360-degree Arthroscopic Management of Scaphoid Pseudarthrosis: Description of Technique and Indications

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Abstract: Nonunion remains one of the main complications of scaphoid fractures, with no consensus being reached as to the best surgical technique for scaphoid pseudoarthrosis. Thus, different types of procedures for bone stability and biological stimulus for consolidation have been described. The use of arthroscopy for scaphoid pseudoarthrosis has advantages as it allows for treating associated injuries, preserving wrist proprioception by minimizing damage to the joint capsule and ligaments and not deteriorating the already fragile scaphoid vasculature, leading to a quick recovery. Arthroscopy was initially indicated for stable scaphoid pseudoarthroses, being used in all patterns of this condition, including unstable ones and those with flexion collapse. However, most scientific articles describe the use of arthroscopy only through the dorsal portals, creating technical difficulty in complete debridement of the site of pseudarthrosis and in placing bone graft. This study describes the 360-degree technique, which standardizes arthroscopy in scaphoid pseudoarthrosis treatment, allowing, with the use of dorsal, volar, and radial portals, direct approach to the entire circumference of the nonunion site, facilitating the debridement of the injury site, the correction of the scaphoid deformity, and the placement of a graft directly on the site of the defect, mainly in its volar region after correction of the flexion deformity. The 360-degree technique aims to help and standardize the arthroscopic procedure for scaphoid pseudarthrosis, creating a routine with defined surgery stages. Additional portals allow complete access to the entire nonunion site and better positioning of the bone graft under direct view.

Key Words: scaphoid bone, pseudarthrosis, arthroscopy/use, grafts

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Nonunion has been one of the main complications in the treatment of scaphoid fractures, even with the advancement of imaging technology, which minimizes the risk of misdiagnosis with an adequate treatment being established. Once the scaphoid pseudarthrosis (SPA) is established, the wrist can progress with a degenerative pattern called scaphoid nonunion advanced collapse (SNAC), which causes loss of function and pain. Therefore, to prevent this serious problem, SPA, even in patients with few symptoms, must be surgically treated.[1–4]

In recent decades, there has been no consensus as to the best surgical technique to be used. Thus, different types of procedures to obtain bone stability associated with the biological stimulus to consolidation have been described. The classic treatment remains open surgery with the use of structured or cancellous bone graft, associated with fixation with cannulated compression headless screws (CCHS), Kirschner wires (KW), or even plates.[5,6] However, depending on the type of injury or the surgeon's preference, there are procedures using vascularized bone grafts, especially indicated in patients with vascular compromise of the proximal fragment.[7] Both approaches correct scaphoid deformity, restoring the anatomy and alignment of the carpus, and achieve bone healing in most patients; however, they require a broad approach that leads to damage to the joint capsule and ligaments, which may cause fibrosis, stiffness, and loss of proprioception.[8]

Recent studies have shown the advantages of the use of arthroscopy and minimally invasive procedures in the treatment of SPA. Their lower morbidity is highlighted, which leads to a fast recovery and allows the treatment of associated injuries during the procedure. Moreover, they preserve wrist proprioception by minimizing damage to the joint capsule and ligaments and do not worsen the already fragile vasculature of the scaphoid. Thus, the use of arthroscopy in the treatment of SPA combines the benefits of other techniques with rigid bone fixation with CCHS, essential for stability and preservation of scaphoid vascularization, generating biological stimulus.[9–11]

Because of the difficulty of correcting scaphoid flexion and pronation deformity, arthroscopy was initially indicated for stable SPAs located in the neck and tuberosity area, with no flexion deformity (humpback), no carpal instability [dorsal intercalated segment instability (DISI)], and no degenerative alterations (SNAC). As a result, the vast majority of patients with SPA could not be treated with this technique and underwent open surgeries.[11] However, studies on open surgeries proved that the use of unstructured cancellous graft in SPA with collapse leads to excellent clinical results and high consolidation rates.[12,13] In accordance with that, and with technical improvement and the increase in the number of patients treated, the arthroscopic technique began to be indicated and used in all patterns of SPA, being recommended in unstable lesions, with humpback deformity and flexion collapse, and in the SPAs of the proximal pole, with an avascular fragment and even in patients with initial degenerative impairment (SNAC I) located in the radial border of the scaphoid fossa of the distal radius.[10,14–16]

However, until recently, most scientific articles have described the use of arthroscopy in the treatment of SPA using only the dorsal portals in the procedure, with the midcarpal ulnar (MCU) portal being used for optic positioning and visualization and the midcarpal radial portal (MCR) as working portal for instrumentation and bone graft insertion.[13,17–21] With this technique, we observed difficulty in the complete cleaning of the nonunion site, in the direct visualization of the reduction of the scaphoid, and in the placement of the bone graft (Figs. 1 and 2).

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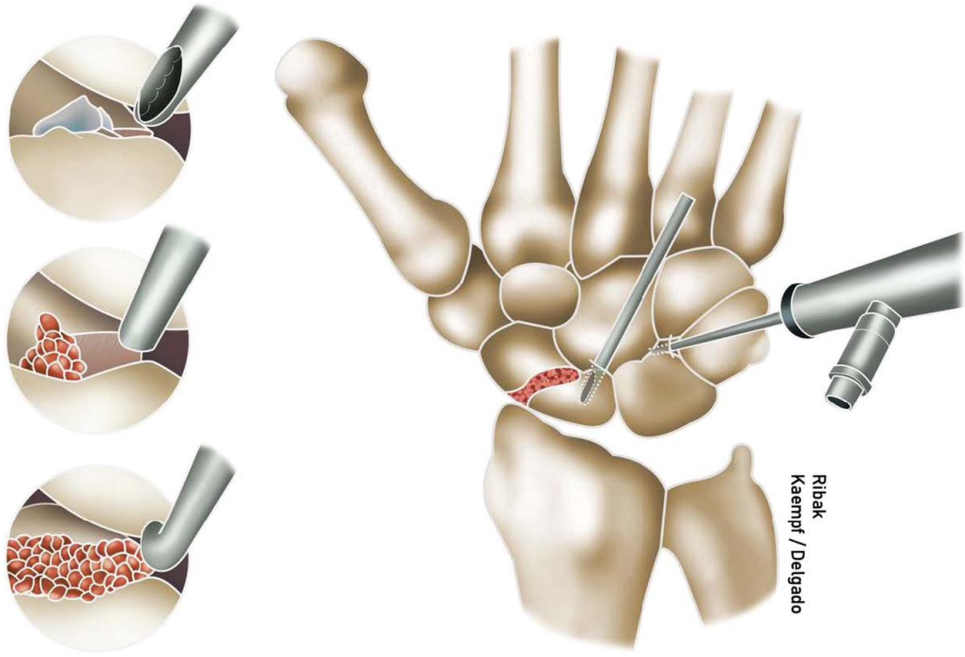

FIGURE 1. Technique initially proposed for the treatment of stable pseudarthrosis of the scaphoid using arthroscopy, where only the dorsal portals were used in the procedure, with the ulnar midcarpal portal being used for optic positioning and visualization, and the radial midcarpal portal being used as the working portal for debridement of the site of the injury and insertion of the bone graft.

ANATOMY

Some anatomic peculiarities of the scaphoid shall be considered when choosing the technique for the treatment of SPA. The first concerns its vascularization. The scaphoid is covered by cartilaginous tissue over almost its entire surface, with few entry sites for nutrient arteries, most of which are located on its dorsal crest and on the tuberosity.[2] The use of techniques that use broad approaches leads to greater soft tissue damage when compared with minimally invasive techniques. In addition, the arthroscopic technique allows complete visualization of the injury and reduces the risk of damage to the vasculature of an already altered bone.

FIGURE 2. Image during surgery showing the difficulty in accessing the radial and volar portions of the scaphoid through the ulnar midcarpal portal.

Another peculiarity regards the shape of the scaphoid in unstable SPA. Over time, the scaphoid tends to flex and pronate, causing resorption of the volar cortical bone and the classic humpback deformity. Using only dorsal portals, after reducing the scaphoid and aligning the proximal row of the carpus, the dorsal cortex closes, and a defect will be created in the volar portion of the scaphoid. Thus, using the 1/2 and the volar transcaphoid (VTS) portals, direct access to the site of the SPA is achieved, facilitating the positioning of the graft, which is difficult through radiocarpal dorsal portals.[4]

Here, we will describe an unprecedented procedure that standardizes the use of arthroscopy in the SPA treatment, called the 360-degree technique. This technique, with the use of dorsal, volar, and radial portals, allowed the direct approach of the entire circumference of the nonunion site, facilitating complete debridement of the lesion, correction of the deformity, and the placement of a graft directly on the site of the defect created, mainly in its volar region after correction of the flexion deformity.

INDICATIONS/CONTRAINDICATIONS

The 360-degree technique is indicated for patients with SPA with at least 6 months of progression of the initial trauma. It can be used and is indicated in all patterns of SPA, in unstable lesions, with humpback deformity and flexion collapse. It is also recommended in the SPA of the proximal pole, with an avascular fragment, and even in patients with initial degenerative impairment (SNAC I).

We contraindicate this technique for patients with SPA located in the proximal fifth, where the proximal fragment does

not have enough bone volume for screw fixation. This technique is also contraindicated for patients with moderate and advanced SNAC; in these cases, salvage techniques are indicated.

Previous surgery on the scaphoid and vascular alteration of the proximal pole of the scaphoid are not considered contraindications for the 360-degree technique.

Description of the 360-degree Technique

The procedure is performed under brachial plexus block anesthesia and sedation, with the patient in supine position and using a pneumatic tourniquet. We used a specific wrist traction tower for arthroscopy, with finger traps placed on the second and fourth fingers. In this procedure, we use classic approaches with 3/4 and 6R dorsal radiocarpal portals (DRCPs) and radial and ulnar dorsal midcarpal portals (DMCPs) for a complete wrist examination. We added the 1/2 DRCP and VTS portal, which allow circumferential access to the nonunion site. The use of fluoroscopy is also essential in this procedure (Fig. 3).

The first stage of the surgery is the inspection of the radiocarpal and midcarpal joints to assess possible associated injuries, such as chondral, intrinsic ligament, and triangular fibrocartilage injuries.

To access the site of SPA, the MCU is initially used for viewing (optic), and the dorsal midcarpal (MCR) is used as the working site (probe, shaver, curettes, and osteotomes). The site of SPA is initially explored through the dorsum of the scaphoid, being opened with a periosteal elevator (Freer of 3 mm), then undergoing debridement of soft tissue and bone with shaver. Then, the fibrous tissue and devitalized bone fragments are removed with the aid of curved curettes and delicate osteotomes. We use the dry arthroscopic technique for most of the procedure, with saline solution used only for joint cleaning and removal of fragments of the removed tissues.

After the debridement of the dorsal and ulnar portions of the scaphoid through the dorsal portals, the 1/2 DRCP and the VTS are made (Fig. 4). The 1/2 DRCP is made using the "outside-in" technique, where with the help of a needle and guided by the optic transillumination, the portal is found from the outside to the inside. In the VTS, the safest way is through the "inside-out" technique, where the volar capsule is pierced, also with the use of a needle and having a direct view of the interior of the joint; subsequently, directly at the tip of the needle, a small incision is made in the skin. One trick to help avoid neurovascular damage to volar noble structures is to using the MCR portal, and instead of using a needle, push a blunt trocar through the volar capsule aiming at the flexor carpi radialis tendon until it reaches the volar skin, and a small incision is made directly on the tip of the trocar. The MCU portal is used for visualization during the maneuver, and this portal is only possible in fractures and nonunions of the scaphoid, with the optic penetrating the defect. Once portals are made, sometimes they must be widened with hemostatic forceps for the introduction of the shaver. This way, we can position the optic in the radial DMCP, and through the 1/2 DRCP and the VTS, we obtain better reach for the arthroscopic debridement of the radial and volar portions of the site of SPA.

In SPA of the middle or distal third, or when radius styloidectomy is recommended, the VTS and 3/4 portals can be alternated as points for view (optic), with the burr being inserted in the 1/2 portal. This switching of view and working portals can also be done, according to the needs, for full access of 360 degrees to the site of SPA, using radial DMCP, 1/2 DRCP, and VTS.

After complete debridement of the site of SPA, the next stage is the correction of the DISI deformity of the proximal row of the carpus, which is obtained by fixing it with a 1.5 mm KW, introduced percutaneously, with entry into the dorsal region of the distal radius to the lunate (Linscheid maneuver). The lunate must come out of its pathologic position in extension (DISI) and be reduced to the neutral position. This is achieved by flexing the wrist, and this movement also automatically reduces the proximal pole of the scaphoid (Fig. 5).

Afterward, the cancellous bone graft shall be placed in the site of the SPA. This can be done with an insulin syringe with its tip cut obliquely to facilitate the entry and positioning of the graft, or even with the use of tweezers through the portals for insertion of the bone, which will later be pushed into the defect. Sometimes, due to the initial flexion deformity of the scaphoid, with its subsequent reduction, a bone defect is created in the volar region, and the placement of the bone graft may be easier through the 1/2 DRCP and the VTS. This trick also allows the homogeneous and circumferential bone cavity filling within the scaphoid fragments. After placing the graft in the nonunion site, it shall be impacted with the back of a curette or with the periosteum elevator.

The last stage of the procedure is the reduction of the distal pole and fixation of the scaphoid with the CCHS. For this, the wrist is removed from the traction tower and placed with the

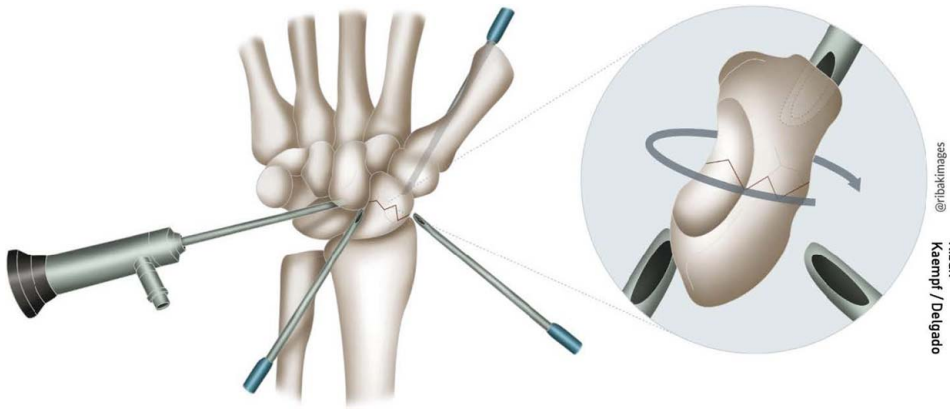

FIGURE 3. In the 360-degree technique, we used the radial and ulnar midcarpal dorsal portals, the 1/2 radiocarpal portal, and the volar radial portal, which allow circumferential access to the entire site of nonunion.

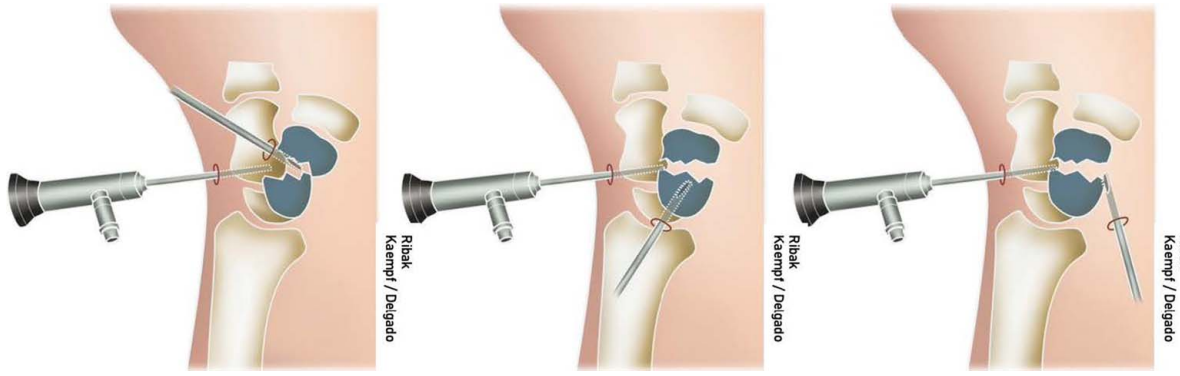

FIGURE 4. Figure showing access to the dorsal and radial portions of the scaphoid through the radial midcarpal portal, with the radial portion accessed through the 1/2 portal and the volar region through the volar radial portal.

palm upward on the hand table. For the reduction of the distal pole, the wrist has to be positioned at maximum extension, a maneuver that also improves alignment and leads to scaphoid length gain. We routinely use the retrograde percutaneous fixation technique for the SPA of the middle and distal thirds. This technique initially uses a guide wire, which shall enter right into or adjacent to the trapezium. Once the wire is fixing the 2 fragments of the scaphoid and is central in its longitudinal axis, it shall serve as a guide for the placement of the CCHS. For SPAs of the proximal third, we used antegrade fixation, which should be performed with the wrist in flexion and with the entry of the guide wire through the dorsum of the radiocarpal joint so that the screw is centrally located in the longitudinal axis of the scaphoid. The correct entry point for the guide wire and subsequently of the screw shall be found using arthroscopy and under direct visualization using an abocath. It shall be positioned in the proximal and ulnar part of the scaphoid, next to the insertion of the scapholunate ligament. Thus, with the abocath fixed in the proximal scaphoid, the guide wire is passed through it.

This procedure is usually performed on an outpatient basis. After the surgery, the patient is immobilized with a plaster splint on the wrist (forearm-palm), leaving the fingers and thumb completely free, for 2 weeks. We keep the KW fixing the radius to the lunate for 4 weeks. After this period, the splint is removed, and the patient is referred for hand therapy.

EXPECTED RESULTS

SPAs treated with the 360-degree technique consolidate in an average period of 7 weeks, and the patient is advised to use a removable orthosis on the wrist in activities requiring strength until consolidation is confirmed.

This rapid consolidation is obtained because the 360-degree technique combines bone stability, obtained by fixation with the CCHS in the longitudinal axis of the scaphoid, which will be arthroscopically ensured during fixation, with preservation of the scaphoid bone vascularization, an essential biological step for achieving consolidation. Moreover, alternation of all portals used in the debridement and bone grafting stages ensures the removal of all the SPA fibrous tissue, increasing the contact surface between the bone fragments.

COMPLICATIONS

Possible complications result from the arthroscopic procedure and percutaneous fixation of the scaphoid.[1] Among them is the

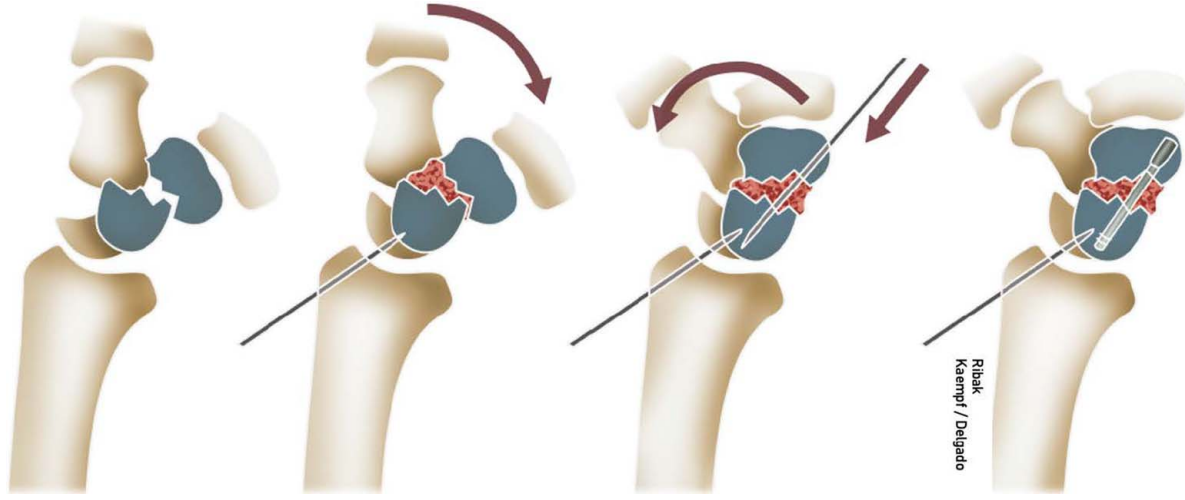

FIGURE 5. Stages of the Linscheid maneuver used to correct the DISI deformity of the proximal row of the carpus, where, after flexing the wrist, the lunate is fixed to the radius. This maneuver reduces the lunate and proximal pole of the scaphoid. With restoration of carpal alignment, the scaphoid can be fixed with a headless compression screw. DISI indicates dorsal intercalated segment instability.

FIGURE 6. Skin burn injury caused by constant and excessive use of a working portal, due to heating of shaver equipment. Complication that can be avoided with constant cooling of the equipment with saline solution and the alternation of the use of the portals.

lesion of the sensory branches of the radial nerve, especially in the preparation and use of the 1/2 DRCP, injury to the radial artery or its branches, especially in the VTS portal, and chondral injury from multiple instrumentation around the scaphoid. Such risks are minimized when the surgeon has training and practice in this type of procedure.[10] Neurotendinous injuries are rare in arthroscopic procedures when care is taken to use the classic portals for wrist arthroscopy. The arthroscopic technique also allows prevention of complications related to the size of the screw and its correct positioning.

The constant and excessive use of a working portal without constant alternation between them, due to shaver and burr equipment heating can lead to superficial burns on the skin, especially when using the dry arthroscopy technique (Fig. 6). This risk can be minimized by alternating the use of portals and constant cooling of the equipment with saline solution, which also helps in joint cleaning and tissue cooling.

Failure in bone reduction and fixation of the scaphoid can lead to complications, such as SPA nonunion. It can take place in this technique and in all others.

DISCUSSION

Postfracture scaphoid nonunion occurs mainly when there is a failure in the initial diagnosis of the injury, inadequate treatment, and in fractures located in its proximal region. The objective of the SPA surgical treatment is bone consolidation and also the recovery of the anatomy of the scaphoid, correcting the carpus alignment. Different techniques have been described for this purpose. Some of them prioritizes mechanical stability, including the use of plates and screws, and others aim to stimulate vascularization and tissue biology, using free and pedicled bone grafts, for early consolidation.[1,2,17,18,22] Minimally invasive procedures in SPA treatment are associated with lower morbidity, as they preserve the joint capsule and ligaments, structures that can be injured with open approaches, and can also keep wrist proprioception without causing greater damage to the already fragile vascularization of the scaphoid.[10,13,17,18,22]

Arthroscopy was initially indicated for stable and fibrous SPAs; however, with the technique improvement and the confirmation that there is no need for a structural graft to correct the

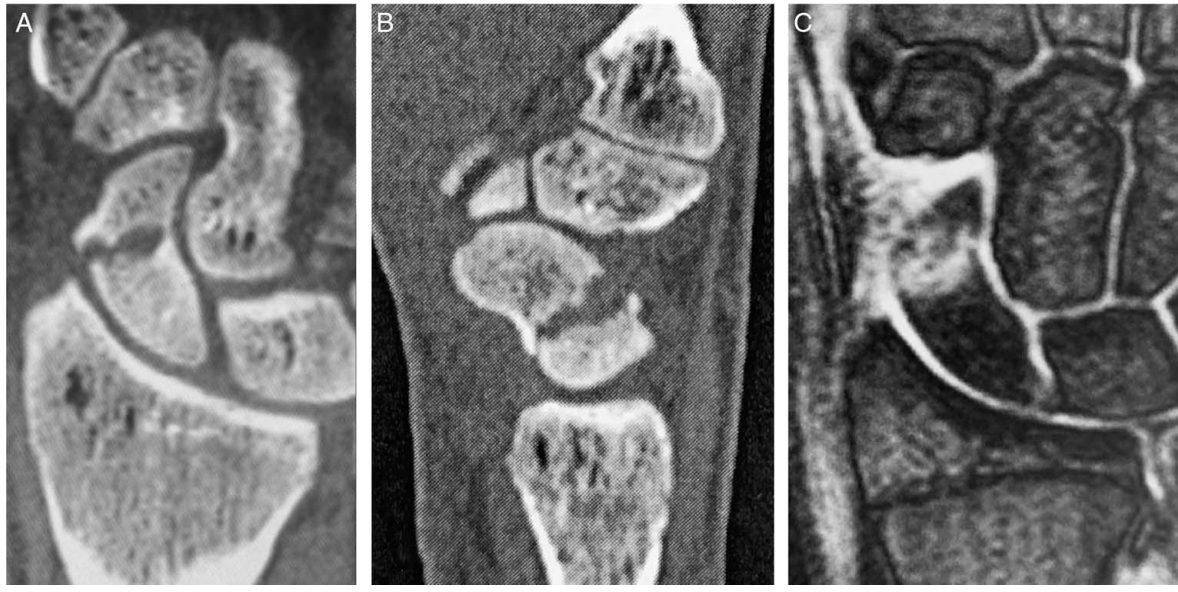

FIGURE 7. Male patient, 36 years old, with pseudoarthrosis of the scaphoid with 3 years of progression. Computed tomography confirms the injury and the flexion deformity of the scaphoid. Magnetic resonance image shows good vascularization of the fragments.

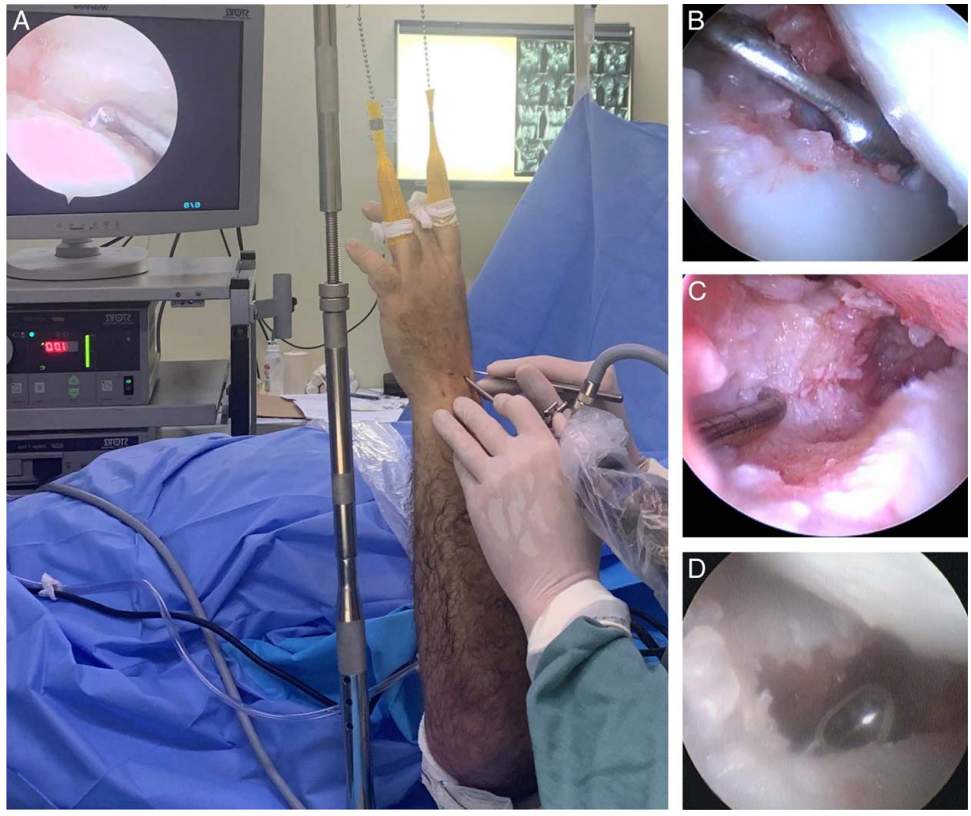

FIGURE 8. Surgical treatment of scaphoid pseudarthrosis using the 360-degree arthroscopic technique (A). It uses the radial and ulnar midcarpal dorsal portals to access the scaphoid dorsum (B), the 1/2 radiocarpal portal to access the radial region (C), and the radial volar portal to access the volar region (D).

deformity in scaphoid flexion, its use was expanded for unstable SPAs and those with collapse in flexion.[10,23] In chronic and unstable SPA, techniques using cortical and cancellous bone grafts (vascularized or not) offer the greatest guarantee of achieving bone consolidation and restoring carpus alignment and anatomy. However, as they are open techniques, they are aggressive to local tissues and neurovascular structures and may also damage the carpal extrinsic stabilizing ligaments. In addition, there is a risk of stiffness, infection, graft protrusion, and delay in achieving complete consolidation, with time varying in the literature between 12 and 19 weeks.[2,5,6]

The points of entry for arthroscopy equipment are called portals. For anatomic reasons, the most used portals for accessing the wrist joint are dorsal, thus avoiding iatrogenic injuries to the noble neurovascular structures, which are mostly located in the volar, radial, and ulnar regions.[1,10] Therefore, despite the large number of portals described, few are used routinely, with the mastering of dorsal portals being sufficient in most procedures. With technical improvement, volar and radial portals were described to compensate for limitations found in visualization through dorsal portals, with the access and repair of dorsal structures that are inaccessible through dorsal portals being our main purpose. For this reason, some authors have already described the use of portals located in the volar and radial regions in the treatment of scaphoid pathologies, although always in isolation and adjuvant to dorsal portals.[15,18,24,25] Golubev[26] showed the use of the volar portal, located between the flexor carpi radialis tendon and the radial artery, to obtain scaphoid elongation in his arthroscopic technique for the treatment of SPA without compression of the site of the injury. He even emphasized that with the use of an accessory volar portal, correction of the scaphoid deformity is achieved in a more effective, safe, and predictable way. Corella et al[27] described a volar central midcarpal portal that offers good visualization of the volar scaphoid and could also be useful for nonunion instrumentation and grafting. Zemirline et al[15] showed a technique where the volar portal is used for the insertion of a cannula that facilitates the placement of the bone graft removed from the distal radius. Cognet et al[19] highlighted the use of the radial midcarpal portal, which is located between the tendons of the radial wrist extensors (second compartment) and the extensor pollicis longus (third compartment), suggesting that this portal facilitates the debridement of the site of SPA and the graft placement. Other authors use the dorsal scaphotrapeziotrapezoid joint portal to access more distal pseudarthrosis.[17,18,28]

There is no rule regarding the type of bone graft to be used in the treatment of SPA. The technique described here associates the use of arthroscopy and cancellous graft in SPA.[12,29] We prefer the use of an iliac graft in patients with severe deformity and bone resorption. In stable SPAs with little deformity, we used a cancellous bone graft removed from the distal metaphysis of the distal radius.[15,29]

In the middle and distal third SPAs, dorsal shift of the lunate and instability in DISI of the carpus increase with disease progression. With this, the wrist develops the progressive degenerative condition called SNAC, which in its initial phase generates arthrosis between the styloid process of the radius and the portion of the scaphoid distal to the site of the SPA.[3] Type I SNAC is not a contraindication for scaphoid reconstruction, and

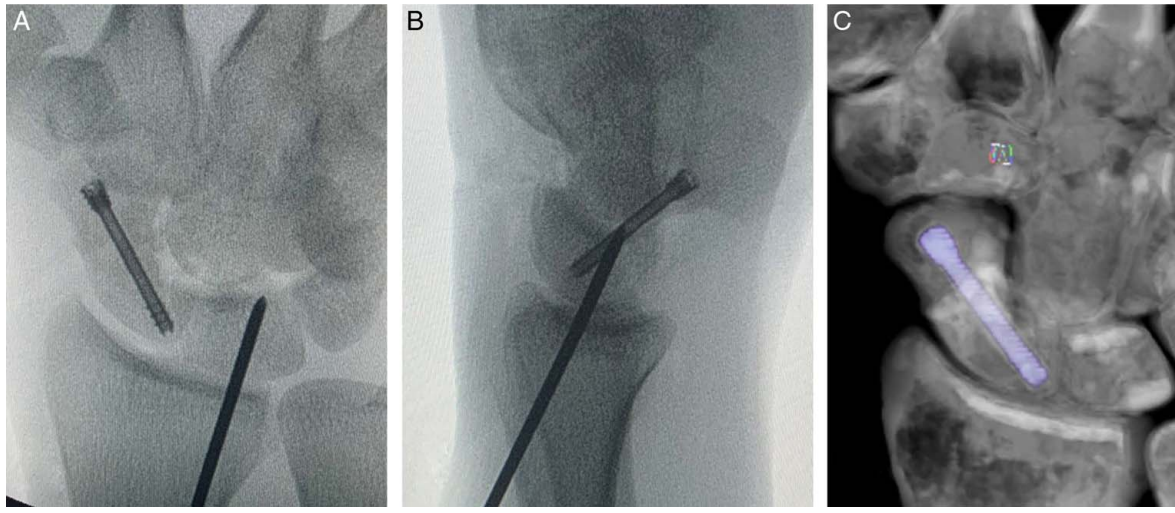

FIGURE 9. Intraoperative images with correction of the DISI deformity of the proximal row of the carpus using the Linscheid maneuver and fixation of the scaphoid with a headless cannulated screw (A and B). Computed tomography image with 3-dimensional reconstruction showing good positioning of the screw and consolidation of the pseudarthrosis 8 weeks after surgery (C). DISI indicates dorsal intercalated segment instability.

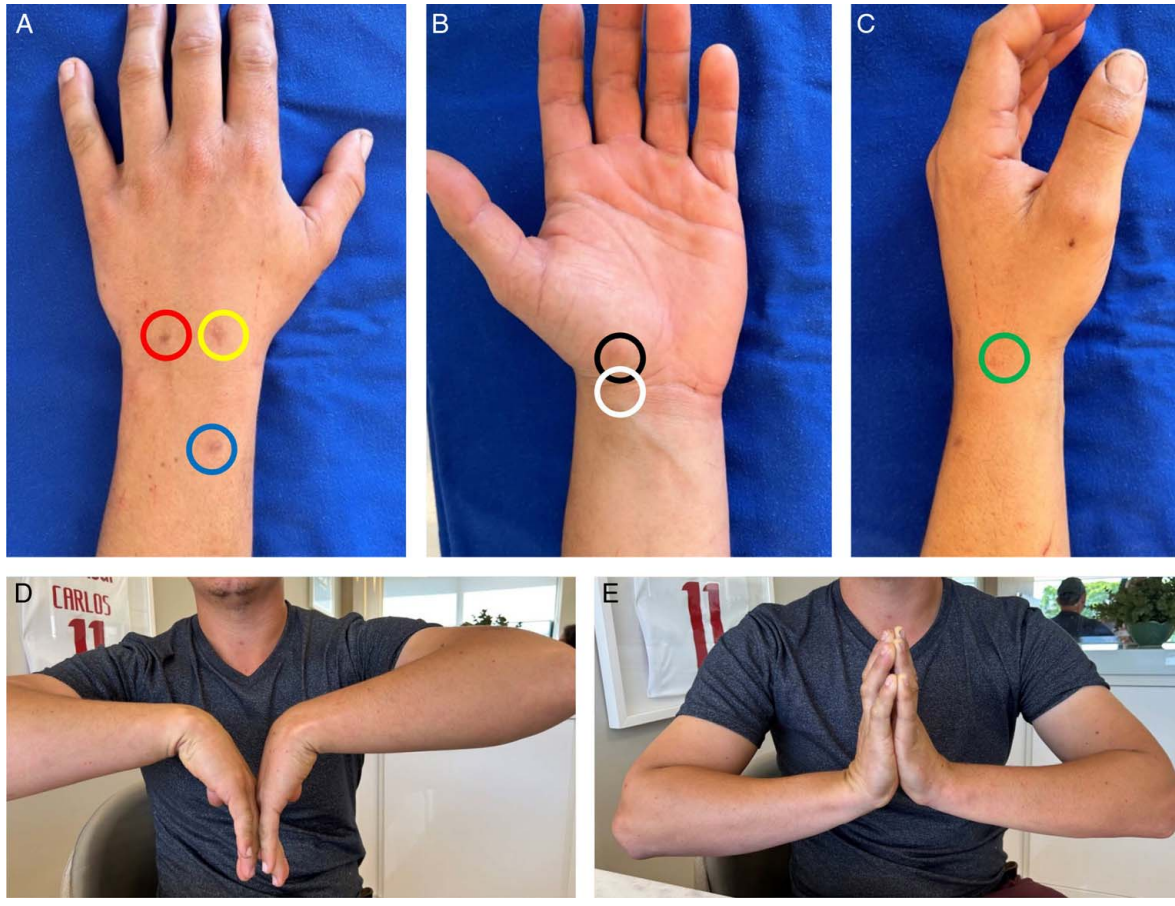

FIGURE 10. Images of the patient's hand showing the marks after the 360-degree arthroscopic procedure for the treatment of scaphoid pseudarthrosis. Ulnar (red) and radial (yellow) dorsal portals and Kirschner wire insertion site for the Linscheid maneuver (blue) (A). Volar transcaphoid portal (white) and insertion site of cannulated headless screw (black) (B). 1/2 Radiocarpal portal (green) (C). Mobility 6 weeks after surgery showing good functional recovery of the affected wrist (left) (D and E).

in these cases, radius styloidectomy is indicated through 1/2 DRCP.[1,22,26] This procedure, besides improving pain, creates space for access to the radial and volar portion of the scaphoid, which can be used for debridement of the nonunion site and to insert the bone graft directly into the radial and volar region of the scaphoid.

We know that this technique is demanding and that to perform it, the surgeon needs prior training in wrist arthroscopy. We consider arthroscopic treatment of SPA a procedure with a medium difficulty level in the learning curve. Thus, we advise that learning should always be started with simpler procedures, such as wrist ganglion resection, central triangular fibrocartilage injury, and even fixation of scaphoid fractures. We also advise the selection of a surgeon who has already had experience and confidence in using the conventional open technique and who, whenever difficulties with the arthroscopic technique arise, can revert the surgery to the open type at any time. Furthermore, it is important for physicians or the team to have their own routine in this procedure and make a box of special materials, such as delicate osteotomes, angled curettes, fine, and sharp periosteum elevators, which are useful materials the surgeons shall have at hand.[10]

CLINICAL CASE

A 36-year-old male patient presents to consultation with pain and stiffness in the left wrist after a fall in sports 3 years before, having suffered a fracture of the scaphoid. After history taking and physical examination, and through radiographs of the wrist, the patient's diagnosis of SPA was confirmed. He has SPA with classic characteristics, sclerosis in the bony borders, and cystic alterations. Before surgery, the patient underwent bilateral radiography of the wrists, computed tomography (CT), and MRI of the affected side (Fig. 7). He was also evaluated clinically through the questionnaire DASH and pain analog scale (VAS 0-10) for strength with the use of a Jamar dynamometer and for range of motion with a goniometer.

The procedure was performed according to the previous description of the 360-degree technique, with no complications (Fig. 8). Postoperatively, the patient underwent weekly dressings. The KW fixing the radius to the lunate was maintained for 4 weeks, a time in which the use of a splint on the wrist was indicated. After this, the patient was referred to rehabilitation. X-rays of the wrist in projections specific to the scaphoid were taken every 2 weeks until consolidation, which was achieved after 8 weeks of progression. We considered that the patient had bone consolidation of the lesion when, clinically, he presented no pain on palpation of the scaphoid, and on all radiographic projections or in at least 2 CT slices, there was a bone bridge between the 2 ends of the SPA. Therefore, CT was performed every 30 days (Fig. 9).

The final follow-up was after 4 years, and at that time, the patient showed an improvement in flexion range from 70 to 85 degrees, in extension from 70 to 80 degrees, in ulnar deviation from 20 to 25 degrees, and in radial deviation from 15 to 18 degrees. Pain improved from 7 to 1, and the DASH questionnaire improved from 46 to 8. The scapholunate angle improved from 70 to 50 degrees, and the radiolunar angle improved from 30 to 5 degrees (Fig. 10).

CONCLUSIONS

Wrist arthroscopy has become a valid alternative in the treatment of SPA, showing good clinical results and rapid consolidation, even in lesions with deformity and carpal instability. It combines the preservation of wrist vasculature and proprioception, with little soft tissue injury, to stable fixation through the headless compression screw.

However, the initial technical descriptions of the use of arthroscopy in the treatment of SPA use only the dorsal portals in the procedure, creating technical difficulties for the complete debridement of the site of pseudoarthrosis and also for the positioning and impaction of the bone graft, which should be positioned more in the volar region of the scaphoid, after correcting the deformity in flexion.

Therefore, the 360 degrees technique is an advance that came to help and standardize the arthroscopic procedure, creating a routine with defined steps during surgery. With the use of additional (radial and volar) portals, we achieved complete access to the entire site of pseudarthrosis, and we were also able to better position the bone graft under direct vision. This is especially useful in cases of severe flexion deformity when grafting of the anterior and radial parts of the bone may be difficult through standard techniques.

We know that to confirm these statements, we need a series of treated patients, with longer follow-ups, with patients being randomized into groups, comparing the different techniques. However, we can say that the initial results obtained with this 360 degrees technique are encouraging.

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