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Use of Different Methods of Intramedullary Nailing for Fixation of Distal Radius Fractures: A Retrospective Analysis of Clinical and Radiological Outcomes

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Background: We aimed to evaluate the clinical and radiologic outcomes of using Sonoma WRx versus Micronail intramedullary nailing for the fixation of distal radius fractures.





Material/Methods: A total of 68 patients with primarily extra-articular and simple intra-articular fractures of the distal radius who underwent intramedullary distal radius fixation using Sonoma WRx (n=39) or Micronail (n=29) intramedullary nails were enrolled in the study. The clinical outcome measures included the range of motion (ROM), visual analog scale (VAS), functional outcomes (patient-reported Disabilities of the Arm, Shoulder and Hand [DASH] score and clinician-based Gartland-Werley score), radiographic scores (Stewart score), and parameters related to the quality of radiographic reduction and complications (radial inclination, volar tilt, radial height, and radio-ulnar variance).

Results: Significantly higher DASH (15.0 ± 3.3 vs. 8.3 ± 1.5 , $p < 0.001$) and Gartland-Werley (4.9 ± 5.4 vs. 2.9 ± 4.2 , $p = 0.029$) scores, longer scopy time (21.0 ± 3.9 min vs. 15.8 ± 2.5 min, $p < 0.001$), lower ROM for wrist extension ($69.5 \pm 4.4^\circ$ vs. $77.1 \pm 7.6^\circ$, $p < 0.001$), higher ROM for wrist supination ($81.9 \pm 5.1^\circ$ vs. $78.7 \pm 3.1^\circ$, $p < 0.001$), and higher complications rates (37.9% vs. 15.4%, $p = 0.034$) were noted in the Micronail group compared to those in the Sonoma WRx group.

Conclusions: Our findings revealed that Sonoma WRx and Micronail implants were equally effective and useful minimally invasive options for treating distal radius fractures. Further, we consider Sonoma WRx superior in terms of shorter operative time, lower complication rates, and better functional outcome scores.

MeSH Keywords: **Fracture Fixation, Intramedullary • Postoperative Complications • Radius Fractures**

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Background

Distal radius fracture is a common upper-extremity injury, accounting for 8–15% of all skeletal injuries observed in orthopedic practice [1–4]. Although open reduction and internal fixation using metal implants on the surface of the distal radius is a widely used technique [4–8], intramedullary fixation of distal radius fractures via minimally invasive operative techniques has been associated with a lower risk of hardware irritation, decreased postoperative pain, and more stable fixation, enabling early range of motion (ROM) and patient rehabilitation [4,5,9,10].

While the initial techniques of intramedullary nailing of the distal radius using percutaneous pins (rods) failed to provide support of the subchondral bone to prevent articular collapse [9], modified intramedullary devices, such as Micronail (Wright Medical Technology Inc., Arlington, TN) [5], allowed the provision of fixed-angle support of the subchondral bone and combination of stable fixation with minimal soft tissue dissection [4,9,11].

The Sonoma WRx (Sonoma Orthopedic Products, Santa Rosa, CA) has also recently been introduced as a novel variation of intramedullary nail fixation for distal radius fractures with unique features that facilitate easier insertion and minimize the risk of soft tissue irritation [9]. Sonoma WRx implants have unique features, such as Wavibody and Activloc technology, that enable easy insertion via the flexible distal portion and rotational stability via expansible blades for proximal fixation without the need for proximal interlocking screws [9].

Considering the differences between Micronail and Sonoma WRx in terms of implant diameter options and proximal fixation technique, the outcomes of these 2 methods may differ with regard to tendon complications as well as stability and success of anatomic reduction.

This retrospective study was therefore designed to compare the clinical and radiologic outcomes of Sonoma WRx versus Micronail intramedullary nailing for fixation of primarily extra-articular or simple intra-articular distal radius fractures.

Material and Methods

Study population

A total of 68 patients with primarily extra-articular and simple intra-articular fractures of the distal radius who underwent intramedullary distal radius fixation using Sonoma WRx (n=39) or Micronail (n=29) intramedullary nails at our clinic between February 2011 and July 2016 were enrolled in this retrospective

study. Patients with simple or impacted unstable extra-articular distal radius fractures with or without dorsal/volar tilt (AO types; A2.1, A2.2, and A2.3) or multi-fragmentary fractures (AO type A3) and those with simple intra-articular distal radius fractures suitable for closed reduction (AO type C2.1) were enrolled. We excluded patients with stable fractures suitable for cast fixation; previous wrist or distal radius injury or deformity; open fractures; concomitant ulnar fractures; open or contaminated wounds without adequate soft tissue coverage; open physes; significantly displaced, small, and comminuted intra-articular fragments; irreducible articular or extra-articular fractures; or partial articular fractures involving the volar or dorsal rim (AO type 23-B).

The study was conducted in complete accordance with the local Good Clinical Practice (GCP) guidelines and current legislations. In addition, permission was obtained from our Institutional Ethics Committee for the use of patient data for publication purposes.

Operative techniques

All surgeries were performed by the same surgeon (MC). Initially, closed reduction and circular casting were performed for all patients with primarily extra-articular or simple intra-articular fractures of the distal radius. Patients with subsequent radiographic findings that included volar tilt $>20^\circ$, articular incongruity >2 mm, radial inclination $<15^\circ$, and radial shortening >5 mm were treated surgically.

Intramedullary nailing was performed under local or general anesthesia (in cases of lack of cooperation and presence of a concomitant injury) and fluoroscopic control in the supine position. First, closed reduction and temporary fixation using a K-wire were performed. Subsequently, a 2- to 3-cm-long incision was made over the radial styloid process.

For Sonoma WRx, the operation was continued with deep dissection between the synovial sheaths of the “extensor carpi radialis” muscle and the combined synovial sheaths of the “abductor pollicis longus” and “extensor pollicis brevis” muscles to reach 3–4 mm proximal to the radioscaphoid joint. From this point, 3 divergent screws were easily placed into the distal radius, and the distal fracture fragment was firmly attached with fixed-angle support [12].

For Micronail, fixation was performed using 3 distal subchondral (locking) screws. A new 2-cm-long incision was made dorsally for proximal locking and was fixated using 2 screws under fluoroscopy. The incisions sites were then sutured [13].

Postoperative treatment included the application of a wrist splint for 5 days, and finger motion was started immediately

Table 1. Baseline characteristics.

	Sonoma WRx (n=39)	Micronail (n=29)	p Value
Age (year), mean ±SD	45.9±5.4	47.0±6.4	0.438 ^a
Gender, n(%)			
Male	19 (48.7)	12 (41.4)	
Female	20 (51.3)	17 (58.6)	0.548 ^b
Handedness, n(%)			
Right	20 (51.3)	13 (55.2)	
Left	19 (48.7)	16 (44.8)	0.598 ^b
Type of injury, n(%)			
Fall	25 (64.1)	20 (69.0)	
Vehicle accident	7 (17.9)	5 (17.2)	
Sports injury	6 (15.4)	3 (10.3)	
Assault injury	1 (2.6)	1 (3.5)	0.965 ^c
Type of distal radius fracture, n(%)			
A2.1	8 (20.5)	8 (20.5)	
A2.2	7 (18.0)	7 (18.0)	0.978 ^c
A2.3	7 (18.0)	7 (18.0)	
A3	8 (20.5)	8 (20.5)	
C2.1	9 (23.1)	9 (23.1)	
Concomitant fractures, n(%)			
None	31 (79.5)	23 (79.3)	
Calcaneus fracture	1 (2.6)	0 (0.0)	
Humerus fracture	1 (2.6)	1 (3.5)	
Lumbar vertebral fracture	1 (2.6)	0 (0.0)	
Shoulder fracture	2 (5.1)	1 (3.5)	
Femur fracture	1 (2.6)	2 (6.9)	1.000 ^c
Malleolus fracture	1 (2.6)	2 (6.9)	
Shoulder dislocation	1 (2.6)	0 (0.0)	

^a Student's t test; ^b Chi square test; ^c Fisher exact test.

postoperatively. Approximately 1 week postoperatively, the splint was removed, and radiography was performed. In the absence of complications, load-carrying physical therapy was initiated. Clinical results were evaluated for 6 months after the surgery during 4 consecutive visits at 3, 6, and 12, weeks postoperatively and at 6 months postoperatively.

Assessments

Data regarding patient demographics (age and sex), handedness, type of injury and distal radius fracture, concomitant fractures, follow-up duration, total surgery and scopy times,

and time to fracture healing were recorded for each patient. Clinical outcome measures included ROM, visual analog scale (VAS), functional outcomes (patient-reported Disabilities of the Arm, Shoulder and Hand [DASH] score and clinician-based Gartland-Werley score), radiographic scores (Stewart score), and parameters related to the quality of radiographic reduction and complications (radial inclination, volar tilt, radial height, and radio-ulnar variance). Radiographic criteria for acceptable healing used in the study were in accordance with the definition used by Graham et al [14].

Table 2. Intra-operational characteristics and outcome measures.

	Sonoma WRx (n=39) Mean ±SD	Micronail (n=29) Mean ±SD	p Value
Time parameters			
Duration of follow up (week)	31.9±3.0	33.3±2.7	0.055
Total surgery time (min)	25.4±2.4	33.6±2.6	<0.001
Scopy time (min)	15.8±2.5	21.0±3.9	<0.001
Time to fracture union (week)	5.5±0.9	5.2±0.6	0.073
Outcome measures			
Flexion	79.9±6.6	74.3±15.1	0.064
ROM (°)			
Extension	77.1±7.6	69.5±4.4	<0.001
Pronation	82.1±3.4	79.6±15.2	0.930
Supination	78.7±3.1	81.9±5.1	<0.001
VAS (pain) score	1.8±0.9	2.2±1.1	0.158
DASH ^a	8.3±1.5	15.0±3.3	<0.001
Gartland-Werley score	2.9±4.2	4.9±5.4	0.029
Stewart score	1.0±1.2	1.6±1.3	0.067

DASH – disabilities of the arm, shoulder and hand; ROM – range of motion; VAS – visual analog scale. ^a Excluding patients with concomitant upper extremity fractures in both groups Student's *t* test or Mann Whitney U test.

DASH score

The DASH score is a patient-reported functional outcome measure that reportedly assesses a patient's own perception of upper-extremity function, based on 6 subscales (30 items), including activities of daily living (105 points), social activities (5 points), work activities (5 points), symptoms (5 points), sleeping (5 points), and confidence (5 points). The scores are normalized to 100 with a minimum score of 0 points and a maximum of 100 points. Higher scores indicate lower function [15–17].

Gartland-Werley score

The Gartland-Werley score is one of the most commonly used clinician-based outcome measures for evaluating wrist and hand function. It relies on the concept that a minimum of 45° dorsiflexion, 30° palmar flexion, 15° ulnar and radial deviation, and 50° pronation and supination is normal [15,17,18]. It comprises 4 subscales and evaluates objective findings (ROM and pain), subjective assessment, and radiographic findings, in addition to the complications and residual deformity. Higher scores indicate lower function [17,18].

Radiographic score and parameters

Radiographic confirmation of distal radius fracture union was defined as complete disappearance of fracture lines in the anteroposterior, lateral, and internal oblique views as determined by a single radiologist blinded to the study aim and protocol. The Stewart score system relies exclusively on radiological findings classified into 3 scales: the final dorsal angle (4 points), loss of radial angle (4 points), and loss of radial length (4 points). The resulting score can be classified into the following 4 categories: excellent (0 points), good (1–3 points), fair (4–6 points), and poor (7–12 points) [19].

Statistical analyses

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). Data were evaluated for normality using the Shapiro-Wilk test. The chi-square (χ^2) or Fisher exact test were used for comparing the categorical data, while the Student's *t* test or Mann-Whitney U test were used for comparing continuous data, according to the normality of the data. To compare the preoperative

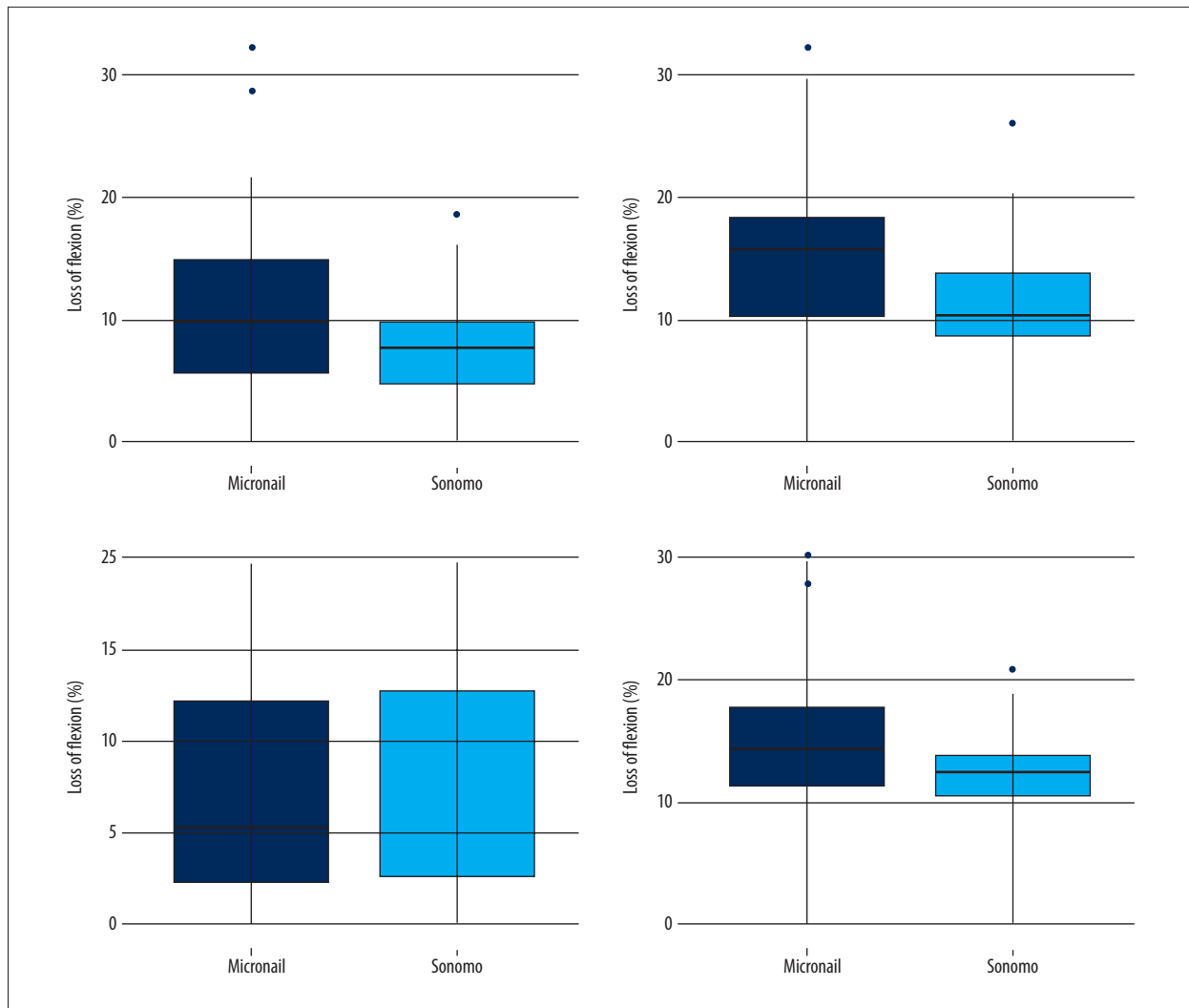


Figure 1. Percent loss of ROM for flexion, extension, pronation, and supination in Micronail vs. Sonoma WRx groups.

and postoperative continuous variables, the paired *t* test or Wilcoxon signed rank test were used, according to the normality of the differences in the variables. Data are expressed as “mean ± standard deviation (SD)” values and percentages (%) as appropriate. *P*<0.05 was considered statistically significant.

Results

Baseline characteristics of the study groups

Patients in the Sonoma WRx (mean ±SD age: 45.9±5.4 years, 51.3% women) and Micronail (mean ±SD age: 47.0±6.4 years, 58.6% women) groups were comparable in terms of demographic and fracture-related characteristics (Table 1).

Intra-operational characteristics and outcome measures of the study groups

Patients in the Micronail group had significantly longer total surgery time (33.6±2.6 min vs. 25.4±2.4 min, *p*<0.001) and scopy time (21.0±3.9 min vs. 15.8±2.5 min, *p*<0.001) than those in the Sonoma WRx group. However, no significant difference was noted between the Sonoma WRx and Micronail groups in terms of the mean time to fracture union (5.5 weeks vs. 5.2 weeks, respectively) and follow-up duration (31.9 weeks vs. 33.3 weeks, respectively) (Table 2).

DASH scores (15.0±3.3 vs. 8.3±1.5, *p*<0.001) and Gartland-Werley scores (4.9±5.4 vs. 2.9±4.2, *p*=0.029) were significantly higher in the Micronail than in the Sonoma WRx group, with no significant difference in their Stewart scores (1.0±1.2 and 1.6±1.3, respectively) (Table 2). Significantly lower ROM for wrist extension (69.5±4.4° vs. 77.1±7.6°, *p*<0.001) and higher

Table 3. Radiographic parameters in study groups.

X-ray findings		Sonoma WRx (n=39) Mean ±SD	Micronail (n=29) Mean ±SD	p Value
Radial inclination (°)	Preop	12.3±6.8	16.5±3.9	0.004a
	Postop	18.0±4.2	19.8±5.7	0.087 ^a
	p Value	<0.001 ^b	0.005 ^b	
Volar tilt (°)	Preop	-13.4±10.4	-14.1±12.3	0.223 ^a
	Postop	7.7±4.1	6.9±6.3	0.150 ^a
	p Value	<0.001 ^b	<0.001 ^b	
Radial height (mm)	Preop	3.2±2.0	3.3±2.9	0.518 ^a
	Postop	6.8±2.4	9.5±1.8	<0.001 ^a
	p Value	<0.001 ^b	<0.001 ^b	
Radio-ulnar variance (mm)	Preop	1.7±1.4	2.5±1.7	0.042 ^a
	Postop	0.7±0.8	1.1±0.9	0.021 ^a
	p Value	0.001 ^b	0.001 ^b	

^a Student's t test or Mann Whitney U test; ^b paired t test or Wilcoxon signed rank test.

Table 4. Fulfilling rates of the radiographic healing criteria defined by Graham et al. [12].

Maintenance of reduction	Sonoma WRx (n=39) n (%)	Micronail (n=29) n (%)	p Value
Radial inclination <15°	28 (71.8)	24 (82.8)	0.292
Radial shortening vs. normal wrist (<5 mm)	7 (17.9)	0 (0.0)	0.017
Volar tilt <20°	39 (100.0)	27 (93.1)	0.178
Articular incongruity (<5 mm)	39 (100.0)	29 (100.0)	-

Chi square proportion test.

ROM for wrist supination (81.9±5.1° vs. 78.7±3.1°, p<0.001) was noted in the Micronail group compared to that in the Sonoma WRx group (Table 2, Figure 1).

Quality of radiographic reduction in the study groups

Considering the preoperative X-ray examination findings, radial inclination (16.5±3.9° vs. 12.3±6.8°, p=0.004) and radio-ulnar variance (2.5±1.7 mm vs. 1.7±1.4 mm, p=0.042) were significantly higher in the Micronail group than in the Sonoma WRx group, with no significant difference between the groups in terms of volar tilt and radial height (Table 3).

Postoperatively, all X-ray examination parameters in each group had improved compared to the preoperative values (significance ranged from p=0.005 to p<0.001), while radial height (9.5±1.8 mm and 6.8±2.4 mm, p<0.001) and radio-ulnar variance (1.1±0.9 mm vs. 0.7±0.8 mm, p=0.021) were

significantly higher in the Micronail group than in the Sonoma WRx group (Table 3).

An assessment of the fulfilment rates of the radiographic healing criteria revealed that radial inclination was <15° and volar tilt was <20° in majority of the patients, and distal radio-ulnar joint incongruity was < 5 mm in all patients of both the groups postoperatively. However, radial shortening (<5 mm) was significantly more common with the use of Sonoma WRx than with that of Micronail (17.9% vs. 0.0%, p=0.017) (Table 4, Figures 2, 3).

Complications in the study groups

The complication rate was significantly higher in the Micronail group than in the Sonoma WRx group (37.9% vs. 15.4%, p=0.034). Tenosynovitis (5.1%) was the most common complication in the Sonoma WRx group, while radial nerve paresthesia



Figure 2. Preoperative (A), postoperative (B), and latest follow-up (C) X-ray findings for Sonoma WRx.

and infection in the locking screw (10.3% for each) were the most common complications in the Micronail group (Table 5).

Primary tendon repair was performed in the Department of Hand Surgery for patients with tendon rupture with complete recovery. Patients with infection in the locking screw were treated via removal of the screws in the early period (week 3) followed by antibiotic treatment and dressing. Physical therapy and contrast bath therapy were applied for Sudeck's atrophy, while physical therapy resulted in recovery in carpal tunnel syndrome patients. In patients with radial nerve paresthesia, recovery was observed in the third month of follow-up.

Discussion

Our findings revealed better patient-reported and clinician-based functional outcomes, shorter total surgery and scopy times, and lower complication rates with Sonoma WRx than with Micronail in intramedullary fixation of primarily extra-articular or simple intra-articular fractures of the distal radius. No significant difference was noted between the 2 groups in terms of the VAS scores, time to fracture union, Stewart scores, and ROM in wrist flexion and pronation.

In previous studies on intramedullary fixation of distal radius fractures using the Sonoma WRx, fracture union was obtained at 10 weeks (6–20 weeks) with good functional, clinical, and radiological outcomes [9]. Our findings with Sonoma WRx implants also revealed significant improvement in radial height, radial inclination, volar tilt, and radio-ulnar variance, as well as satisfactory improvement in the wrist ROM. The DASH, Gartland-Werley, and Stewart scores in the Sonoma WRx group indicated a favorable patient-reported and clinician-based functional outcomes and good reduction after 31.9 weeks postoperatively.

In studies evaluating Micronail for intramedullary fixation, the clinical, radiological, and functional outcomes were also reported to be very good [1,5,20]. Our findings with Micronail implants also revealed significant improvement in the radial height, radial inclination, volar tilt, and radio-ulnar variance postoperatively, as well as improved wrist ROM; however, the average DASH score was 15.0 after 33.3 weeks postoperatively. Although similar to previous trials, our study showed successful fracture reduction and improved ROM with Micronail implants in distal radial fractures, the DASH scores in our Micronail group were higher than those reported in previous studies [1,5,20]. In fact, our experience suggests that both Sonoma WRx and Micronail are very useful minimally invasive



Figure 3. Preoperative (A), postoperative (B), and latest follow-up (C) X-ray findings for Micronail.

Table 5. Complications in study groups.

Complications, n(%)	Sonoma WRx (n=39)	Micronail (n=29)	p Value
None	32 (82.1)	19 (65.5)	
Tendon rupture	1 (2.6)	1 (3.4)	
Carpal tunnel syndrome	1 (2.6)	0 (0)	
Sudeck atrophy	1 (2.6)	1 (3.4)	0.239
Radial nerve paresthesia	1 (2.6)	3 (10.3)	
Pain at wrist	0 (0)	0 (0)	
Infection	0 (0)	3 (10.3)	
Tenosynovitis	3 (7.8)	2 (6.9)	

Fisher exact test.

options for fixation of distal radius fractures, with satisfactory radiological outcome, improved wrist ROM, high stability and quality of reduction, and short time to fracture union.

However, despite similar quality and stability of reduction in the 2 groups, Sonoma WRx was associated with a shorter scopy time and better patient-reported and clinician-based functional

outcomes than Micronail implants in our study. This emphasizes the likelihood of easier insertion provided by Sonoma WRx implants to enable further reduction in the risk of soft tissue irritation, tendon adhesion, and malreduction in the fixation of distal radial fractures [9]. Supporting this, Sonoma WRx has unique features, such as Wavibody and Activloc technology, flexible distal portion, and the lack of proximal interlocking screws as opposed to the Micronail implants [9].

In a systematic review of 16 studies, intramedullary nails were found to be as strong as locking plates and to have ROM and functional outcome comparable to other fixation techniques for distal radius fractures [21]. However, the complication rate of intramedullary nailing was 17.6% (0–50%), which is higher than those reported in studies for volar plating [21].

The overall complication rate associated with intramedullary nail fixation was 25.0% in our cohort. Significantly higher complication rates were observed in the Micronail group (37.9%) compared to that in the Sonoma WRx group (15.4%). Tenosynovitis involving “extensor pollicis brevis” and “abductor pollicis longus” tendons was more common in the Sonoma WRx group, while radial nerve paresthesia and infection were more common in the Micronail group. This difference between Micronail and Sonoma WRx in terms of frequency and characteristics of complications can be explained by the range of the implant diameters and the different proximal fixation techniques used by these 2 intramedullary fixation methods. Similarly, previous data on complications associated with intramedullary fixation of distal radius fractures revealed lower complication rates, with no cases of screw penetration into the distal radio-ulnar joint (DRUJ), loss of reduction, tendon irritation, complex regional pain syndrome, or need for hardware removal for Sonoma WRx implants [9]. However, Micronail implants have been associated with superficial radial sensory neuritis (13–20%), screw penetration into the DRUJ (0–30%), and loss of reduction (13–20%) [5,20,22].

Consistent with the complications observed in our cohort, the distal aspect is not affixed on the dorsal cortex of the distal radius adjacent to the extensor tendons, and mobilization of the “extensor pollicis longus” and removal of Lister’s tubercle are not required during the insertion of a Micronail implant [5]. Moreover, the Sonoma WRx implant comprises a solid proximal hub 5–6 mm in diameter that is curved to enhance percutaneous insertion in a manner compatible with the patient’s anatomy [9]. Hence, our findings emphasize the role of technical factors in the differences between the 2 methods in the likelihood of complications, with a minimal risk of tendon complications in Micronail implants [1,20] and a lower likelihood of radial nerve paresthesia with Sonoma WRx [9].

Given the similar baseline characteristics of the patients in both study groups in terms of age, sex, type of distal radius

fracture, and concomitant fractures, as well as their similar satisfactory outcomes in terms of reduction and stable fixation, our findings indicate that Sonoma WRx is preferable for use in intramedullary fixation of distal radius fractures due to its better functional outcome, ease of surgical manipulation, length of operation, and complication risk.

Based on our experience with Sonoma WRx and Micronail implants in intramedullary nailing for the fixation of distal radius fractures, the main advantages of Sonoma WRx implants include the need for a smaller incision over the radial styloid; flexibility, enabling easier intramedullary insertion; and proximal fixation technique, enabling the use of expansible blades. Micronail implants seem to offer better and more stable reduction by filling the intramedullary area; however, the lack of flexibility, use of a larger and more rigid implant, need for a larger incision and entry over the radial styloid, and the need for a second incision on the dorsal side appear to be its major disadvantages as compared with Sonoma WRx implants.

It is noteworthy that the total surgery time and scopy time are shorter with Sonoma WRx than with Micronail implants because rotational stability is provided with the use of expansible blades in Sonoma WRx as opposed to that in the Micronail method, necessitating additional incisions and the use of transfixation screws to enable rotational stability.

The retrospective, single-center design of the present study can be considered the major limitation that restricts the establishment of the temporality between the cause and effect, as well as the generalization of our findings to overall patient populations. Nonetheless, we believe that our findings present a valuable contribution to the literature in terms of a comparison of the Sonoma WRx and Micronail implant methods for intramedullary fixation of distal radial fractures in a relatively large cohort.

Conclusions

In conclusion, Sonoma WRx and Micronail implants are equally effective and useful minimally invasive options for treating distal radius fractures. Based on our experience, we consider Sonoma WRx superior due to its shorter operative time, lower complication rates, and better functional outcome scores. Longer-term outcome studies are warranted to further assess the advantages of intramedullary nail fixation over other techniques in the treatment of distal radius fractures, given the non-negligible postoperative complication rates.

Conflict of interest

None.

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