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Treatment of scapholunate advanced collapse by 3D-modelled scaphoid prostheses

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SUMMARY

A male patient in his 50s presented with severe bilateral wrist pain caused by scapholunate advanced collapse (SLAC). He did not wish to undergo a salvage treatment, and consecutively both affected scaphoids were replaced by 3D-modelled prostheses. 3 and 2 years postoperatively, the patient had significant pain reduction, good wrist function and grip strength. Final X-rays demonstrated no signs of dislocation of the implant or signs of periprosthetic arthritis. Studies have shown that once SLAC occurs, the treatment should consist of either a proximal row carpectomy or scaphoidectomy and four-corner fusion. In our case, despite collapse, replacement of the single affected bone by a 3D-modelled prosthesis led to good return of function.

BACKGROUND

Ruptures of the scapholunate (SL) ligament are often missed initially and only discovered when arthritis and collapse have commenced: a scapholunate advanced collapse (SLAC) wrist. SLAC is most commonly a consequence of undiagnosed or untreated SL ligament injury and rotatory subluxation of the scaphoid bone, resulting in radioscaphoid malalignment, progressive chondromalacia and osteoarthritis. Once arthritis is present, it is no longer worthwhile to reconstruct the SL ligament. Only salvage treatments like proximal row carpectomy, scaphoidectomy and four-corner fusion or total wrist arthroplasty are left to treat pain and loss of function.[1] We performed the first ever treatment of SLAC by replacing the collapsed and arthritic scaphoid by a 3D-printed titanium version. Because of the success of this approach, the patient's contralateral wrist was treated in a similar version. In this way, a situation where it is traditionally accepted that only salvage is possible, 3D techniques enabled us to reconstruct the wrist.

CASE PRESENTATION

A male patient in his 50s presented with severe bilateral wrist pain. As a professional cyclist, he had encountered several falls. By now, he could only cycle if he wore a wrist brace. Wrist radiographs demonstrated bilateral SLAC wrists (figures 1 and 2). Because he was still an active athlete, salvage techniques that all led to wrist shortening and therefore decrease in strength did not appeal to him. In search of a suitable solution, we tried to preserve the wrist length by replacing the collapsed and arthritic left scaphoid by a 3D-printed titanium version. We had had positive experiences with this procedure in a patient with a destroyed scaphoid.[2]

Figure 1 Preoperative X-rays of the right side demonstrating arthritis between the radius and the scaphoid.

1 year later, because of the success of this approach, the patient's right wrist was treated in a similar version (figures 3 and 4).

Manufacturing of the prosthesis

The customised scaphoid replacements are modelled using CT data for each individual patient. The 3D model of the patient's scaphoid includes a hole for

Figure 2 Preoperative X-rays of the right side demonstrating arthritis between the radius and the scaphoid.

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Figure 3 X-ray at 3 years follow-up demonstrating no signs of dislocation of the implant or signs of periprosthetic arthritis.

suture passing of the flexor carpi radialis tendon for fixation purpose (figure 5).

The custom-made scaphoid implants are manufactured by an additive technique using the electron beam melting (EBM) process.[3 4] This technology is based on forming layers of powder and alternate melting of these layers by an electron beam with bonding to the previous layer, as defined by the computer model of the part.

These implants are manufactured from a titanium alloy powder (TiAl6V4 – Tilastan-E), according to the process described, leading to the creation of the customised shape of the implant. Postprocessing

Figure 4 X-ray at 3 years follow-up demonstrating no signs of dislocation of the implant or signs of periprosthetic arthritis.

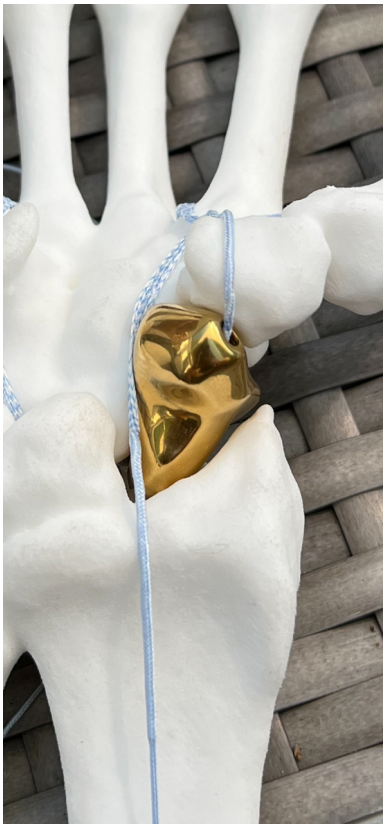

Figure 5 Volar detail demonstrating the fixation technique of the scaphoid prosthesis with a strip of flexor carpi radialis tendon through the printed hole in the implant.

Figure 6 Both sides of a model of the hand and wrist showing the 3D-printed prosthesis in position.

Figure 7 Both sides of a model of the hand and wrist showing the 3D-printed prosthesis in position.

includes steps of polishing and a hot isostatic pressing method to improve mechanical implant properties,[3 4] as well as the application of a golden-coloured ceramic PorEx (TiNbN – Titanium Niobium Nitride) coating, which significantly reduces the metal ion release of the substrate and shows low friction properties.[5 6]

Further postprocessing steps comprise cleaning, washing, packaging and sterilisation according to certified processes at the manufacturer (Link, Hamburg, Germany).

OUTCOME AND FOLLOW-UP

At 3 years follow-up, concerning the left wrist (figures 6 and 7), pain intensity had decreased from 6 to 0, patient-rated wrist/hand evaluation (PRWHE) from 62.5 to 4.5, quick Disabilities of the Arm, Shoulder and Hand (quickDASH) from 52.5 to 2.5, grip strength from 36.5 to 34.8 n, wrist flexion from 55° to 19° and wrist extension from 57° to 38°.

At 2 years follow-up for the right side, pain intensity had decreased from 5 to 1, PRWHE from 32.5 to 3, quickDASH from 15 to 2.5, grip strength from 45.8 to 44.9 n, wrist flexion from 40° to 29° and wrist extension from 60° to 57°. Final X-rays on both sides demonstrated no signs of dislocation of the implant or signs of periprosthetic arthritis. Although 3 years is quite a period, the follow-up might have to be longer to comment on the periprosthetic arthritis following the surgery.

DISCUSSION

The present study showed that a SLAC wrist can be treated by replacing the affected scaphoid by a 3D printed titanium version without loss of strength. The common salvage techniques for wrist arthritis, proximal row carpectomy and four-corner fusion are associated with either affected grip strength or mobility.[7 8]

Two recent retrospective case series concluded that 3D-printed titanium scaphoid replacement may be an alternative to salvage procedures for unreconstructable scaphoid non-union.[9 10] For the indication of destructed scaphoid replacement, it appeared to improve the range of motion and function. The procedure had never been described for SLAC wrists. Whereas replacing the scaphoid by 3D printed versions in two SLAC wrists in the present study led to a decrease in mobility, there was a vast improvement in function, a reduction in pain intensity and no loss of strength.

Watson and Ballet identified SLAC wrist as the most common form of wrist osteoarthritis, occurring in 57% of 210 patients with wrist osteoarthritis.[11] The fact that 3D printed scaphoid replacement works for both SNAC and SLAC wrists makes it useful for almost all forms of wrist arthritis.

The theoretical idea behind scaphoid replacement is that no wrist shortening occurs so that the tension of the flexor and extensor tendons remains the same. Indeed, our case maintained the same level of grip strength after surgery.

In the case of an SL rupture without arthritis, the ligament can be reconstructed to treat the patient.[12] In the case of radioscaphoid (RS) arthritis, the pain will not subside after ligament reconstruction alone. The present case suggests that changing bone-to-bone contact to metal-on-bone contact creates a non-painful situation. Because the presented procedure includes a ligament reconstruction as well, the progress of wear on the RS joint is prevented. Either only bone replacement or ligament reconstruction could not generate this success of the combination of both techniques.

A disadvantage of 3D scaphoid replacement is the added expense. For that reason, further studies will have to prove that the higher costs are justified.

Patient's perspective

Before the surgery, I experienced a lot of pain in my wrists. Simple tasks that most people take for granted became almost impossible for me. I could only mountain bike for short periods because the pain became unbearable after a while, and even something as basic as turning a screwdriver or using keys was out of the question. Essentially, every movement that involved turning my wrists or putting weight on them was painful. Work wasn't a problem since I don't need my hands for my job; otherwise, I wouldn't have been able to work. Initially, I thought it was carpal tunnel syndrome, but that turned out not to be the case. Through the hand therapist, I was referred to a plastic surgeon, who diagnosed me with a SLAC wrist. The surgeon presented a new option: to replace my scaphoid bone with a 3D prosthesis. After some consideration, I agreed, as it was a joint-sparing procedure.

The surgery went well. After the initial prosthesis, the stiffness and pain were significantly reduced. During the first three months, I couldn't do much, but after that, my strength began to return. Mountain biking became possible again without any issues, which motivated me to have the second wrist operated on.

Now, I have regained strength in both wrists, and the pain has almost completely disappeared. Tasks that once seemed impossible, like turning a screwdriver or mountain biking without pain, are now things I can do again without a second thought. The only difference now is the angle of my hands; push-ups are a bit more challenging, but this does not hinder my daily life.

Would I choose this treatment again? Absolutely. I had a lot of pain beforehand, but now I can do everything again. The first two weeks were the most challenging, but after that, the rehabilitation went smoothly. I can fully resume my daily activities and would recommend the treatment to anyone.

Learning points

- Scapholunate advanced collapse does not necessarily require a salvage procedure.
- Based on a CT scan of the affected wrist, it is possible to model the scaphoid that has to be replaced.
- Fear of dislocation of the implant or periprosthetic arthritis appears to be unfounded.

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Case reports provide a valuable learning resource for the scientific community and can indicate areas of interest for future research. They should not be used in isolation to guide treatment choices or public health policy.

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