PRC+
An Augmented Alternative to Four Corner Fusion

In Sok Yi, MD
Peak Orthopaedics & Spine
Denver, CO, USA

Randall W. Culp, MD
Thomas Jefferson University
The Philadelphia Hand Center
Philadelphia, PA, USA

Introduction

Degenerative arthritis of the wrist occurs in specific progressive patterns[1-3] and 95% of those occur in the peri-scaphoid area[2]. In a comprehensive radiographic study, Watson et al. showed that the most common pattern (57%) occurred between the scaphoid, lunate, and radius; 27% of cases were observed between the scaphoid, trapezium, and trapezoid; a combination of these two patterns occurred in 15%[1]. The authors found it noteworthy that the radio-lunate joint was almost never involved.

Based on their findings, the authors introduced the term scapholunate advanced collapse (SLAC) as the leading form of degenerative symptomatic arthritis in the wrist[1].
The most frequently encountered posttraumatic form of wrist arthritis has been described as scaphoid nonunion advanced collapse (SNAC)[4]. Both SLAC and SNAC wrists follow a similar progressive pattern which has been well described in the literature (Table 1).

Table 1: Progression of Wrist Arthritis [1]

- **Stage I**: Radiostyloid scaphoid distal articulation arthritis.
- **Stage II**: Proximal radioscaphoid articulation arthritis.
- **Stage III**: Arthritis within the mid carpal joint.
- **Stage IV**: Pan-carpal arthritis with preservation of the radiolunate joint.

While there are many surgical treatment options for advanced stages of SLAC and SNAC, the most popular choices include proximal row carpectomy (PRC) and scaphoid excision with four corner fusion (FCF). This review is focused on the discussion of these procedures.

Treatment of SLAC and SNAC Wrist Arthritis

Initial treatment for all stages includes splint immobilization, anti-inflammatory medication, and steroid injections[5-7]. Symptomatic patients, who have failed non-operative management, may require surgical treatment.

For Stages I and II, surgical options include proximal row carpectomy and scaphoid excision with four corner fusion). Long term (17 years) results reveal similar clinical outcomes[8]: Active range of motion was slightly better after PRC; however, there were no differences in grip strength and patient-reported outcomes between the groups. The authors considered PRC technically easier with a shorter operating time, and a faster post-operative recovery, without the need for hardware removal. Four corner fusion showed a higher incidence in postoperative complications. In a systematic review of the literature comparing the two procedures for SLAC and SNAC wrists, Saltzman et al. evaluated seven studies (Levels I-III; 240 patients, 242 wrists)[9]. Four-corner fusion showed greater post-operative radial deviation and grip strength as a percentage of the opposite side. Wrist flexion and extension were better after proximal row carpectomy. The overall complication rate was more than twice as high with FCF (29%) compared to PRC (14%) with non-union having the highest incidence (7%).

Presently, the standard of care for young patients with Stage III is a four corner fusion while PRC with facial interposition is reserved for older, low demand patients. Motion preservation is normally the preferred treatment choice for younger patients in any other joint, with fusion being reserved as an end stage salvage procedure; however, midcarpal degeneration involving the head of the capitate is considered a contraindication for PRC particularly for younger patients less than 35 years with higher demands[10]. Stage IV arthritis requires total wrist arthroplasty or wrist fusion.

Overall, patient preference appears to be favoring motion preserving treatment options even in light of residual pain when compared to joint fusion procedures[11].

PRC Limitations

A substantially higher FCF complication rate and patient preference make PRC a more attractive solution for advanced wrist arthritis; however, the procedure is not without its shortcomings.

Kinematics

In a kinematic study following PRC, Blankenhorn et al.[12] found that the capitate had to flex and extend more due to the loss of the proximal row; radioulnar deviation was associated with more capitate translational motion, and radial deviation was restricted by impingement of the trapezoid on the radial styloid. Although overall wrist range of motion decreased after PRC, it was sufficient for activities of daily living, as reported by Palmer et al.[13].

Congruency

Following PRC, the load usually shared by the combination of the scaphoid and lunate articulations is transmitted entirely through the head of the capitate leading to increased contact forces[14]. Using MRI data, Hawkins-Rivers et al. determined the radius of curvature of the capitate to be only 37% +/-10 of the lunate fossa on the coronal view and to be 57% +/-10 on the sagittal (lateral) view. In addition, the study showed a large variation of the capitate's curvature affecting the surface area available for the transmission of joint reaction forces. A reduced surface area for force transmission and the incongruency in the lunate fossa are both leading to increased stress on this articulation. Although the clinical consequences of this mismatch after PRC are largely unknown, a low ratio of capitate to lunate curvature, particularly in the coronal plane, may predispose the joint to higher radiocapitate contact stresses, potentially leading to pain and accelerated cartilage degeneration[14].

In 2015, Lenoir et al. measured the radius of curvature of the tip of the capitate in 27 patients who underwent PRC and the congruency of the future radiocapitate joint[15]. At a mean follow-up of 59 months, the authors reported that the shape of the proximal capitate did not affect outcomes; however, in the frontal plane, a better radiocapitate congruency resulted in a significant increase in wrist flexion and better function. Poor congruency was associated with poor results for the DASH at 5 years[15].

Based on observed variations in capitate morphology, the potential for associated alterations in joint contact forces after proximal row carpectomy are evident. Despite the multifactorial causality of clinical outcomes, the inherent mismatch in articular morphology may be a contributing factor to suboptimal results[14].

Arthritic Stage

The success of PRC depends on relatively normal articular surfaces between the head of the capitate and the lunate fossa,[15,16]. Patients not considered suitable candidates for PRC are those with midcarpal degeneration and multicystic carpal disease which may weaken the subchondral support in the radiocapitate articulation[16].

PRC+ Solution: Augmentation with Hemiarthroplasty of the Capitate

PRC + expands a motion preserving treatment options into patients with midcarpal degeneration as the proximal pole of the capitate is replaced with a hemiarthroplasty that matches the surface curvature of the lunate fossa.

The new implant (HemiCAPITATE, Arthrosurface, Franklin, MA) was designed to treat Stage III arthritis of the wrist by augmenting the simplicity of a proximal row carpectomy with a capitate resurfacing rather than performing the technically challenging surgery of scaphoid excision and four corner fusion. This PRC+ procedure essentially converts the capitate into a lunate by transferring the curvature of the lunate fossa onto the capitate bone. In cases where the capitate demonstrates degenerative changes or the

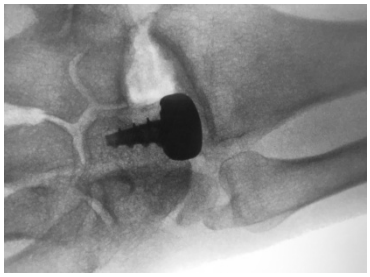
shape of the head is incongruent with the lunate fossa, the implant can be used to restore an anatomic articulation.

The system combines a conically shaped, titanium alloy fixation screw with a cobalt chrome modular resurfacing cap that are both connected via morse taper. Intraoperatively, the radius of curvature of the lunate fossa is measured using a series of mapping templates. There are two different sizes (12 or 15mm) and 6 different convexities. The implant has two surface curvatures, one coronal, and one in the sagittal plane, both of which mimic the native lunate anatomy[14] (Table 2). A 30% extension of the dorsal articular surface provides congruency throughout the full arc of wrist motion (Figure 1A).

Previous basic science and clinical studies have demonstrated excellent fixation strength of the HemiCAP Platform. Kirker-Head et al. reported on the safety, biocompatibility, and functional response following HemiCAP implantation[17] (Figure 2). Intraosseus fixation showed trabecular remodeling with bone abutting the anchoring screw and the CAP resurfacing implant. There was no evidence of medullary cyst formation. The increasing literature evidence supports the concept in the metatarso-phalangeal joint[18,19], talotibial[20,21], tibiofemoral[22,23], patellofemoral[24,25], femoroacetabular[26,27], and glenohumeral articulations[28,29].

The congruency limitation of PRC and the mismatch in the radius of curvature of the capitate and the lunate fossa can be effectively reduced using a hemiarthroplasty of the capitate. Furthermore, the anatomic variability of the capitate surface morphology is reduced using a lunate fossa matching implant. This may improve the reproducibility and comparability of the procedure to alternative treatment options by adding a standardized element to the technique. The comparison of PRC to the augmented PRC + technique using the capitate hemiarthroplasty demonstrates the potential advantages of the procedure (Table 3).

1A



1B

Figure 1
A) HemiCAPITATE Arthroplasty

B) AP postoperative radiograph following PRC+ with the capitate hemiarthroplasty articulating in the lunate fossa.

2A

2B

Figure 2
A) Low power histology of HemiCAP implantation in a caprine model at 26 weeks postoperative.
B) High power view showing bony abutment against the fixation component.

Table 2: Comparison of the Radius of Curvature[14]

Radius of Curvature (mm)	Lunate Fossa	PRC+	Capitate
Coronal	23.2 +/-5.9	17.02 – 27.94	8.1 +/-1.7
Sagittal	10.9 +/-2.0	9.02 – 12.70	6.1 +/-0.8

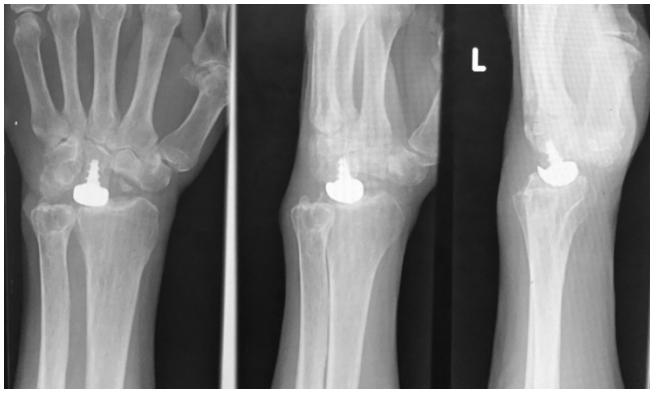
Table 3: Comparison of PRC and PRC +

PRC	PRC+
Congruency[14] • Radius of curvature mismatch between capitate and lunate fossa • Lower capitate surface area affects transmission of joint reaction forces and increases stress • A reduced surface area for force transmission and incongruity in the lunate fossa act synergistically to increase articular stress	**Congruency** • Radius of curvature of the capitate hemiarthroplasty matches the lunate fossa (Table 2) • Larger surface area matching the lunate fossa may reduce joint reaction forces and stress • Increased surface area with matching congruity in the lunate fossa reduces articular stress and may complement each other for improved outcomes
Reproducibility • Dependent on large anatomic variability[14] of the capitate	**Reproducibility** • Independent from anatomic variability of the capitate
Arthritic Stage • Not indicated for midcarpal arthritis	**Arthritic Stage** • Improves articulation in midcarpal, capitate arthritis
Survivorship • Progression of radiocapitate degeneration due to variable congruency particularly in younger and higher demand patients	**Survivorship** • Improved radiocapitate congruency may advance survivorship and treatment of younger and higher demand patients

Recommended Rehabilitation following PRC+

1. Immobilization for 3 weeks (cast or splint)
3. Removable wrist splint and range of motion on their own at 4 weeks
4. PT for range of motion and strengthening
5. Weight bearing at 2 months
6. Impact activities at 3 months

Case Study



Due to increased pain with the activities of daily living, patient underwent PRC+. At 3 months post op, the pain level was minimal with 30 degrees of extension, 35 degrees of flexion and 48 pounds of grip strength.

Figure 3:
Left: AP radiograph following capitate hemiarthroplasty
Center: Same patient, lateral view in flexion
Right: Lateral radiograph in extension

Conclusions

The loss of motion created by PRC cannot be restored with augmentation of capitate hemiarthroplasty; however, recreating the lunate on the capitate with PRC+ may provide improvement in surface congruency and predictability, expand PRC into midcarpal arthritis, and may support the use of this technique in younger, higher demand patients. PRC+ is an attractive alternative to scaphoid excision and four corner fusion. Future clinical studies are needed to confirm these conceptual benefits.

Key Words

Indications: Wrist Arthritis, Scapholunate Advanced Collapse (SLAC), Scaphoid nonunion advanced collapse (SNAC)
Procedures: Proximal Row Carpectomy (PRC), Capitate Hemiarthroplasty
Joints: Wrist

References

1. Watson HK, Ballet FL. The SLAC wrist: Scapholunate advanced collapse pattern of degenerative arthritis. J Hand Surg [Am]. 1984 May. 9(3):358-65.

2. Watson H, Ryu J. Evolution of arthritis of the wrist. Clin Orthop Relat Res. 1986;202:57–67.

3. Tischler BT, Diaz LE, Murakami AM, Roemer FW, Goud AR, Arndt WF 3rd, Guermazi A. Scapholunate advanced collapse: a pictorial review. Insights Imaging. 2014 Aug;5(4):407-17.

4. Culp RW, Williams CS. Proximal row carpectomy for the treatment of scaphoid nonunion. Hand Clin. 2001 Nov;17(4):663-9, x.

5. Trumble TE, Rafijah G, Alexander H, Waitayawinyu T. Scaphoidectomy and Capsulodesis for SNAC or SLAC Stage II. J Wrist Surg. 2012 Nov;1(2):129-34.

6. Bain GI, McGuire DT. Decision making for partial carpal fusions. J Wrist Surg.2012 Nov;1(2):103-14.

7. Shah CM, Stern PJ. Scapholunate advanced collapse (SLAC) and scaphoid nonunion advanced collapse (SNAC) wrist arthritis. Curr Rev Musculoskelet Med. 2013 Mar;6(1):9-17.

8. Berkhout MJ, Bachour Y, Zheng KH, Mullender MG, Strackee SD, Ritt MJ. Four-Corner Arthrodesis Versus Proximal Row Carpectomy: A Retrospective Study With a Mean Follow-Up of 17 Years. J Hand Surg Am. 2015 Jul;40(7):1349-54.

9. Saltzman BM, Frank JM, Slikker W, Fernandez JJ, Cohen MS, Wysocki RW. Clinical outcomes of proximal row carpectomy versus four-corner arthrodesis for post-traumatic wrist arthropathy: a systematic review. J Hand Surg Eur Vol. 2015 Jun;40(5):450-7.

10. Wall LB, Didonna ML, Kiefhaber TR, Stern PJ. Proximal row carpectomy: minimum 20-year follow-up. J Hand Surg Am. 2013 Aug;38(8):1498-504.

11. Neviaser RJ. On resection of the proximal carpal row. Clin Orthop Relat Res. 1986 Jan;(202):12-5.

12. Blankenhorn BD, Pfaeffle HJ, Tang P, Robertson D, Imbriglia J, Goitz RJ. Carpal kinematics after proximal row carpectomy. J Hand Surg Am. 2007 Jan;32(1):37-46.

13. Palmer AK, Werner FW, Murphy D, Glisson R. Functional wrist motion: a biomechanical study. J Hand Surg Am 1985;10:39–46.

14. Hawkins-Rivers S, Budoff JE, Ismaily SK, Noble PC, Haddad J. MRI study of the capitate, lunate, and lunate fossa with relevance to proximal row carpectomy. J Hand Surg Am. 2008 Jul-Aug;33(6):841-9.

15. Lenoir H, Toffoli A, Coulet B, Lazerges C, Waitzenegger T, Chammas M. Radiocapitate congruency as a predictive factor for the results of proximal row carpectomy. J Hand Surg Am. 2015 Jun;40(6):1088-94.

16. Calandruccio JH. Proximal row carpectomy. Journal of the American Society for Surgery of the Hand Vol. 1, No. 2, May 2001.

17. Kirker-Head CA, Van Sickle DC, Ek SW, McCool JC. Safety of, and biological and functional response to, a novel metallic implant for the management of focal full-thickness cartilage defects: Preliminary assessment in an animal model out to 1 year. J Orthop Res. 2006 May;24(5):1095-108.

18. Carpenter B, Smith J, Motley T, Garrett A. Surgical Treatment of Hallux Rigidus Using a Metatarsal Head Resurfacing Implant: Mid-term Follow-up. J Foot Ankle Surg. 2010 July - August;49(4):321-325.

19. Kline AJ, Hasselman CT. Resurfacing of the Metatarsal Head to Treat Advanced Hallux Rigidus. Foot Ankle Clin. 2015 Sep;20(3):451-63.

20. Anderson D, Tochigi Y, Rudert J, Vaseenon T, Bron T, Amendola A. Effect of Implantation Accuracy on Ankle Contact Mechanics with a Metallic Focal Resurfacing Implant.. J Bone Joint Surg Am, 2010 June, 1490-1500.

21. van Bergen CJ, van Eekeren IC, Reilingh ML, Gerards R, van Dijk CN. The Use of HemiCAP for the Treatment of Osteochondral Lesions. Oper Tech Ortho Vol 24, Issue 3, September 2014, pp 190–194.

22. Becher C, Kalbe C, Thermann H, Paessler HH, Laprell H, Kaiser T, Fechner A, Bartsch S, Windhagen H, Ostermeier S. Minimum 5-year Results of Focal Articular Prosthetic Resurfacing for the Treatment of Full-Thickness Articular Cartilage Defects in the Knee. Arch Orthop Trauma Surg. 2011 Aug;131(8):1135-43.

23. Miniaci A. UniCAP as an Alternative for Unicompartmental Arthritis. Clin Sports Med. 2014 Jan;33(1):57-65.

24. Provencher M, Ghodadra N, Verma N, Cole BJ, Zaire S, Shewman E, Bach B. Patellofemoral Kinematics After Limited Resurfacing of the Trochlea. J Knee Surg. 2009;22:310-316.

25. Feucht MJ, Cotic M, Beitzel K, Baldini JF, Meidinger G, Schöttle PB, Imhoff AB. A matched-pair comparison of inlay and onlay trochlear designs for patellofemoral arthroplasty: no differences in clinical outcome but less progression of osteoarthritis with inlay designs. Knee Surg Sports Traumatol Arthrosc. 2015 Aug 1.

26. Van Stralen RA, Haverkamp D, Van Bergen CJ, Eijer H. Partial Resurfacing with Varus Osteotomy for an Osteochondral Defect of the Femoral Head. Hip Int. 2009 Jan-Mar;19(1):67-70.

27. Lea MA, Barkatali B, Porter ML, Board TN. Osteochondral lesion of the hip treated with partial femoral head resurfacing. Case report and six-year follow-up. Hip Int 2014; 24 (4): 417-420.

28. Uribe JW, Botto-van Bemden A. Partial Humeral Head Resurfacing for Osteonecrosis. J Shoulder Elbow Surg. 2009 Sep-Oct;18(5):711-6. Epub 2009 Jan 30.

29. Sweet SJ, Takara T, Ho L, Tibone JE. Primary Partial Humeral Head Resurfacing: Outcomes with the HemiCAP Implant. Am J Sports Med. 2015 Mar;43(3):579-87.