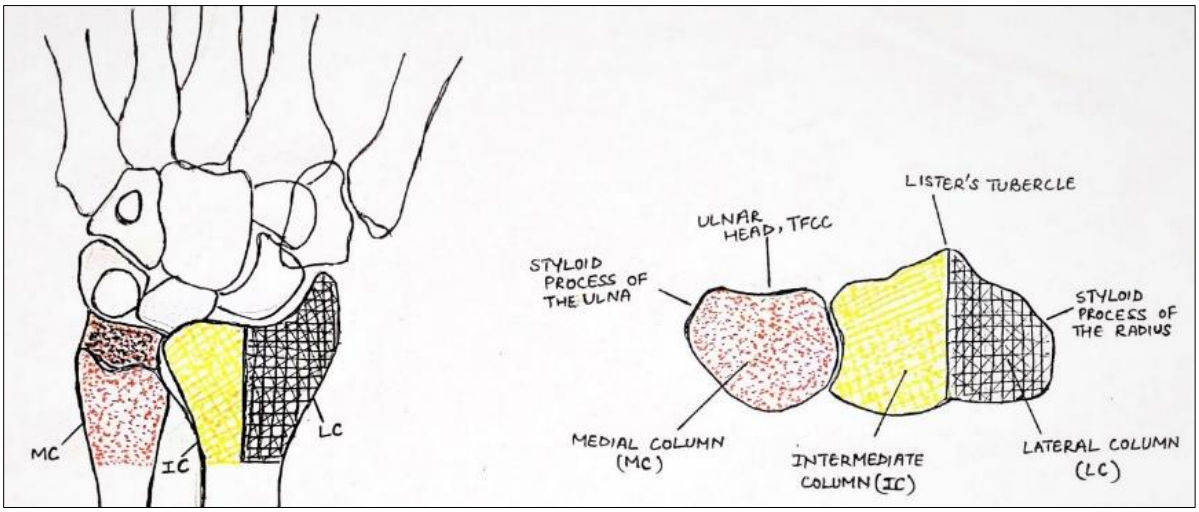

Fig 1: Three columns of the wrist joint

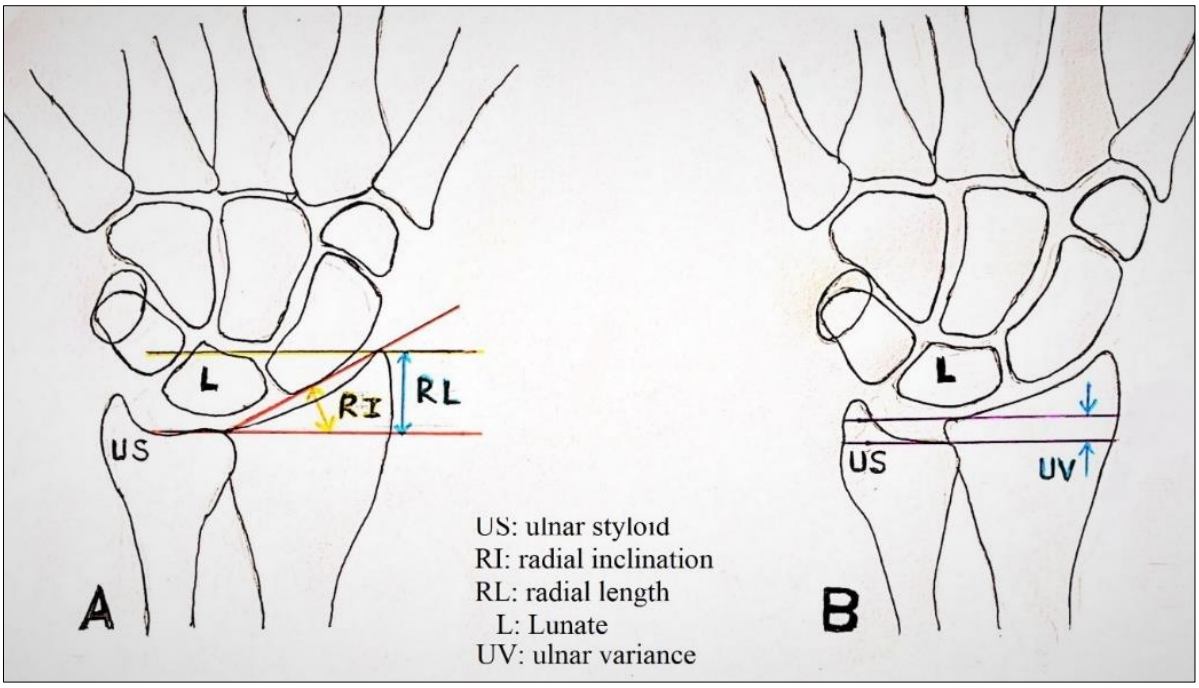

Fig 2: Radiographic parameters distal radius

2. Materials and Methods

The present study was conducted in the Department of Orthopaedics in a Medical college teaching hospital. It was a prospective study in which two groups were made A and B were admitted to the orthopedic department. The odd ones were added to group A and even were added to group B. Group A included 25 patients who underwent percutaneous K-Wire fixation, while Group B included 25 patients who underwent open reduction and volar plating internal fixation. They had an initial clinical evaluation done pre-operatively followed by fracture fixation and were further evaluated functionally and radiologically post-operatively in OPD.

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Inclusión criteria

1. Displaced (≥20 degrees) extra-articular distal radius fractures (with or without an undisplaced intra-articular component) with dorsal cortical comminution as seen on the lateral radiograph.
2. Displaced intra-articular distal radius fractures with an articular step or gap in the radiocarpal joint surface. Configuration is such that the fracture would be amenable to stabilization via a volar locking plate (not un-reconstructable).

Exclusion criteria

1. Proximal metaphyseal fractures (more than 2.5 centimeters from the articular surface).
2. Open fractures.
3. Bilateral wrist fracture.
4. Previous fractures of the distal radius of the same limb.
5. Patients who will unable to consent themselves to treatment.
6. Undisplaced distal radius fracture.

Functional results were analyzed by
- Modified Demerit point system of Gartland and Werley [5].

Anatomical results were analyzed by
- Sarmiento's modification of Lindstrom criteria [10].

Radiological assessment as given by
- NANA *et al*. [11].

Appropriate statistical tests were used to analyze the data with Statistical Package for the Social Sciences (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, New York).

3. Results

The mean age of the patients in group A was 43.80 ± 16.698 years with the youngest patient being 20 years and the eldest being 90 years. The mean age among group B was 44.32±14.381 with age variations from 18 to 65 years (Table 1). Mode of injury among volar locking plate group was Road traffic accident in 18 patients followed by domestic fall in 5 patients and fall from height in 2 patients while in k-wire group 13 cases had a history of the roadside accident, 11 cases had domestic fall and 1 patient had a history of fall from height.
As per Fernandez's classification, it was found that among the volar locking plate group 13 patients were of type 2 which accounts for 52% of the cases, eight of type 3, and four of type 1. Among the k-wire group, 10 are of type 1 followed by type 3 and 1 with 8 and 7 patients respectively.
The study revealed that 37 patients had a radial inclination of more than 15 degrees, in this 20 patients were of the volar locking group and 17 were of the k-wire group. The remaining 13 had angles less than 15 degrees, out of the 13 patients 5 were in the volar locking plate group and 8 were in the k-wire group.
In this study length of the radius was regained in a total of 41 patients out of which 22 belong to the volar plate group and 19 belong to the k-wire group. Only three cases where the length of the radius is less than 5mm were reported in the volar plate group whereas 6 patients of the k-wire group showed radial length short than 5mm.

It was observed that volar tilt was present in a total of 27 patients out of which 17 were of volar plate grows and 10 were of the k-wire group. Neutral tilt was present in 17 patients that including 8 patients with volar plate and 9 of k-wire. None of the patients of the volar plate had dorsal tilt whereas 6 patients of k-wire had dorsal tilt.

Out of the total 25 patients in the volar plate group, 23 (92%) patients showed no particular incongruity whereas 20 (80%) patients in the k-wire group had no particular incongruity.

The mean range of flexion and extension regained after one month, three months, and six months post-operatively are documented in (Table 2) and (Table 3) respectively.

Similarly, (Table 4) and (Table 5) illustrate the mean pronation and supination respectively at one, three, and six months. While the mean radial and ulnar deviation have been put up in (Table 6) and (Table 7) respectively.

In (Table 8) it is observed that at 1 month no patient showed excellent results, good results were shown by fifteen patients, and all of them belong to the volar plate group. We got fair results in 35 of the patients that including all 25 patients of the k-wire group and the remaining 10 patients of the volar plate group. At 3 months there is an improvement in functional results is seen in 22 cases from the volar plate group and 3 of the k-wire group had good results. A fair result was shown by 3 patients with VLP and 22 0f k-wire. In a third follow-up visit (6 months) total of 12 patients had excellent results that include 6 from each group. 35 had good results (19 VLP, 16 k-wire), and 3 patients in the wire group had fair results.

As per Sarmiento's modification of Lindstrom criteria, it was seen that 6 patients had excellent results out of which 5 belong to the volar plate group and 1 to k-wire. A total of 42 patients had good results (Table 9) with a major contribution from k-wire (22) and the rest by volar plate (20). Only 2 patients in the k-wire group had fair results.

The complications encountered in our study have been documented in (Table 10) Pin tract infection was seen in 10 patients of the k-wire group.

Table 1: Age distribution

Age Group	Volar locking Plate		K-Wire		Total
	No. of patients	Percentage	No. of Patients	Percentage	
Less than 20	2	8%	1	4%	3
21-40	10	40%	9	36%	19
41-60	10	40%	10	40%	20
More than 60	3	12%	5	20%	8
Total	25	100%	25	100%	50

Table 2: Mean flexion at follow-up

Flexion	Volar Plate	K-Wire	p-value	
at 1 month	22.4±4.856	17.20±2.141	0.000	Significant
at 3 months	74.12±7.108	53.96±8.876	0.000	Significant
at 6 months	83.8±2.101	83.00±2.273	0.203	Non-significant

Table 3: Mean extension at follow-up

Extension	Volar locking Plate	K-Wire	p-value	
at 1 month	29.08±8.036	23.44±2.84	0.000	Significant
at 3 months	75.32±9.196	59.36±10.97	0.000	Significant
at 6 months	82.96±3.335	82.08±2.25	0.280	not significant

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Table 4: Mean pronation at follow-up

Pronation	Volar locking Plate	K-Wire	p-value	
at 1 month	28.84±4.99	25.56±3.57	0.000	significant
at 3 months	79.44±7.500	59.76±11.37	0.000	significant
at 6 months	82.20±1.527	81.60±2.614	0.574	not significant

Table 5: Mean supination at follow-up

Supination	Volar locking Plate	K-Wire	p-value	
at 1 month	29.16±3.95	24.20±3.51	0.000	significant
at 3 months	79.16±8.097	63.56±12.810	0.000	significant
at 6 months	82.12±5.036	80.80±3.240	0.276	not significant

Table 6: Mean radial deviation at follow-up

Radial deviation	Volar locking Plate	K-Wire	p-value	
at 1 month	10.00±1.581	7.20±1.471	0.000	significant
at 3 months	16.24±1.640	10.00±2.198	0.000	significant
at 6 months	17.72±1.242	17.24±1.004	0.188	not significant

Table 7: Mean ulnar deviation at follow-up

Ulnar Deviation	Volar locking Plate	K-Wire	p-value	
at 1 month	10.60±1.958	7.96±1.369	0.000	significant
at 3 months	19.76±2.006	15.48±2.845	0.000	significant
at 6 months	23.52±2.694	22.44±2.274	0.132	not significant

Table 8: Gartland and Werley score

At 1 Month					
Gartland and Werley score	Volar locking Plate		K-Wire		Total
	No. of Patients	Percentage	No. of Patients	Percentage	
Excellent	0	0%	0	0%	0
Good	22	88%	3	12%	25
Fair	3	12%	22	88%	25
Total	25	100%	25	100%	50
At 3 Months					
Gartland and Werley score	Volar locking Plate		K-Wire		Total
	No. Of patients	percentage	No. Of Patients	Percentage	
Excellent	0	0%	0	0%	0
Good	15	60%	0	0%	15
Fair	10	40%	25	100%	35
Total	25	100%	25	100%	50
At 6 Months					
Gartland and Werley score	Volar locking Plate		K-Wire		Total
	No. of patients	percentage	No. Of Patients	Percentage	
Excellent	6	24%	6	24%	12
Good	19	76%	16	64%	35
Fair	0	0%	3	12%	3
Total	25	100%	25	100%	50

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Table 9: Sarmiento's modification of Lindstrom criteria

Lindstrom Criteria	Volar locking Plate		K-Wire		Total
	No. of Patients	Percentage	No. of Patients	Percentage	
Excellent	5	20%	1	4%	6
Good	20	80%	22	88%	42
Fair	0	0%	2	8%	2
Total	25	100%	25	100%	50

Table 10: Complications

Complication	Volar locking Plate		K-Wire		Total
	No. of patients	Percentage	No. of Patients	Percentage	
No complication	23	92%	17	68%	40
Pin tract infection	0	0	6	24%	6
Malunion	0	0	2	8%	2
decreased grip strength	1	2%	0	0%	1
Extensor tendon attrition	1	2%	0	0%	1
Total	25	100%	25	100%	50

4. Discussion

Fracture distal end radius is a common fracture in elderly patients and the most frequent fracture of the radius. Perfect anatomical reduction and maintenance are desired for treatment. Maintenance can be achieved by percutaneously fixing the fracture fragments with k-wires or by opening the fracture site and fixing the fracture with locking plates.

The present study was conducted on fifty cases of either sex having a fracture distal end radius. 25 cases were treated with percutaneous k-wire fixation and the rest 25 were treated with a volar locking plate. The male predominance in our study can be due to their involvement in outdoor activities.

In our study, better radial inclination could be achieved and maintained with volar plating. Karantana *et al*. also reported better radial inclination in volar locking plate (95%) than k-wire (89%) [12]. In another study, Lee *et al*. concluded that the volar plate had a better radial inclination (22.0^0) as compared to the k-wire group (14.4^0) [13]. Hollevo *et al*. had given similar results with the volar plate group having a value of 25^0 and the k-wire group having 22^0 [14].

A radial length of more than 5 mm was seen in 88% of patients of the volar plate group and 76% of patients of the k-wire group. A similar observation was seen in other studies, Karantana *et al*. showed a radial length of 10 mm in 96% of patients of the volar group in comparison to the k-wire group which had 82% of patients who regained radial length [12]. Higher values of radial length for the volar locking plate were also observed by Brennan SA *et al.* [15]. Dzaja *et al*. had radial shortening of 0.25 mm in the volar plate and 0.92 mm in the k-wire [16].

Our study revealed that none of the patients operated by volar plate showed dorsal tilt. While 6 patients belonging to the k-wire group had dorsal tilt.

In our study, articular congruity was better maintained in the volar plate group. A total of 36% of patients treated with K-wires and 29% with volar locking plates had a step greater than or equal to 1 mm present in a study conducted by Johnson NA *et al.* [17].

Thus as it can be observed that the volar plate group is radiologically better than of k-wire group in terms of radial inclination, radial length, radial tilt, and articular congruity.

In our study, we observed that at 1 month the statistically significant (P-value 0.0000) better mean flexion was observed in the volar plate group as compared to the k- wire group, a

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similar trend is observed at three months. But at 6 months there is a marked decrease in the difference is observed with values for VLP and K-wire group (p-value 0.203, insignificant). Chaudhary *et al*. too documented there was a small early advantage in flexion in the volar locking plate group (3.7°) [95% CI, 0.3°-7.1°; p = 0.04] at 3 months, but not at later follow-ups (6 or 12 months) [18]. Rozental also had similar results in his studies with mean flexion 50 $\pm 12^0$ vs 27±10° (p<0.01) and at 1 year 68±14°vs. 75±15° [19].

Mean extension at first-month follow-up is better too for volar plate than K-wire group. It remained statistically significant in the third month also. Again, the difference became insignificant in the sixth month.

In our study mean pronation in the first month for the volar plate group is 28.84±4.99 and for the k-wire group is 25.56±3.57 which is statistically significant. This trend continued at the third-month follow-up visit, but after that, the difference became statistically insignificant. Shuang-Le Zong *et al*. in their study had similar results with 71^0 pronation for VLP and 70^0 for k-wire [20]. Karantana *et al.* showed similar results at 6 weeks score for VLP and KW groups are 57±22% vs 17±30% and at 1 year 93±17% vs 93±18% [12].

Mean supination at one month for VLP is 29.16±3.95 and for KW it is 24.20±3.51, the values remained statistically significant even at the second follow-up visit which is at the third month but at the third follow-up (6 months) the values came out to be statistically insignificant. Rozental demonstrated equivalent results at 6 weeks values were 77±17 vs 63±26 and at one year 88±4 vs 88±4 [19]. Lee *et al*. also had identical results after 6 months 84.6±9.1 vs 75.3±9.1 [20].

Our study witnessed a 10.00±1.581 mean radial deviation for the VLP group and 7.20±1.471 for the K-wiring group after one month. There was upgrading noted in the sixth month when the values became 17.72±1.242 vs 17.24±1.004. Dzaja *et al*. also had resembling results with values of 17.4 vs 17.4 at one year [16]. Lee *et al*. in their study observed that the value of radial deviation for VLP was 24.1±8.8 and for KW was 22.5±9.6 [20].

The mean ulnar deviation was found to be 10.60±1.958 in the first month for the volar plate group and 7.96 ±1.369 for the K-wire group. An identical trend was seen in the third month also were mean for the volar plate group was 19.76 ±2.006 and for k-wire was 15.48±2.845 (p-value 0.000, significant) but at the third follow-up visit (6 months) there was improved ulnar deviation seen in the k-wire group (22.44) which was very much near to volar plate group (23.52). Comparable results were also given by Hollevoet where values were 97±8% vs 98±6% [14].

All the patients were assessed as per modified Gartland and Werley Scores at their respective follow-up visits. It was found that during the First visit 15 patients had a good score, all these patients belong to the VLP group, and the remaining 10 patients of the volar plate group had fair results. All the patients belonging to the KW group showed fair results at their first follow-up visit.

At the second follow-up (3 months) 22 patients of VLP and 3 of KW had good results. Only 3 patients of VLP and 22 of KW had fair results.

Final functional results showed 12 patients had excellent results with 6 patients belonging to both groups and 35 patients having good results out of which 19 belonged to the VLP group and 16 belong to the KW group. Only three patients had a fair result and they belonged to the KW group.

It is observed that in 5 patients there is a prominent ulnar styloid out of which 1 belongs to the VLP group and 4 belong to the KW group. Residual dorsal tilt was seen in 6 patients all of them belonged to the k-wire group. None of the VLP patients had residual dorsal tilt. None of the patients had a residual elevation of the hand.

Anatomical results were assessed by Sarmiento's modification of Lindstrom criteria. 20% of the patients belonging to the volar plate group and 4% of the k-wire group had excellent results. 80% of volar plate patients and 88% of k-wire patients had good results. Only 2

patients of the k-wire group had fair results which are due to loss of palmar tilt and radial shortening.
The most common complication encountered in our study was pin tract infection in the k-wire group affecting 10 (20%) patients. No complications were seen in 36 patients. Orbay JL and Fernandez DL noticed one complication of dorsal tendon attrition in their study [8].
There are different methods for the fixation of distal radius fracture. Every method has its advantage and disadvantages. The radiologically and anatomically volar plate had better results as compared to k-wire, during the initial follow-up of fractures of the distal radius. The volar plate also dominated over k-wires in terms of functional results but at 6 months there was very little difference seen functionally. Both techniques provide great clinical results, without a clear superiority of either fixation method for the surgical management of distal radius fractures.

Conclusion

We conclude that locking plates offer no functional advantage over the older and economical method of Kirschner wire fixation for patients with displaced fractures of the distal radius.

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Presentation at a meeting: None.

Conflicting Interest: None.

Ethical statement: The manuscript has been read and approved by all the authors, the requirements for authorship have been met, and each author believes that the manuscript represents honest work.

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