Original Article

An Alternative Treatment Option for Scaphoid Nonunion Advanced Collapse (SNAC) and Radioscaphoid Osteoarthritis: Early Results of a Prospective Study on the Pyrocarbon Adaptive Proximal Scaphoid Implant (APSI)

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Abstract

Introduction: Scaphoid nonunion advanced collapse (SNAC) and radioscaphoid osteoarthritis are difficult to treat. Options include proximal row carpectomy (PRC), four corner fusion (4CF) and wrist arthroplasty or arthrodesis. However, with inevitable disease progression, a significant proportion of patients undergo total wrist fusion. This reduces function by abolishing wrist movement. We review the preliminary results of a pyrocarbon interpositional radiocarpal implant in a small cohort of patients from our prospective study and challenge the assumption that there are no surgical alternatives. Materials and Methods: This study prospectively studied 12 consecutive pyrocarbon interpositional arthroplasty day cases over 3 years. Patients were assessed using level of pain, ranges of motion, grip strength, key pinch, type of and time to return to work and the disabilities of the arm, shoulder and hand (DASH) score, both preoperatively and postoperatively. Radiographs were also taken and patient satisfaction recorded. Results: All 12 patients could be contacted and were satisfied with their surgery. There were no immediate, early or late postoperative complications associated with the procedure. Promising results were noted in terms of pain, ranges of motion, grip strength, key pinch, type of and time to return to work, DASH scores, photographs and radiographs. The mean follow-up was 18 months, range between 11 months and 3 years. Conclusion: Our early results are encouraging, warrant further and longer studies and support the use of pyrocarbon implants as a primary procedure in what is a generally young and active subgroup of patients.

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Introduction

Scaphoid nonunion advanced collapse (SNAC) and radioscaphoid osteoarthritis are well recognised conditions that are considered very difficult to treat, not only by general orthopaedic surgeons but also hand and upper limb specialists. Some of the more popular treatment options for SNAC wrists include proximal row carpectomy (PRC) and four corner fusion (4CF). A systematic review in 2009 compared these 2 procedures and found grip strength, pain relief and subjective outcomes to be similar in both treatment groups.[1] The same review also found that PRC provides better postoperative range of movement and lacks the potential complications specific to 4CF such as nonunion, hardware issues and dorsal impingement but has a significantly higher risk of subsequent osteoarthritis. Regardless of procedure performed, both have their own specific associated complications and see progression of disease with a significant proportion of patients needing further, technically difficult, major procedures, usually in the form of total wrist fusion which in turn reduces function by abolishing wrist flexion and extension.

With regard to osteoarthritis of the wrist, a variety of surgical options including arthroscopic wrist procedures, denervation, synovectomy, ulnar resection or replacement, arthrodesis and arthroplasty also exists, depending on the extent of arthritis.[2] Again, regardless of procedure performed, all have their own specific associated complications. In a recent article on midterm follow-up of universal total wrist arthroplasties, the authors reported 5 complications in

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their series of 21 patients.[3] With such complication rates as well as the issues previously mentioned, it is difficult to offer such procedures to patients and expect excellent results and patient satisfaction. Indeed if PRC or 4CF were considered as joint replacements are, current published results would not be acceptable. An alternative procedure in cases of SNAC wrists is to just resect part or all of the scaphoid. This however, results in collapse of the carpus and necessitates a further procedure. Previous attempts to replace the scaphoid have failed, primarily due to the material being too soft (silastic),[4] too hard (metal or ceramic) or causing severe synovitis.[5] A replacement with a material with Young's modulus close to bone may have better results. Such an option exists with the pyrolytic carbon (pyrocarbon) Adaptive Proximal Scaphoid Implant (APSI).

The APSI is a non-fixed orthopaedic pyrocarbon interpositional implant, designed to replace the proximal pole of the scaphoid.[6] With only 2 studies on the APSI showing promising results,[4,7] this paper presents the early results of a prospective study on pyrocarbon interpositional arthroplasty as an alternative treatment option for SNAC and radioscaphoid osteoarthritis with the use of the APSI.

Materials and Methods

This study prospectively followed 13 consecutive APSI arthroplasty day cases between 2008 and 2011 in 13 patients. However, as 1 APSI was converted to an Amandys (a different pyrocarbon interpositional implant)[8,9] for reasons explained later, and only followed up after the secondary procedure, our results are based only on 12 procedures in 12 patients. Exclusion criteria for day case surgery included patients being deemed medically unfit, travel time exceeding 1 hour, not having a responsible adult escorting the patient home and supervising them overnight as well as patients having a body mass index (BMI) of greater than 40. There were 10 men and 2 women. Age ranged from 26 to 71 years with a mean age of 45 years. The dominant hand was involved in 6 patients. Patients attended for pre-assessment the same day as their outpatient appointment and were given information regarding the procedure, day case protocol and postoperative physiotherapy regime. All procedures were performed under general anaesthesia and by the senior author, with tourniquet times recorded.

While insertion of the APSI has been described to be performed arthroscopically,[10,11] our surgical technique utilises a routine dorsal approach to the wrist between the third and fourth compartments. Additional mobilisation of the second compartment is also undertaken. In this way, access is made available to both the proximal scaphoid and the radial styloid. A styloidectomy may be necessary either in patients with concomitant radioscaphoid pathology or to accommodate the implant in order to eliminate dislocation via a cam effect. This will occur during movement of the wrist if scaphoid resection alone is insufficient to contain the smallest implant. Excessive scaphoid resection is to be avoided. Trial implants of varying size are tested under fluoroscopic control for stability between the surface of the radius and a congruous bony resection of the scaphoid. The correct size is one that allows a full range of motion without dislocating at the extremes. An implant that is, "stable on the table" will remain so in the long term once the soft tissues have healed. Styloidectomy should be carried out cautiously. No more than 7 mm in height should be excised as this risks detaching the extrinsic ligaments of the wrist. In addition, the floor of the first extensor compartment must not be perforated during removal of the styloid as this may provide a path for escape of what is an unconstrained implant. Any defect must be repaired securely along with the dorsal wrist capsule at the end of the procedure.

Rehabilitation commenced with a physiotherapy regime 3 weeks postoperatively, to allow time for encapsulation of the prosthesis prior to mobilisation. Prior to this, patients were fitted with Futuro splints that were kept on at all times, only allowing finger mobility. At 3 weeks, in order to prevent stiffness and increase the range of motion as well as reduce swelling and regain finger function, exercises consisted of gentle active and active assisted wrist movement, within the patient's comfort level only. Six weeks postoperatively, once the senior author was satisfied with the implant position radiographically, the Futuro splint was weaned off with the patient advised to use their hand for light activities of daily living such as dressing and preparing meals. At that stage, the aims of treatment were to further increase range of motion, build grip strength and strengthen the biceps, triceps, brachioradialis and any areas of weakness arising from the shoulder stabilisers. As wrist movement improved and functional movement achieved, strengthening of the wrist was progressed with particular importance placed on strengthening the extensor carpi ulnaris in supination for stability. Patients were followed up for 3 months following surgery with the goals of achieving adequate wrist range of motion and grip strength for good functional use of the hand and wrist. Further improvement over the subsequent 9 months was expected and explained to the patients.

Patients were assessed by a single physiotherapist using level of pain, ranges of motion, type of and time to return to work and the disabilities of the arm, shoulder and hand (DASH) score, both preoperatively as well as between 11 months and 3 years postoperatively with a mean of 18 months. Grip strength and key pinch were only assessed postoperatively due to the preoperative inability secondary to extreme pain. While we accept that measuring it preoperatively would have given a better picture for comparison postoperatively, this was deferred in the patients' best interest. Using a 2-sample t-test, data

were analysed using the MATLAB Statistics Toolbox (MathWorks, Natick, Massachusetts, 2007) to establish whether the differences between the mean values of the pain and DASH scores were statistically significant. This was performed with a 5% significance level (P <0.05) and the variance of each sample was assumed to be equal. At final follow-up, radiographs were also taken and patients were asked by the lead author if they were satisfied with their procedure.

Results

All 12 patients could be contacted but due to 2 having moved cities, only 10 were able to attend the follow-up and formed the basis of this study. With the indications for APSI arthroplasty being the posttraumatic changes following a scaphoid fracture, SNAC I and very proximal fractures, 6 of our cases were of stage I SNAC and 6 of radioscaphoid osteoarthritis. Based on the responses received by the lead author, 1 patient was satisfied and 11 very satisfied subjectively with their surgery, the 2 unable to attend giving their responses over the telephone. There were no immediate, early or late postoperative complications associated with the procedure. Though the single patient who was only satisfied with his surgery stated that his pain was much improved, he was unhappy because of the decreased active range of motion postoperatively (Table 3). In the case of the patient excluded from our study, she fell postoperatively while working as a prison guard and required replacement of the APSI with an Amandys (a different pyrocarbon interpositional implant)[8] secondary to a traumatic volar displacement of the implant as well as conversion from a SNAC to a SLAC. No complications were associated with the secondary procedure. Tourniquet times ranged between 19 and 42 minutes with a mean of 27 minutes. Pain scores as measured on a visual analogue scale (range, 0 to 100) were found to be much improved with a mean score of 19 (range, 0 to 45) postoperatively versus 81 (range, 50 to 100) preoperatively (P <0.05). All patients except 1 had better ranges of motion in terms of wrist flexion and extension and radial and ulnar deviation. In comparison to the contralateral side, wrist flexion and extension and radial and ulnar deviation were 54%, 67%, 58%, and 71%, respectively. A full range of pronation and supination remained unchanged except in 1 patient who saw an improvement. With all patients stating their grip was weaker preoperatively, the mean postoperative grip strength was 30 kg (range, 10 to 48), correlating to 65% of the contralateral hand. Mean thumb pinch, thumb key and thumb tripod strengths were 5 kg (range, 0.5 to 8.5), 8 kg (range, 1.5 to 11.5) and 7 kg (range, 2.5 to 13), correlating to 73%, 83% and 82% of the contralateral hand, respectively. Average time to return to work was 11 weeks (range, 0.5 to 20). Improved DASH scores were also noted with a mean of 20 (range, 4 to 48) postoperatively compared to 55 (range, 37 to 85) preoperatively (P <0.05). The specific DASH work and sport/instrument modules also showed improvements with a mean of 15 (range, 0 to 38) and 5 (range, 0 to 19) postoperatively, respectively compared to 57 (range, 38 to 100) and 64 (range, 38 to 100) preoperatively (P = 0.004, P = 0.008). The mean follow-up was 18 months with a range of between 11 months and 3 years. Tables 1, 2, 3 and 4 show a summary of these individual results. All postoperative radiographs at time of final follow-up noted excellent position of the implants and showed no progressive pathology. Figures 1 and 2 show both the preoperative and postoperative radiographs and postoperative clinical photographs of the patient who was only satisfied, to demonstrate findings in what we consider being the worst result in our study.

Table 1. Individual and Mean Visual Analogue Pain and DASH Scores

	Age (Years)	Sex	Follow-up (Months)	Dominant Hand	Preoperative Pain	Postoperative Pain	Preoperative DASH	Postoperative DASH
	71	Female	18	No	100	15	85	16
	47	Male	23			Unable To Attend Follow-Up		
	29	Male	28	No	68	20	38	13
	30	Male	14	Yes	87	33	62	38
	61	Female	12	No	87	20	72	48
	53	Male	12	Yes	50	12	37	5
	26	Male	26			Unable To Attend Follow-Up		
	67	Male	12	No	77	0	38	6
	47	Male	36	Yes	84	14	76	14
	44	Male	15	Yes	83	7	40	18
	38	Male	11	Yes	90	45	48	41
	30	Male	14	No	83	27	49	4
Mean	45		18		81	19	55	20

Table 2. Individual and Mean Lengths of Return to Work and DASH Module Scores

	Age (Years)	Sex	Follow-up (Months)	Dominant Hand	Occupation	Return To Work (Weeks)	Pre-Op DASH (Work)	Post-Op DASH (Work)	Sport/ Instrument	Pre-Op DASH (Sport/ Instrument)	Post-Op DASH (Sport/ Instrument)
	71	Female	18	No	Hairdresser	8	100	0	-	-	-
	47	Male	23				Unable To Attend Follow-Up				
	29	Male	28	No	Careers Advisor	0.5	0	0	Football Goalkeeper	44	0
	30	Male	14	Yes	Postman	28	56	38	Darts, Football, Fishing	100	0
	61	Female	12	No	Retired	-	-	-	-	-	-
	53	Male	12	Yes	Accountant	3	38	0	Golf	75	0
	26	Male	26				Unable To Attend Follow-Up				
	67	Male	12	No	Retired	-	-	-	-	-	-
	47	Male	36	Yes	Lighting Operative	20	75	31	-	-	-
	44	Male	15	Yes	Electrician	3	75	6	-	-	-
	38	Male	11	Yes	Labourer	12	50	38	Fishing	38	19
	30	Male	14	No	Factory Worker & Driver	16	63	6	-	-	-
Mean	45		18			11	57	15		64	5

Pre-Op: Preoperative; Post-Op: Postoperative

Table 3. Individual and Mean Ranges of Postoperative Active Motion at Final Follow-up

	Age (Years)	Sex	Follow-up (Months)	Dominant Hand	Flexion (Degrees) Pre-Op/ Post-Op	% of Contralateral	Extension (Degrees) Pre-Op/Post-Op	% of Contralateral	Radial Deviation (Degrees) Pre-Op/Post-Op	% of Contralateral	Ulnar Deviation (Degrees) Pre-Op/Post-Op	% of Contralateral
	71	Female	18	No	12 / 45	82	18 / 55	110	5 / 10	42	8 / 30	83
	47	Male	23									
	29	Male	28	No	52 / 78	92	42 / 51	65	26 / 24	77	39 / 37	95
	30	Male	14	Yes	0 / 34	45	0 / 5	9	0 / 10	42	0 / 5	10
	61	Female	12	No	10 / 12	16	33 / 38	60	4 / 8	36	19 / 22	76
	53	Male	12	Yes	70 / 27	36	58 / 55	79	20 / 10	46	29 / 26	84
	26	Male	26									
	67	Male	12	No	8 / 45	57	43 / 44	76	0 / 14	61	24 / 36	103
	47	Male	36	Yes	38 / 16	24	44 / 38	83	0 / 5	24	0 / 27	66
	44	Male	15	Yes	67 / 65	81	45 / 40	67	12 / 15	100	29 / 35	88
	38	Male	11	Yes	78 / 48	59	54 / 29	49	17 / 11	58	50 / 40	73
	30	Male	14	No	20 / 40	52	35 / 39	68	18 / 16	89	12 / 14	30
Mean	45		18		36 / 41	54	37 / 39	67	10 / 12	58	21 / 27	71

Pre-Op: Preoperative; Post-Op: Postoperative

Table 4. Individual and Mean Strengths of Gross Grip, Thumb Pinch, Thumb Key and Thumb Tripod

	Age (Years)	Sex	Follow-up (Months)	Dominant Hand	Gross Grip (kg)	Operated Side % of Contralatera	Thumb Pinch (kg)	Operated Side % of Contralateral	Thumb Key (kg)	Operated Side % of Contralateral	Thumb Tripod (kg)	Operated Side % of Contralateral
	71	Female	18	No	12	60	1.5	60	1.5	75	2.5	83
	47	Male	23				Unable To Attend Follow-Up					
	29	Male	28	No	48	109	5	91	9.5	86	9.5	100
	30	Male	14	Yes	12	21	0.5	10	6	75	2.5	21
	61	Female	12	No	10	39	2	50	3.5	64	2.5	50
	53	Male	12	Yes	44	79	7.5	88	9	95	11.5	110
	26	Male	26				Unable To Attend Follow-Up					
	67	Male	12	No	26	52	8.5	81	9	82	7	67
	47	Male	36	Yes	26	68	5	100	8	100	8	146
	44	Male	15	Yes	34	71	6.5	65	8.5	71	8.5	81
	38	Male	11	Yes	42	81	6.5	108	9.5	91	13	96
	30	Male	14	No	42	70	6.5	81	11.5	88	8.5	68
Mean	45		18		30	65	5	73	8	83	7	82

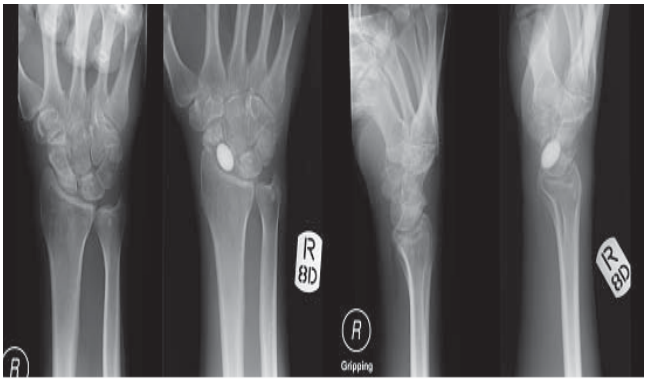

Fig. 1. Pre- and postoperative radiographs of a patient with an APSI for radioscaphoid osteoarthritis.

Fig. 2. Postoperative clinical photographs of the worst APSI in our study, the patient complaining of a reduced active range of motion compared to before surgery.

Discussion

Despite advances in orthopaedic surgery, surgical options for SNAC and radioscaphoid osteoarthritis continue to raise debate as to what is best for the patient. Salvage procedures like PRC and 4CF are 2 of the more popular operations but both have their own drawbacks, including loss of grip strength and movement, respectively. Another procedure, namely wrist arthrodesis, while surprisingly still considered to be the ultimate solution for post-traumatic wrist osteoarthritis,[12] unsurprisingly still results in poor hand function.[13] While many patients scheduled for these procedures are demanding in respect to the function they need in the wrist to enable them to return to work and leisure activities, this paper challenges the assumption that there are no surgical alternatives and promotes the use of pyrocarbon implants.

Pyrocarbon, with one of its properties being thromboresistant,[4] remains the most widely used material for mechanical heart valves and was first introduced into the medical industry by chance in the 1960s after artificial heart valves constructed from various other materials failed secondary to blood clotting.[14] With the ideal orthopaedic implant having characteristics that match those of bone, the APSI takes advantage of being manufactured from pyrocarbon. Not only does this make the implant thromboresistant but also biocompatible, biochemically inert, highly wear resistant and most importantly, very similar to cortical bone (same elastic modulus and density), the latter resulting in reduced chances of stress shielding.[15] However, its high cost may be a limiting factor in its use, especially in the current economic climate.

While the use of pyrocarbon implants in orthopaedic surgery is not novel,[16-18] only 2 studies on the APSI showing promising results[4,7] exist. Although the patient excluded from our study required a secondary procedure, this does not represent a failure of the initial procedure. This patient sustained a traumatic volar displacement of her APSI after a mechanical fall and converted to a SLAC from a SNAC soon after her primary procedure and had her APSI replaced with an Amandys. At the time of this study's final follow-up, the patient had already had her secondary procedure 8 weeks previously. As a result, her postoperative clinical course will be included in an ongoing prospective study on the Amandys implant. In the case of the single patient who had a reduced postoperative active range of motion, it should be noted that his passive range of motion was very similar to the contralateral side (Fig. 2) and that he did not attend the majority of his physiotherapy sessions. At the time of this follow-up study, he acknowledged this fact and has been given further instructions by the physiotherapist and is being followed up.

Compared to PRC, 4CF and total wrist arthroplasty or arthrodesis, the APSI offers quicker and less invasive surgery, better pain relief and a speedier return to a "normal wrist". In sole comparison to arthrodesis, an APSI is certainly a more viable and attractive option than a complete abolishment of wrist motion. In terms of functional range of wrist motion, a summary of PRC and 4CF results shows an average of 37 and 33 degrees of flexion, 41 and 34 degrees of extension and grip strength 78% and 74% of the contralateral side, respectively.[19] Comparing just these 2 procedures to the APSI, our study shows a similar range of motion with 41 degrees of flexion, 39 degrees of extension and grip strength 65%, 73%, 83% and 82% of the contralateral side in terms of gross grip, thumb pinch, thumb key and thumb tripod strengths, respectively. Should it fail, then the previous salvage options are not compromised as there is no evidence to suggest that any of these salvage procedures would be more difficult following APSI arthroplasty. With our current results, the senior author is of the opinion that there is no rationale for a major ablative procedure which has an uncertain long-term result and a high incidence of disease progression requiring major revision surgery with poor outcomes when an easy alternative offers the potential for better function. In cases where PRC, 4CF and wrist arthroplasty or arthrodesis are considered, we propose that the APSI may be a better option. It is understood that there is no long-term data for pyrocarbon interpositional arthroplasty of the hand. With the time scale of recovery known to be lengthy and often extending beyond a year following the previously mentioned salvage procedures, our early results are encouraging, support the use of pyrocarbon implants as alternative treatment options for SNAC and radioscaphoid osteoarthritis and warrant further, larger and longer studies. These studies should perhaps also categorise patients into age groups since 1 of the drawbacks in ours was too small a sample size to have any age-related differences evident from our results. Most importantly, pyrocarbon interpositional arthroplasty burns no bridges for further surgery and should therefore be considered as a first procedure in what is a generally young and active subgroup of patients.

Conclusion

Our early results are encouraging, warrant further and longer studies, and support the use of pyrocarbon implants as a primary procedure in what is a generally young and active subgroup of patients.

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