RESEARCH ARTICLE

Four-Corner Fusion Surgery for SLAC and SNAC of the wrist: Screw Versus Staple Fixation

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Abstract

Objectives: This study hypothesizes that, in patients undergoing four-corner fusion (4CF) surgery, the choice of fixation method—either headless compression screw (HCS) or staples (ST)—will not significantly impact postoperative complication rates, union rate, and functional outcomes.

Methods: A retrospective chart review was conducted on patients who underwent 4CF for scapholunate advanced collapse (SLAC) or scaphoid nonunion advanced collapse (SNAC) wrist at a single institution over thirteen years. Functional outcomes included postoperative complications, nonunion, subsequent surgery, wrist flexion-extension range of motion (ROM), Quick Disabilities of Arm, Shoulder & Hand (QuickDASH) score, and the 12-Item Short Form Survey (SF-12).

Results: Thirty-seven patients were identified with an average follow-up of 9.1 months (range: 3-24 months). Nineteen patients were treated with HCS, and 18 were treated with ST. There were no significant differences in the complication rates between the HCS and ST groups (P=0.73). In the HCS group, the main complications were pain (n=4), subsequent surgeries for revision or hardware removal (n=3), and nonunion (n=2). For the ST group, these were pain (n=5), subsequent surgeries for revision or hardware removal (n=5), and hardware loosening (n=4). Postoperatively, wrist flexion and extension ROM did not significantly change in either group. QuickDASH improved postoperatively in both groups (P<0.005). Only the ST group improved in the SF-12 physical component postoperatively (P=0.01).

Conclusion: In this small, retrospective case series with short follow-up, fixation choice between HCS and ST in 4CF for SLAC or SNAC did not significantly impact complication rates or functional recovery. Postoperative complications occurred at similar rates, with pain and the need for subsequent surgery being the most common.

Level of evidence: IV

Keywords: 4-corner, Four corner fusion, Scaphoid excision, Screw, Staple

Introduction

First described by Watson and Ballet in 1984, the Four-Corner Fusion (4CF) procedure has become a standard surgical treatment for progressive carpal collapse, particularly in cases of scapholunate advanced collapse (SLAC).[1] This procedure involves the removal of the scaphoid bone and arthrodesis of the midcarpal joint while maintaining the carpal height to create a stable, pain-free wrist.[2]

Over the years, various fixation methods have been explored to optimize the outcomes of 4CF surgery, including K-wires, staples (ST), plates, and headless compression screws (HCS).[3-6] The choice of fixation method may influence postoperative outcomes such as pain, wrist mobility, and functional recovery, though evidence is mixed.[7] For instance, Erne et al. reported that patients who underwent 4CF with HCS experienced significantly better postoperative outcomes, including reduced pain and improved wrist mobility, compared to those treated with K-wires.[3] Conversely, studies by Le Corre et al. and Pauchard et al. indicated that the use of ST and plates did not show

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significant differences in patient satisfaction, pain relief, or functional outcomes, suggesting that these methods may offer comparable results.[4,5]

Staples have shown as low as a 5.7% conversion rate to total wrist arthrodesis and are associated with improved postoperative pain scores.[8,9] Screws have also been demonstrated to be a reliable option for 4CF surgery, having consistently shown high union rates and low complication rates across multiple studies.[10-12]

Despite these findings, there remains a notable gap in the literature concerning the comparative effectiveness of ST versus HCS in 4CF surgery. Understanding the relative benefits and potential complications associated with these fixation methods is essential for optimizing surgical outcomes and patient care. Therefore, we hypothesized that there is no significant difference in functional outcomes and complication rates between ST and HCS in 4CF surgery.

Materials and Methods

Study Population

A retrospective chart review was conducted on patients who underwent 4CF for SLAC or scaphoid nonunion advanced collapse (SNAC) wrist conditions at one institution from January 2011 to October 2020, identified using the Current Procedural Terminology (CPT) code 25800. The study was exempt from Institutional Review Board (IRB) review. Inclusion criteria consisted of patients who underwent 4CF surgery specifically for SLAC or SNAC wrist, utilizing either HCS or ST. Patients who underwent limited lunocapitate arthrodesis and 4CF using other hardware, such as K-wires or plates, were excluded. Additionally, as this CPT code covers other arthrodesis procedures of the wrist, patients were excluded if they did not specifically receive 4CF.

Data Collection

Data was collected on the type of hardware used (HCS vs. ST), patient demographics (age, sex, hand laterality), the presence of SLAC or SNAC, and the distribution of the number of screws or staples utilized in each case. Using the follow-up anteroposterior and lateral radiographs of the affected wrist, union was assessed by cortical bridging between the carpal bones. Computed tomography (CT) scans were not routinely performed and were obtained only when clinically indicated, such as in cases of progressive nonunion with persistent pain, failed reduction, or lack of interval healing. These radiographs were evaluated by a senior hand surgeon in conjunction with a resident. Outcome variables focused on functional outcomes and complications, including a postoperative range of motion (ROM) in wrist flexion and extension, Quick Disabilities of Arm, Shoulder, & Hand (QuickDASH) scores, the 12-Item Short Form Survey (SF-12) physical and mental components, and postoperative complications, including pain, nonunion, hardware loosening, and subsequent surgeries.

Statistical Analysis

Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population. Means and standard deviations were calculated for continuous variables such as age and ROM, while percentages were used for categorical variables like sex and complications. Comparative analyses were performed between the groups (staples vs. screws) using Student's t-tests for continuous variables to compare means, and chi-squared tests with Fisher's exact test for categorical variables to assess distribution differences. Statistical significance was set at a *P-value* of <0.05.

Results

The study included 37 patients with an average follow-up of 9.1 months, with 19 patients treated with HCS and 18 with ST [Table 1].

Table 1. Demographics and Surgical Details of the Two Patient Groups

	HCS (n=19)	ST (n=18)
Male	79%	83%
Female	21%	17%
Age at 4CF	59 ± 15	59 ± 14
Laterality (% Right)	53%	44%
SLAC	95%	83%
SNAC	5%	17%
Hardware used	1 screw = 1 2 screws = 14 3 screws = 3 4 screws = 1	2 staples = 5 3 staples = 10 4 staples = 3

HCS: headless compression screws; ST: staples; 4CF: Four-corner fusion; SLAC: Scaphoid lunate advanced collapse; SNAC: Scaphoid nonunion advanced collapse

Postoperative wrist ROM showed no significant changes in either group. However, QuickDASH significantly improved in both groups. SF-12 physical scores improved in ST (P=0.01) but not HCS (P=0.24); mental scores were unchanged in both (HCS P=0.87, ST P=0.93). [Table 2].

Table 2. Postoperative Functional Outcomes of the Two Patient Groups

	HCS (n=19)			ST (n=18)		
	Pre-op	*Post-op*	*P-value*	*Pre-op*	*Post-op*	*P-value*
Wrist flexion	30° ± 17°	29° ± 16°	0.87	30° ± 20°	30° ± 16°	0.76
Wrist extension	30° ± 17°	26° ± 16°	0.09	37° ± 19°	31° ± 13°	0.19
QuickDASH	39 ± 19.0	21 ± 20	0.003	45 ± 20	16 ± 21	0.001
SF-12 physical component	42 ± 8	43 ± 11	0.24	37 ± 10	46 ± 11	0.01
SF-12 mental component	50 ± 9	55 ± 10	0.87	60 ± 5	55 ± 12	0.93

HCS: headless compression screws; ST: staples; QuickDASH: Quick Disabilities of Arm, Shoulder, & Hand. SF-12: 12-Item Short Form Health Survey

Postoperative complications were observed in 32% of patients (n=6) in the HCS group and 39% (n=7) in the ST group, though this difference was not statistically significant (*P=0.73*) [Table 3]. Out of these thirteen patients, eight experienced multiple complications – two from the HCS group and six from the ST group – though this difference was not statistically significant (*P=0.12*) [Table 3]. In the HCS group, one patient had pain and nonunion, while another experienced pain, hardware loosening, nonunion, and required a salvage procedure. In the staples group, one patient experienced pain, and removal of hardware needed and a salvage procedure; another had hardware loosening and hardware removal; a third experienced pain, hardware loosening, and nonunion; a fourth had pain and hardware loosening; a fifth experienced pain and underwent hardware removal; and a sixth had hardware loosening, nonunion, and required a salvage procedure.

The rate of hardware loosening, hardware removal, and salvage procedures was higher in the ST group, although the rate was not statistically significant. The rate of nonunion was comparable, with no significant difference [Table 3].

Table 3. Patients with Postoperative Complications

Patient	HCS vs. ST	Sex	Age	SLAC vs. SNAC	Nonunion	Salvage procedure	Pain	Hardware loosening	Hardware removal
1	HCS	Male	44	SLAC			*		
2	HCS	Male	57	SLAC			*		
3	HCS	Male	66	SLAC					*
4	HCS	Male	66	SLAC	*		*		
5	HCS	Male	62	SLAC	*	*	*	*	
6	HCS	Male	60	SLAC					*
7	ST	Female	46	SNAC		*	*		*
8	ST	Male	51	SLAC				*	*
9	ST	Male	63	SLAC			*		
10	ST	Female	86	SLAC	*		*	*	
11	ST	Male	33	SNAC			*	*	
12	ST	Male	69	SLAC			*		*
13	ST	Female	80	SLAC	*	*		*	

*complication present; HCS: headless compression screws; ST: staples; SLAC: Scaphoid lunate advanced collapse; SNAC: Scaphoid nonunion advanced collapse

Fisher's exact test revealed no significant association between the number of screws and complication rates (*P>0.99*) or between the number of staples and complication rates (*P=0.68*) [Tables 4 and 5].

Discussion

This study is the first to evaluate and compare the functional outcomes and complication rates of patients who underwent 4CF surgery using either ST or HCS fixation. By analyzing postoperative recovery and patient-reported outcomes, the authors sought to determine which fixation method might offer superior clinical benefits or reduced complications, thereby guiding surgeons in selecting the most appropriate technique for achieving optimal wrist function and patient satisfaction. The results demonstrated that both HCS and ST effectively improve patient-reported outcomes, as evidenced by the reductions in QuickDASH scores in both groups. However, despite these improvements, there were no statistically significant differences between the two methods concerning postoperative wrist ROM or complication rates, indicating that both HCS and ST provide comparable clinical outcomes. Further analysis revealed that the number of

screws and staples used did not significantly affect complication rates, supporting the conclusion that hardware type or quantity does not significantly influence complications. While both methods showed similar results, the ST group exhibited a significant improvement in SF-12 physical component scores, potentially reflecting variations in patient demographics, preoperative status, or perceptions of recovery.

It is important to acknowledge our study's limitations. First, the study is retrospective in nature, which introduces selection bias. The small sample size (n = 37) precluded a formal power analysis and likely underpowered the study to detect statistically significant differences, particularly for rare events such as nonunion. Additionally, the average follow-up period of 9.1 months may not capture long-term outcomes, including late hardware failure. SLAC/SNAC stages were not uniformly documented, precluding subgroup analysis. Another limitation is the variation in the number of screws or staples each patient received during the fusion procedure, which may affect outcomes, and for which our small sample size does not allow us to analyze effectively. Future studies with larger cohorts and extended follow-up periods are needed to validate our findings, explore the potential impact of the number of screws or staples on outcomes, and provide a more comprehensive understanding of the long-term outcomes of 4CF surgery, comparing HCS to ST fixation.

Table 4. Complication Rates Based on the Number of Screws

	Complications (# patients)	No Complications (# patients)	Total
1 screw	0	1	1
2 screws	5	9	14
3 screws	1	2	3
4 screws	0	1	1

Fisher's exact test P-value >= 0.99

Table 5. Complication Rates Based on the Number of Staples

	Complications (# patients)	No Complications (# patients)	Total
2 staples	3	2	5
3 staples	3	7	10
4 staples	1	2	3

Fisher's exact test P-value = 0.68

Hayes et al. recently conducted a systematic review that examined the effectiveness of various fixation methods in 4CF surgery, including K-wires, screws, staples, nonlocking plates, metal locking plates, and radiolucent locking plates.[13] Their findings indicated no statistically significant differences between these groups regarding flexion or extension ROM, which aligns with our study's comparison of HCS and ST. Additionally, the study reported union rates of 95% for screws and 94% for staples, which are comparable to our findings of 89% for screws and 89% for staples, despite our small sample size. A recent systematic review by Andronic et al. analyzed 1103 cases and found fusion rates >90% across fixation techniques, with no significant differences, though data heterogeneity limited comparisons of functional outcomes.[14] These prior results further support the idea that both HCS and ST are similarly effective in achieving union, reducing complication rates, and preserving wrist mobility postoperatively.

Ledgard et al. conducted the only study we found that directly compared variables between screw and staple fixation; however, their study involved 3D-printed carpal bones and not patients.[15] They examined the biomechanics of midcarpal arthrodesis using memory staples versus cannulated screws, demonstrating that constructs utilizing screws had a significantly higher peak torque to distraction compared to those using staples.[15] Based on their findings, they recommend fusing the midcarpal joint with two headless compression screws when performing midcarpal arthrodesis following scaphoid and trapezium excision.

The complication rate in both groups of our study was higher than reported in larger reviews, potentially due to our broad definition, short follow-up, missing resolutions, or selection bias in a small cohort.

Both fixation methods carry the inherent risk of requiring hardware removal or revision surgery, as supported by multiple studies.[4,8,16] In our study, 17% of patients in the staple fixation group required hardware removal due to pain or hardware irritation, while 22% experienced hardware loosening. Among the two patients in the staple group who required salvage procedures, one received an arthrodesis with a plate, and the other underwent a proximal row carpectomy. The primary reasons for these salvage procedures were nonunion and hardware loosening. This aligns with findings from other studies, such as Le Corre et al., who reported a 5% nonunion rate, an 18% revision rate, and a 24% implant failure rate for staple fixation.[4] Similarly, Bain and Watts found a 13% nonunion rate and a 14% revision rate with staples.[8] For screw fixation, our study found a non-significant difference in the incidence of salvage procedures compared to staples,

with only one patient (5.3%) requiring revision surgery for nonunion, which consisted of revision surgery with two staples and bone graft. However, this incidence was considerably lower than the 30% revision rate reported by d'Almeida et al., which highlights a possible high complication rate associated with screw fixation.[16] The included X-rays [Figures 1 and 2] illustrate representative cases of hardware removal for both headless compression screws and staples. In these cases, hardware removal was prompted by patient-reported symptoms, such as discomfort with pronation and supination or persistent pain. These findings underscore the importance of carefully selecting the most appropriate technique for each patient undergoing 4CF surgery, considering the inherent risks associated with both fixation methods.

Figure 1. (A) Anteroposterior (AP) and lateral X-rays of the wrist immediately following four-corner fusion surgery with headless compression screws. (B) AP and lateral X-rays of the wrist after hardware removal due to discomfort with pronation and supination, likely caused by soft tissue irritation

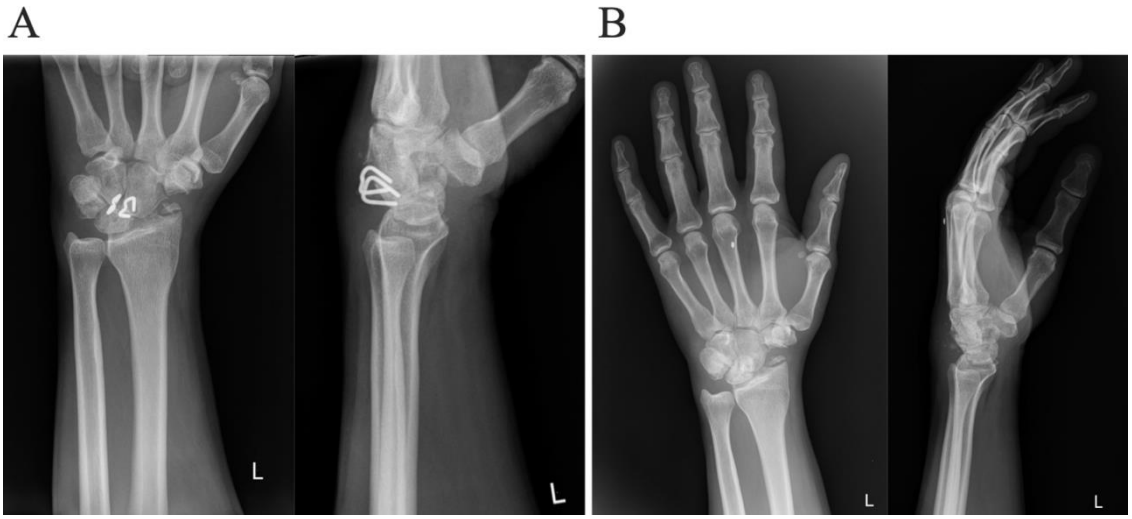

Figure 2. (A) Anteroposterior (AP) and lateral X-rays of the wrist immediately following four-corner fusion surgery with staples. (B) AP and lateral X-rays of the wrist after hardware removal due to pain

Interestingly, the SF-12 physical component scores improved significantly in the ST group but not in the HCS group. This difference might be due to variations in patient demographics, preoperative functional status, or differences in the perception of physical recovery. The lack of significant improvement in the HCS group's SF-12 score suggests that, while HCS provides stable fixation, it may not translate into perceived physical health improvements as effectively as ST. While some studies have questioned the reliability of SF-12 in hand or wrist surgery, others have

found it to be a valid tool in orthopaedic trauma.[17,18] This variability highlights the need for careful interpretation of SF-12 results when assessing recovery in 4CF surgery.

Surgeons should prioritize using the fixation technique they are most comfortable with when performing 4CF surgery, as this can greatly impact the success of the procedure. Given that our study found no significant differences in clinical outcomes between HCS and ST, it suggests that neither method is definitively superior. The choice of fixation should be tailored to the individual patient's needs and the surgeon's expertise, with both methods offering comparable results in terms of complication rates and functional recovery. Ultimately, the focus should be on selecting the approach that best suits the specific circumstances of each case to optimize patient outcomes.

Conclusion

The findings of this study suggest that both HCS and ST offer comparable clinical outcomes regarding postoperative wrist ROM, complication rates, and patient-reported outcomes, as evidenced by improvements in QuickDASH scores. hardware-related symptoms were more common with the staples. However, the overall lack of significant differences between HCS and ST indicates that neither fixation technique is definitively superior. For surgeons, the choice of fixation method should be guided primarily by their comfort and expertise with the technique, tailored to the individual patient's needs. Given the comparable outcomes of HCS and ST, the selection should focus on optimizing patient care and ensuring the best possible functional recovery.

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