



Four-Corner Arthrodesis: Comparative Analysis of Open Technique Versus Percutaneous Technique with Arthroscopic Assistance

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J Wrist Surg 2022;11:127–133.

Abstract

Introduction Four-corner arthrodesis is a salvage technique for patients with carpal advanced osteoarthritis. Nowadays, percutaneous techniques with arthroscopic assistance have been described, achieving favorable results with minimally invasive techniques advantages over open surgery.

Objective To compare functional and radiological results in patients with SLAC or SNAC wrists operated with open surgical technique versus percutaneous surgery with arthroscopic assistance.

Materials and Methods Retrospective case-control study of clinical records and radiological images of patients with carpal advanced osteoarthritis operated with both surgical techniques. We studied demographic variables, pain with visual analog scale (VAS) score, function in ranges of mobility, time of consolidation, and correction of DISI deformity.

Results A total of 22 male patients with an average age of 32.5 years were studied. Thirteen patients in the case group (percutaneous technique with arthroscopic assistance) and nine patients in the control group (open surgery). Pain score in VAS at discharge was 3 for cases and 5 in controls ($p = 0.008$), and at 30 days postoperatively, it was 0 and 3 respectively ($p = 0.00$). The extension and flexion ranges were 52.6° and 38.7° in the cases and 35.7° and 32.4° in the control group ($p = 0.119$ and 0.0016, respectively). The capitulate angle was 10° in the controls and 5° in the cases ($p = 0.0008$). The time of consolidation was 8.8 weeks in cases and 12.5 weeks in controls ($p = 0.039$).

Keywords

- ▶ 4-Corner arthrodesis
- ▶ SNAC
- ▶ SLAC
- ▶ wrist arthroscopy
- ▶ wrist surgery

* The work was carried out with patients treated at the Clínica Dávila in Santiago, Chile, and in Hospital Regional de Talca, Talca, Chile.

Conclusions The percutaneous technique with arthroscopic assistance for the 4-corner arthrodesis is a reproducible technique and is effective in achieving consolidation, pain reduction and preservation of wrist motion. In the present study, we demonstrate superiority of this technique over the open surgery.

Level of Evidence This is a Level III, therapeutic study.

Noninflammatory osteoarthritis of the carpus is a chronic degenerative pathology of the articular cartilage that in the long term leads to structural changes and carpal collapse,¹⁻³ with posttraumatic causes being the most frequent.² Post-traumatic osteoarthritis secondary to chronic carpal instability generally occurs progressively in a pattern that follows a relatively constant sequence.¹ It is a pathology that can produce chronic pain and significant deterioration of wrist function, and although it is often well-tolerated for years, it is not unusual to find symptomatic patients in early stages.² The most common form of carpal collapse is called scapholunate advanced collapse (SLAC)¹ and is the result of a carpal misalignment due to an alteration in the scapholunate ligament. Similar to this degenerative pattern, scaphoid nonunion can result in a carpal collapse known as scaphoid nonunion advanced collapse (SNAC).^{3,4}

In both cases, chronic carpal instability causes progressive joint damage with successive stages of carpal misalignment, leading to advanced carpal collapse and severe panarthrosis.^{1,4,5} Four evolutionary stages are described, where in stage I, the radial styloid is involved. In stage II, the entire radioscaphoid joint is affected. In stage III, the degenerative involvement of the midcarpal joint is added, specifically damage to the joint between the lunate and capitate, and in stage IV, generalized osteoarthritis is observed with complete involvement of the radiocarpal and midcarpal joint, and there may even be damage to the distal radiocubital joint.^{1,5} For each of these stages, different therapeutic modalities have been described, where in early stages, the objective is to perform procedures that reduce pain while preserving wrist mobility.⁵ In advanced stages, this is difficult because of cartilage damage to the carpal, so they opt for total wrist arthrodesis surgery.⁵

Four-corner arthrodesis is the procedure indicated in patients with SLAC or SNAC grade II and III wrists when capitate arthrosis is present.^{2,4} This technique consists of performing an arthrodesis of the lunate, capitate, hamate, and triquetrum bones associated with excision of the scaphoid.⁴ Fixation techniques using K-wires, dorsal plates and cannulated screws have been described, with the latter being the most frequently used, and it can be performed using open techniques or percutaneously with arthroscopic assistance.^{4,6,7} Good results are described in the literature with both techniques in the medium- and long-term,⁸ achieving mobility ranges of up to 50%,² pain reduction of up to 80%, and absence of pain in half of the patients.^{2,9} The percutaneous technique with arthroscopic assistance, although demanding and requiring training in wrist arthroscopy, presents advantages over the open technique, since it allows better visualization of the articular cartilage, better pre-

serves the vascular supply of the carpus, eventually improving bone consolidation, and decreases soft-tissue injury.⁷

The aim of this study is to compare functional and radiological results of patients with SLAC and SNAC wrists with midcarpal arthrosis treated with open surgical technique versus those treated with percutaneous technique and arthroscopic assistance. The technique used in the arthroscopic-assistance group is described.

Materials and Methods

Retrospective case-control study of 22 consecutive patients undergoing 4-corner arthrodesis in a level V trauma center by the same surgical team between the years 2011 to 2016. The control group was composed of those patients treated between 2011 to 2013 with open technique and the case group by those patients treated between 2014 to 2016 in a percutaneous way with arthroscopic assistance.

The inclusion criteria were patients over 18 years of age with a clinical-radiographic diagnosis of SLAC/SNAC grade II and III wrist, preoperative pain greater than 4, measured on a visual analogue scale (VAS), in their activities of daily living. Patients with stage I and IV SNAC and SLAC wrists were excluded.

The variables analyzed in both groups were as follows: demographics; functional results by a range of motion of flexion and extension evaluated at 6 months in both groups with goniometer; postoperative pain at day 1 and 30 using the VAS; radiological consolidation time; and the dorsal intercalated segment instability (DISI) correction measuring the capitollunate angle (►Fig. 1). Radiological consolidation was evaluated every 2 weeks since the 6th week postsurgery through anteroposterior and lateral wrist radiographs reviewed by the two senior surgeons of the study; the presence of bony bridges in the X-ray between the capitollunate joint, hamate-triquetral joint, and the corner of the four bones was considered as consolidated.

A statistical study was conducted with the STATA 15 program using the Shapiro-Wilk test to demonstrate normality of variables, Student's *t*-test for comparison of means, and Mann-Whitney U test for comparison of medians. Variables expressed as means are normally distributed, while those expressed as medians are not. A significant *p* was considered to be less than 0.05.

Surgical Technique of Percutaneous Surgery with Arthroscopic Assistance

The patient is positioned in dorsal decubitus on the surgical table and hand table after regional anesthesia with brachial plexus block. Ischemia is performed by emptying the limb

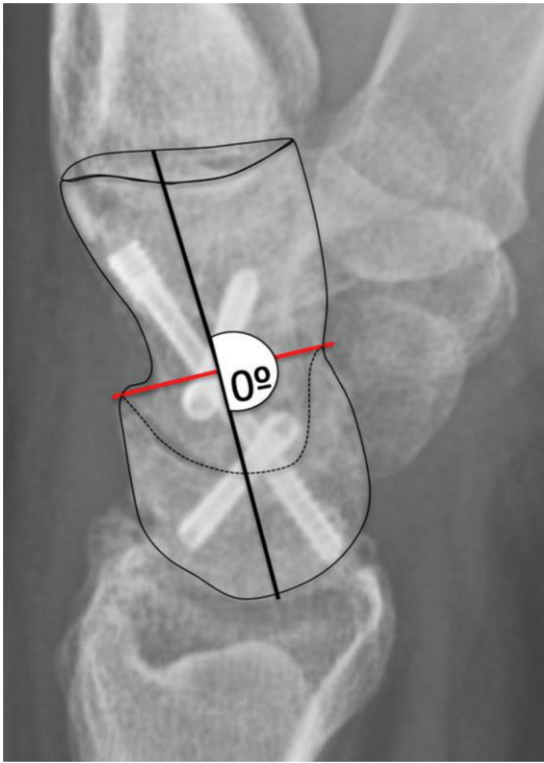


Fig. 1 Lateral X-ray of the wrist showing the measurement of the capitolunate angle.

with an elastic bandage and an ischemia cuff is used at a pressure of 100 mm Hg above the patient's diastolic pressure.

A "mini-open" approach is performed, consisting of a longitudinal approach on the anatomical snuffbox. The dorsal branch of the radial artery is dissected and protected, and the radial joint capsule is opened up to the scaphoid. The scaphoid is divided into two parts with a chisel, and the ligaments inserted in the scaphoid are released with a scalpel. Both poles of the scaphoid are resected with gouge forceps, and then a bone graft is taken from the same resected scaphoid (**►Fig. 2**). Under the radioscopic vision,

the reduction of the DISI is performed, correctly aligning the radius and the lunate in the lateral vision and fixing them with a 1.6-mm radius-lunate K-wire (**►Fig. 3**).

Then the traction of the extremity is made from the index and middle fingers with 15 pounds in the ACUMED (Hillsboro, OR) arc wrist tower, taking special care in the attachment point at on the arm, which must be on the tourniquet to prevent skin and neurological injuries.

Cubital midcarpal (C-MCP) and radial midcarpal (R-MCP) portals are made and diagnostic arthroscopy of the midcarpal joint is performed with a 2.7-mm scope to evaluate, under direct vision, the state of the articular cartilage of the carpal bones.

We proceeded to remove the articular cartilage of the lunate, triquetrum, capitate, and hamate with the hand motor and burr tip (**►Fig. 4**). The intermittent supply of physiological serum using a 20 mL syringe connected to the optics is important for joint cleaning and reducing the heat generated by the burr.

From the previously resected scaphoid, cancellous bone graft is taken, which is introduced into the joint space through a 2.5-mm drill protector from the small fragment set through the same midcarpal portals. The graft is accommodated, under arthroscopic vision (**►Fig. 5**), over the entire bone surface of the capitolunate joints and between the triquetrum and the hamate.

The fixation of the arthrodesis is made through percutaneous cannulated screws—first, the lunate, then the screw from the triquetrum to the lunate and, finally, a screw that fixes the triquetrum, hamate and capitate (**►Figs. 6 and 7**). The radiolunate K-wire is removed. The maximum ischemic time should be less than 120 minutes.

Finally, the portals and the radial "mini-open" are closed with Ethilon 5-0. Cleaning, ischemia removal, and installation of an antebrachial-palmar cast are performed. Clinical control is performed after 2 weeks for the removal of sutures, and the valve is maintained for 2 more weeks. After 4 weeks, the immobilization is removed, and kinesiology is started. The result with consolidation at 8 weeks is shown in **►Fig. 8**.

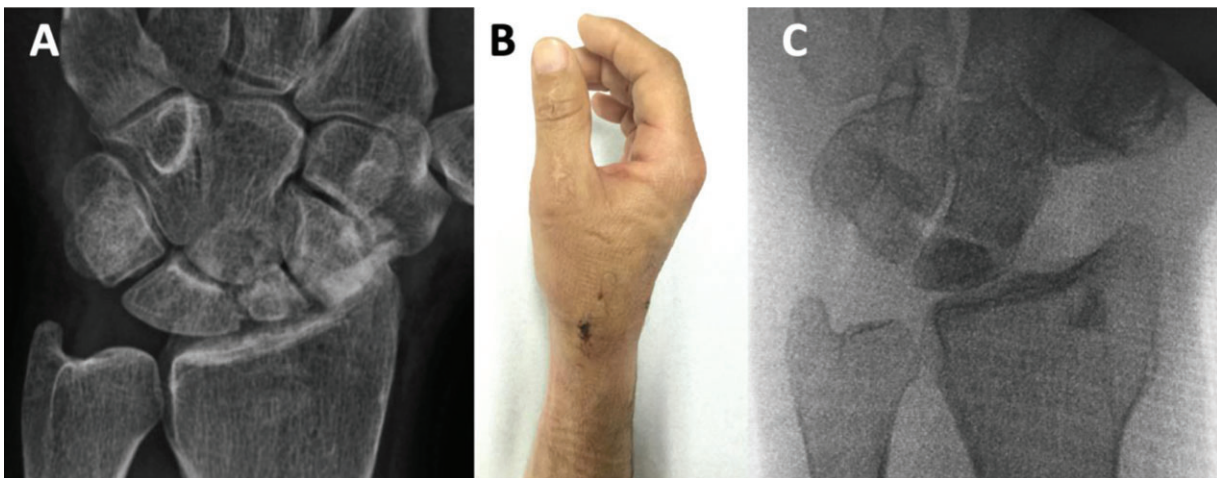


Fig. 2 Resection of the scaphoid by "mini-open" incision. (A) Preoperative anteroposterior (AP) wrist radiography. (B) Lateral image of the hand and wrist of a patient treated with percutaneous technique. The "mini-open" incision is observed. (C) Intraoperative AP wrist radioscopy showing complete resection of the scaphoid.

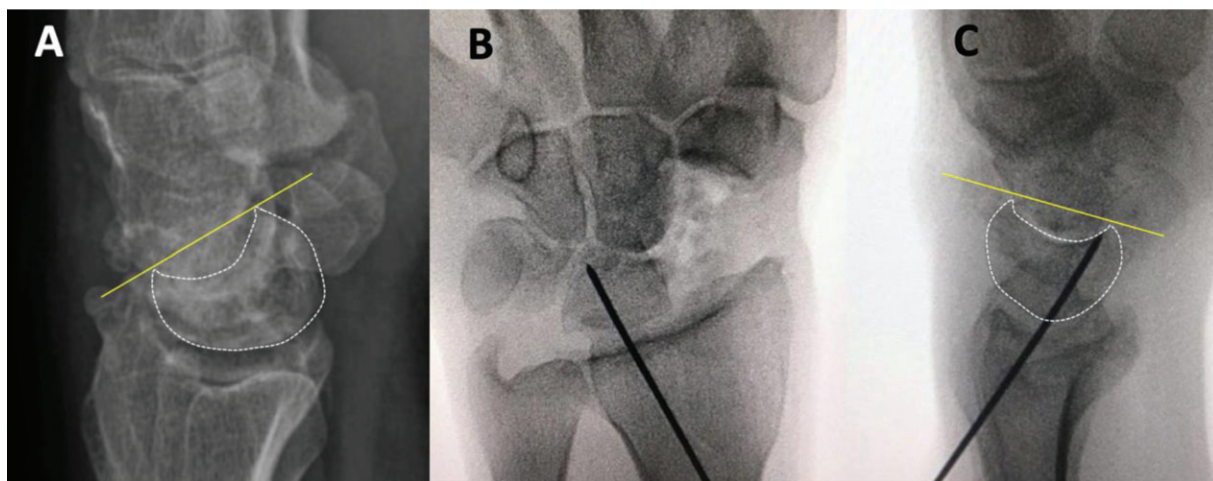


Fig. 3 Reduction of dorsal intercalated segment instability (DISI) by reducing the lunate. (A) Preoperative lateral X-ray of the wrist of a patient with DISI. (B-C) Intraoperative anteroposterior and lateral radiography respectively of lunate reduction with a radiolunate Kirschner wire.

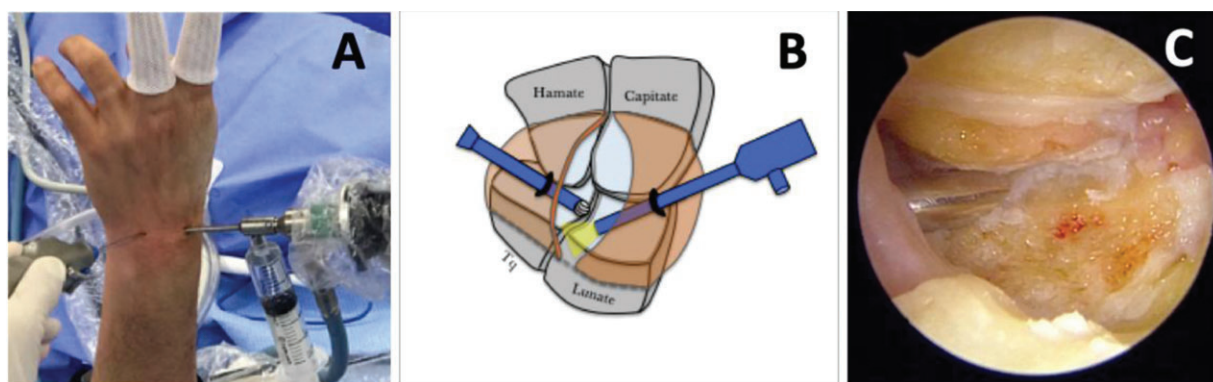


Fig. 4 Diagnostic arthroscopy of the midcarpal joint and resection of the articular cartilage. (A) Intraoperative diagnostic arthroscopy imaging of the midcarpal joint. (B) Scheme of midcarpal articular cartilage resection. Scope through radial midcarpal portal and working portal in cubital midcarpal portal with burr. (C) Arthroscopic image of articular cartilage resection result.

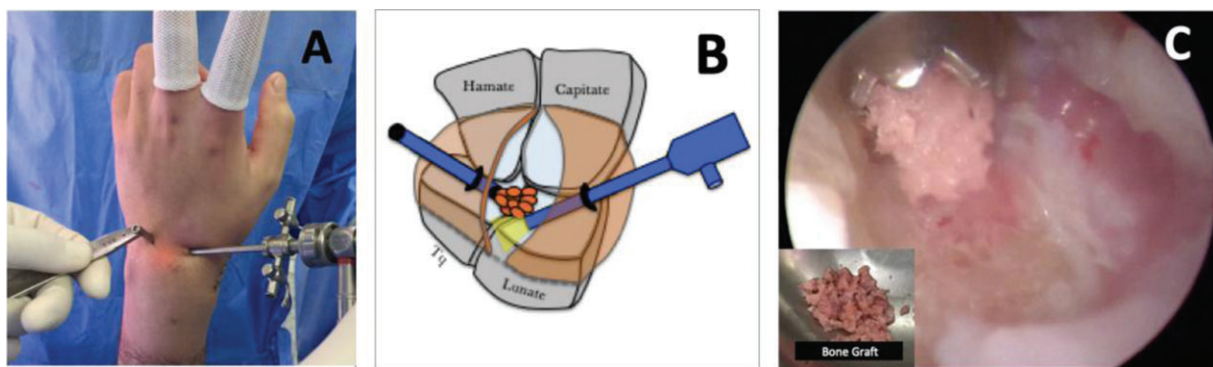


Fig. 5 Percutaneous bone graft on the midcarpal joint. (A) Intraoperative image of the graft placement through the cubital midcarpal portal (C-MCP) through a 2.5-mm drill protector. (B) Diagram of the graft placement through the C-MCP with the scope in the radial midcarpal portal (R-MCP). Arthroscopic image of the introduction of the graft in the midcarpal joint. The cancellous graft previously obtained from the resected scaphoid is shown.

Open Surgical Technique

A dorsal wrist approach is performed, dissection by planes until the opening of the joint capsule, according to Berger and Bishop.¹⁰ Then, the posterior interosseous nerve is identified and sectioned at the proximal level. After this, the scaphoid is excised with gouge forceps and bone graft is extracted from

it. The articular cartilage is resected with a surgical spoon and gouge forceps. A 1.25-mm K-wire is inserted into the lunate to be used as a joystick to reduce the DISI. Then, cancellous scaphoid bone graft, previously split, is added, and a bicolumnar fixation is performed with two 2.4-mm HFS (Synthes) cannulated screws.

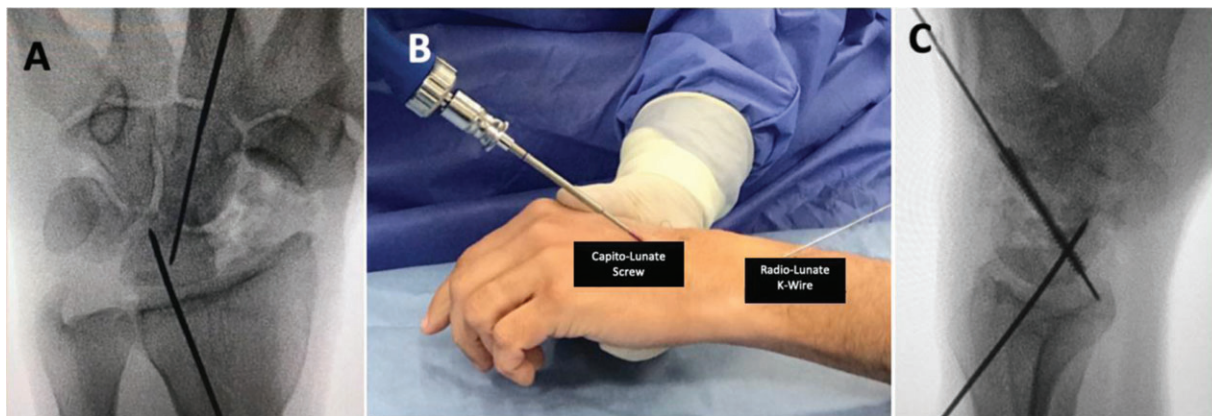


Fig. 6 Capitulum-lunate screw fixation. (A) Intraoperative anteroposterior wrist radiography. The capitulum-lunate K-wire and the drilling is shown. (B) Insertion of the capitulum-lunate screw. (C) Intraoperative lateral wrist radiography. The capitulum-lunate screw is shown.

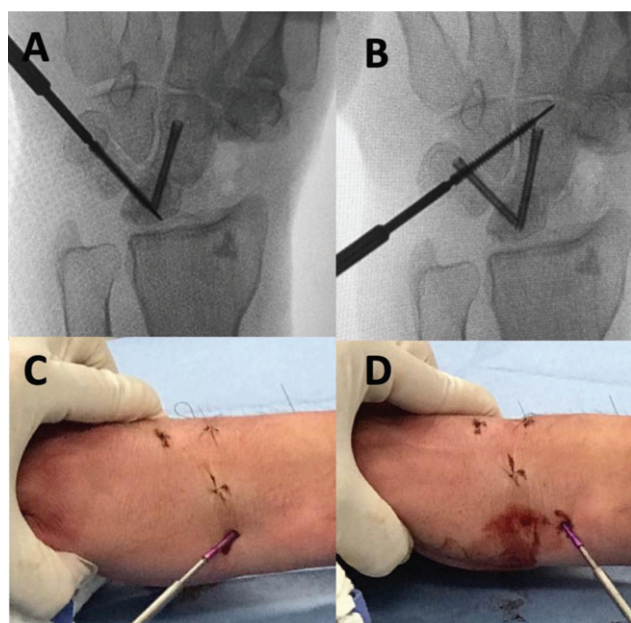


Fig. 7 Triquetrum-lunate and triquetrum-hamate-capitate screw fixation. (A) Intraoperative anteroposterior (AP) radiography showing the placement of the triquetrum-lunate screw. (B) Intraoperative AP wrist radiography. It shows the placement of the triquetrum-hamate-capitate screw. (C) Intraoperative clinical image of the triquetrum-lunate screw fixation. (D) Intraoperative clinical image of triquetrum-hamate-capitate screw fixation.

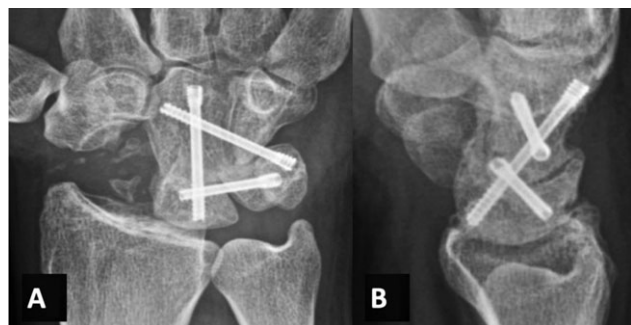


Fig. 8 Anteroposterior (A) and lateral (B) X-rays of a patient treated with percutaneous technique and arthroscopic assistance with bone consolidation at 8 weeks.

Results

We found nine patients in the control group and 13 patients in the case group, who were all males. The mean age of both groups was 32.5 years, being 32.3 years (standard deviation [SD] 6.6) in the control group and 32.6 years (SD 6.2) in the case group with no statistical difference with a *p*-value = 0.82. The average follow-up was 12 months, with a range of 6 to 18 months. All patients had an ischemic time of less than 120 minutes.

The results regarding pain are shown in ►Table 1, and the results regarding range of motion in ►Table 2.

The correction of the position of the DISI was measured using the capitulum angle, which was 10° (SD 3.5)

Table 1 Pain measured on a VAS at discharge and at 30 days and decrease in pain

	Control group	Case group	<i>p</i> -Value
VAS at discharge Median (range)	5 (3–8)	3 (1–5)	0.008 ^a
VAS at 30 days Median (range)	3 (1–5)	0 (0–0)	0.00 ^a
VAS decrease Median (range)	3 (1–5)	3 (1–5)	0.069

Abbreviation: VAS, visual analog scale.
Note: Mann–Whitney *U* test was performed.
^a*p*-value < 0. 05

Table 2 Cases and controls ranges of motion

	Controls	Cases	<i>p</i> -Value
Final flexion (mean–SD)	32.4 (SD 9.2)	38.7 (SD 6.3)	0.1119
Final extension (mean–SD)	35.7 (SD 6.4)	52.6 (SD 11.4)	0.0016 ^a

Abbreviation: SD, standard deviation.
Note: t-Student test was performed.
^a*p*-value < 0. 05

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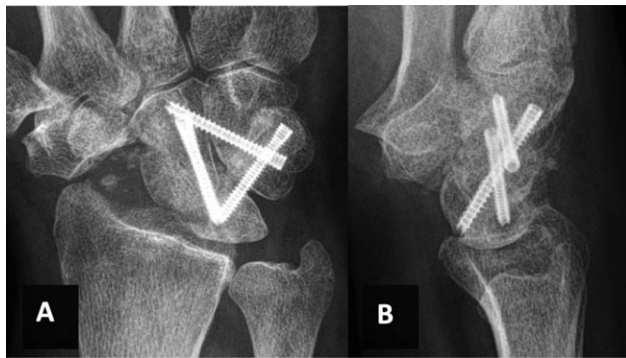


Fig. 9 Anteroposterior and lateral X-rays of wrist with 4-corner arthrodesis with percutaneous technique with arthroscopic assistance at 8 weeks. The configuration of the cannulated screws is shown.

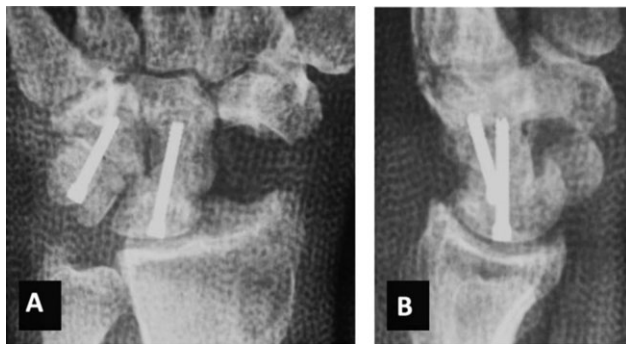


Fig. 10 Four-cornered arthrodesis anteroposterior and lateral wrist radiographs with the open technique with cannulated screws.

for controls and 5° (SD 3.5) for cases with a p -value of 0.0008.

The average consolidation time for controls was 12.5 (SD 1.58) weeks and 8.8 (SD 1.16) weeks for cases, with a p -value of 0.039.

There were no complications or drawbacks; the only inconvenience of the arthroscopic technique was that in the first cases, the ischemia time was around 120 minutes, and in the last operated patients, it was close to the 100-minute mark.

An example of the imaging results of a patient from the case group and another from the control group are shown in **►Figs. 9 and 10**.

Discussion

Four-corner arthrodesis is a salvage procedure for patients with advanced carpal arthrosis, such as patients with SNAC or SLAC wrists, reducing pain and preserving some degree of mobility.¹¹ The success of the surgery is based on obtaining consolidation of the capitulunate and hamate-triquetrum joints, achieving a correct reduction of the DISI.^{1,6,7,12}

This technique can be performed by percutaneous surgery with arthroscopic assistance with good results,^{6,7} with advantages over the open technique due to less damage to tissues, being a minimally invasive technique, greater protection of blood supply, preservation of proprioception, and better aesthetic results.^{6,7}

The present work shows the surgical technique performed by minimally invasive surgery with arthroscopic assistance with good results.

The results of pain at discharge and at 30 days postoperative are significantly better in the arthroscopic-assistance group. The patients included in this study had persistent chronic pain with a VAS greater than or equal to 4 in their activities of daily living, which is a product of their SLAC/SNAC wrist base pathology. Both techniques allow a reduction of pain in the short-term but significantly better results in patients treated with the percutaneous technique. We believe that this difference may be due to less soft-tissue damage associated with the surgical procedure in the percutaneous technique, but since it is not an isolable factor, it is not possible to make an adequate recommendation.

The consolidation time was significantly shorter in the group treated with percutaneous technique and arthroscopic assistance. Although we believe that minimally invasive surgery enhances bone consolidation, it is not possible to isolate this factor in the present work, since the configuration of the screws used differs in both techniques (**►Figs. 9 and 10**), which is a factor that may influence the stability provided by the osteosynthesis and modify the results to consolidation. Although there is no recommendation in the international literature regarding screw configuration, we believe that the one used in patients with percutaneous technique is the optimal one to achieve the necessary stability.

The use of cannulated screws has proven to be a technique with better results in pain and range of motion than other types of osteosynthesis,¹³ so we believe it is the most suitable method for 4-corner arthrodesis surgery.

The ranges of motion obtained in both patient groups were similar to those found in the literature^{7,8}. In our study, extension was significantly better in patients treated with percutaneous technique and arthroscopic assistance than those treated with open surgery.

The DISI correction, evaluated using the capitulunate angle, was achieved in both groups of patients with an angle within normal limits,^{14,15} and although there is a statistical difference in the correction of this angle in both groups, this should not have clinical repercussions since, as previously mentioned, the capitulunate angle is in the normal range in both groups.

In both groups that were part of the study, function was favorable by the end of the follow-up, achieving great range of flexion-extension mobility, with one completely pain-free wrist in the arthroscopic group and more limited range in the open group, accompanied by only mild discomfort.

We believe that the percutaneous technique with arthroscopic assistance and fixation with cannulated screws is a reproducible and effective technique in achieving consolidation and pain relief and maintaining a certain degree of wrist mobility, with these parameters being significantly better than in patients treated with an open technique. Prospective randomized comparative studies are needed to make a recommendation.

Conclusion

Four-cornered arthrodesis for patients with advanced carpal arthrosis is a reproducible technique with good results in terms of pain reduction, joint range maintenance, and bone consolidation. Both proposed techniques present favorable results, achieving 100% consolidation in our series. There are differences between both groups to the reduction of early postoperative pain and consolidation time, which cannot be attributed exclusively to the use of arthroscopic assistance.

Ethical Approval

The authors obtained the ethical approval from their Institution for the study.

Conflict of Interest

None declared.

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