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ORIGINAL PAPER
PŮVODNÍ PRÁCE

Stemless Hemiarthroplasty of the Shoulder Using the SMR® System: Summary of Six-Year Experience and Surgical Technique

Hemiartroplastika ramenního kloubu SMR® typu Stemless: operační technika a souhrn šestiletých zkušeností

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ABSTRACT

PURPOSE OF THE STUDY

In the last number of years, the anatomic hemiarthoplasty has gradually been pushed out of clinical practice by modern reverse shoulder arthroplasty (RSA) designs. This is due to the clear excellent functional results of RSAs in a wide spectrum of indication criteria. Nevertheless, RSAs have several possible complications that cannot occur in an anatomic hemiarthroplasty.

In anatomic hemiarthoplasty, the importance of correct indication criteria and observing correct operative technique including soft tissue reconstruction is much more important than in RSA.

Furthermore, there is a clear recent trend of increased use of humeral components fixed only in the proximal metaphyseal cancellous bone. Our aim was to summarise our six-year experience with the SMR® Stemless (LimaCorporate, Italy) system which is one of the most modern ones.

MATERIAL AND METHODS

Twenty cases of SMR® Stemless anatomic shoulder hemiarthroplasty performed between 2016 and 2021 were included in the study. All patients were followed up prospectively. The function was evaluated preoperatively and at the last follow-up. We evaluated the range of active elevation, classic Constant Score (CS) and pain level according to the visual analogue scale (VAS). Statistical evaluation was performed by using basic statistical methods and the statistical significance of the results was assessed with a paired t-test. Level of statistical significance was set at p= 0.01.

RESULTS

The mean follow-up in our cohort was 3.01 years (range 0.32-5.69, Median 2.82, SD 1.56) All cases were indicated for surgery due to primary osteoarthritis with a limitation of movement and pain. The mean postoperative CS was 85.7 (range 70–96, Median 86, SD 6.83). The mean active elevation postoperatively was 143° (range 100–170°, Median 150°, SD 20.76). Mean postoperative pain according to VAS was 1.05 (range 0-4, Median 1, SD 1.02).

The mean preoperative elevation was 60.5° (range 30–100°, Median 65°, SD 18.83). After surgery the mean elevation increased to 143° (range 100–170°, Median 150°, SD 20.76). Statistical evaluation showed a statistically significant increase in the CS (41.7 preoperatively to 85.7 postoperatively), range of active elevation (60.5° preoperatively to 143° postoperatively) and a statistically significant decrease in pain (VAS 6.95 preoperatively to 1.05 postoperatively).

We observed no cases of failure or loosening of the implant. A statistically significant increase in post-operative range of motion was demonstrated.

DISCUSSION

Most modern shoulder arthroplasty designs now include implants allowing for proximal humerus metaphyseal fixation in hemiarthroplasty and even RSA designs. The advantage of metaphyseal fixation without the use of a longer stem is clear. Notably, treatment of periprosthetic humeral fractures is simpler, extraction of the implant for any reason is easier and the preoperative anatomic position of the humeral head can be respected.

As with any anatomic shoulder arthroplasty, the functional result is dependent on correct indication criteria, precise surgical technique, correct humeral head position and soft tissue reconstruction – primarily the rotator cuff.

CONCLUSIONS

Between 2016 and 2021, we performed 20 SMR® stemless shoulder hemiarthroplasties for primary osteoarthritis. The mean follow up was 3 years. The shoulder function improved significantly post-operatively in all patients. There were no cases of implant loosening or failure. Radiographic evaluation showed no implant loosening or change in implant position in the humeral metaphysis.

Key words: shoulder joint replacement, reverse shoulder arthroplasty, SMR, stemless, total shoulder arthroplasty, shoulder hemiarthroplasty, EPOCA, wear.

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INTRODUCTION

The first attempts at shoulder joint replacement can be traced back to the first half of the 20th century, where Charles Neer is often described as the father of modern shoulder arthroplasty (11). The correlation between an intact rotator cuff and good functional outcome of a hemiarthroplasty was soon observed (12). For patients where the rotator cuff was defective and did not fulfil its biomechanical function, so-called reverse shoulder arthroplasty (RSA) implants started to be developed in the 1970s. These implants utilised the principle of a spherical component fixed into the glenoid and a cup as the humeral component (7). An implant designed by Paul Grammont in 1985 is considered to be the first truly modern RSA design (8).

Apart from the aforementioned advances in development relating to the mechanism of humeral and glenoid component interaction, we can also note advances in fixation methods of the humeral component.

The development of short stem components that allow for metaphyseal fixation due to improved surface treatment technologies has first been observed in the field of hip arthroplasty. A parallel development occurred also in shoulder arthroplasty, where the idea of implant impaction into metaphyseal bone of sufficient quality has been proving to have many advantages.

Due to minimal mechanical stresses present at the humeral component implant – bone interface, new implants were developed that did not utilise stems implanted into the humeral canal. Various methods have been developed to anchor the artificial head to the metaphyseal bone.

The first person who utilised the new concept of shoulder replacement with a spherical cap that replaced only the articular surface was Stephen A. Copeland in 1979. The CSRA (*Cementless Surface Replacement Arthroplasty*) implant that he designed is based on minimal bone resection and eliminates the need for a stem inserted into the humeral medullary canal. First version of the implant, named **Mark 1** (3M, UK), had a cap shaped design with a short anchoring peg and a stabilising screw ensuring additional fixation. A cemented component was used for the glenoidal surface replacement. This implant was gradually modernised over a series of generations (15). The **EPOCA** TSA system was introduced to the market in 2006. It was developed by the Synthes company in collaboration with prof. Hertel. In the first generation of the implant, the humeral component had a classic design with a humeral stem, but the second generation offered a surface replacement with preservation of humeral head bone stock.

The concept of removing only the surface cartilage, preserving the humeral head bone stock and covering it with an artificial cap was also used by other constructors and manufacturers. Some examples include **Global C.A.P** and **Global Advantage** from DePuy J&J or **Durom** Cup from Zimmer.

An Italian company by the name of Lima LTO S.P.A. created a new complex modular TSA system called **SMR®** in 2002. The father of this system is prof. Mario Randelli (13).

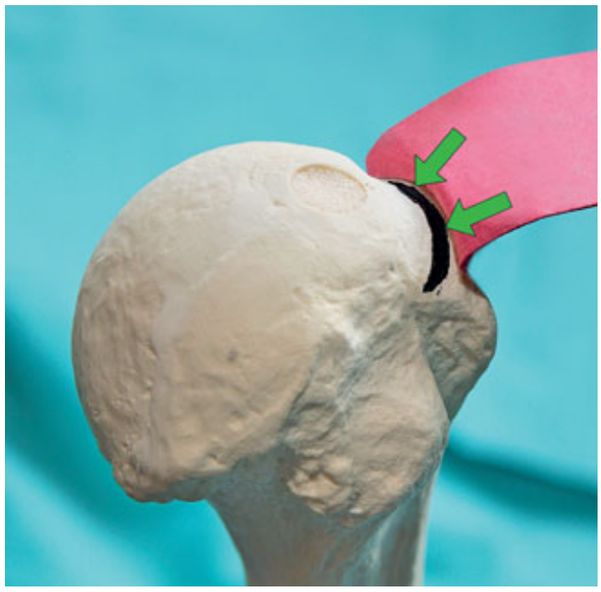

Fig. 1. Critical zone (green arrows) of supraspinatus attachment (supraspinatus muscle retracted laterally), demonstrated on a model along with a black line showing the osteotomy line.

As a part of the SMR® system development, a shoulder resurfacing option was included. This resurfacing implant was introduced to the market in 2004. It utilised a peg for fixation of the component into the humeral head. An advantage of the resurfacing implants is sparing of the humeral head bone stock.

While it has many advantages, shoulder resurfacing is unsuitable in patients where the humeral head has lost its integrity due to necrosis or if marked osteoporosis is present. Implants that utilised only a ring-shaped structure for fixation of the implant often showed insufficient osseointegration.

Because of this, a new generation of implants was developed within the last decade. These implants require a resection of the humeral head and impaction into metaphyseal bone of sufficient quality. An example of this new generation of implant is the Lima Corporate SMR® Stemless, which was introduced to the market in 2015. The **SMR® Stemless** system can be used as an anatomic hemiarthoplasty, TSA or RSA. Additionally, it allows for conversion from one design to another. For example, an anatomic hemiarthoplasty can be converted to an RSA with preservation of the fully integrated metaphyseal component.

MATERIAL AND METHODS

At the 1st Department of Orthopaedics, 1st Faculty of Medicine, Charles University in Prague and Motol University Hospital, we performed a total of 20 SMR® Stemless (LimaCorporate, San Daniele del Friuli, Udine, Italy) anatomic shoulder arthroplasties between April

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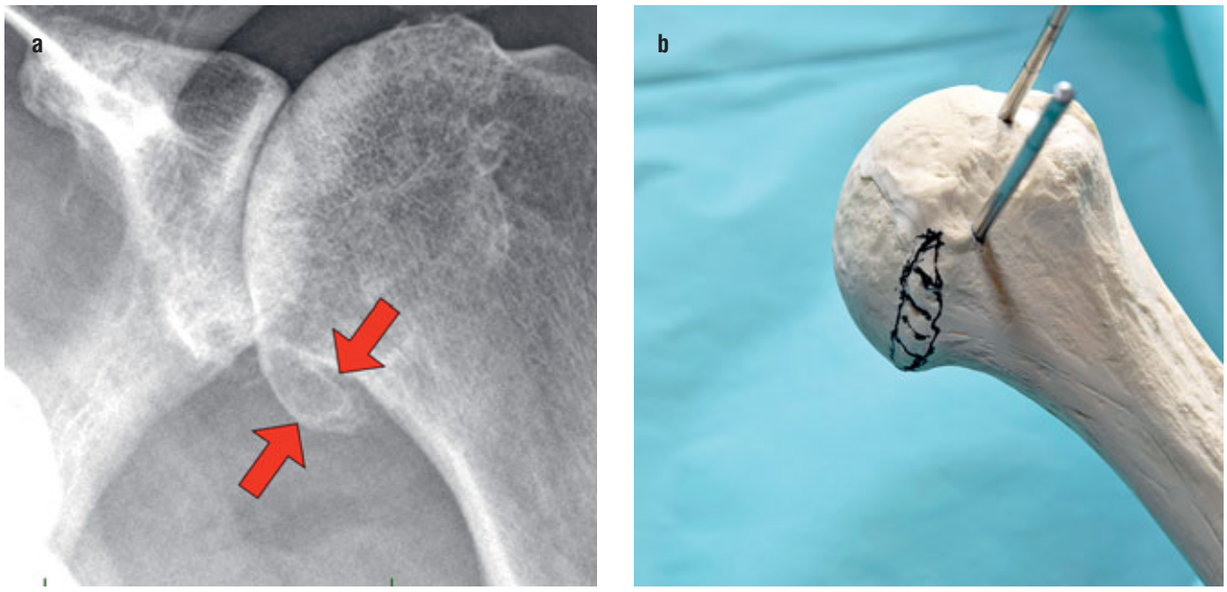

Fig 2. a, b. Typical caudal osteophyte. Radiograph on the left, visualisation on a model (black marked out area) on the right.

2016 and December 2020. The main author performed 16 of the surgeries and assisted with the other 4. In all cases, an anatomical hemiarthoplasty was performed for primary osteoarthritis.

To successfully utilise the SMR® Stemless system as a hemiarthoplasty, we consider the following to be basic prerequisites:

– Intact rotator cuff - both structurally and functionally
– adequate metaphyseal cancellous bone quality for impaction of humeral implant
– good quality of glenoid articular surface - at least partially retained cartilage without bone defects.

Surgical technique

Surgery in all patients was performed via a classic deltopectoral approach. Due to the fact that the aforementioned implant is not meant for use in cases with large anatomical changes (post-traumatic destruction etc.), approach to the shoulder joint does not pose a problem. Arthrotomy is performed by incising the subscapularis tendon in its entirety approximately 3-5mm from its insertion. Retention sutures are then placed in the tendon for ease of identification at the end of surgery. The long head of biceps tendon is also cut and retention sutures are placed into it.

Due to arthritic changes of the humeral head, its release and dislocation sometimes proves more difficult. Following its dislocation, there are two relatively essential parts of the procedure:

– Precise identification of the supraspinatus tendon at the edge of the humeral head (Fig. 1).
– Release of the caudal part of the joint capsule along with removal of caudal osteophytes on the humeral head (Fig. 2) that are often present.

These steps will enable a significantly easier dislocation and the surgeon will gain more orientation about the humeral head edges. (Fig. 3).

An external jig from the instrument set can be used to guide the humeral head resection. Alternatively, an intramedullary guide can be used. In the case of an anatomic hemiarthoplasty, the resection is performed at an angle of 45° to the long axis of the humerus and a retroversion of 30°. The resection level is extremely important. The osteotomy line must trace the border between the supraspinatus tendon insertion and the anatomical neck of the humeral head (Fig. 1). If the resection is

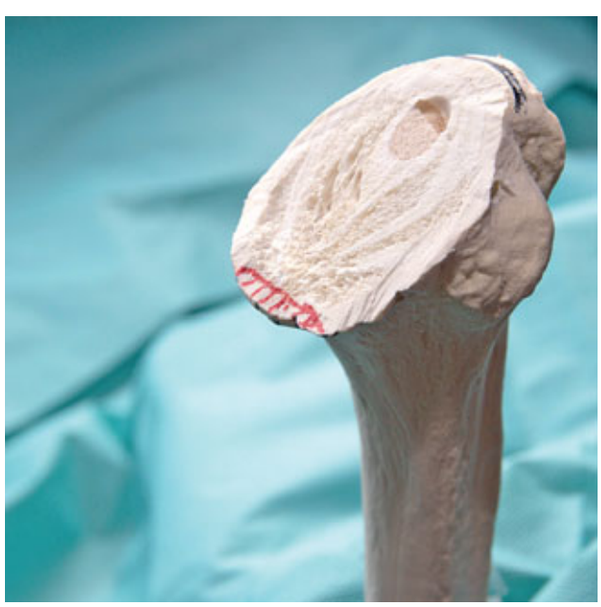

Fig. 3. Remainder of the marginal osteophyte after head resection marked in red on a model.
To achieve a good range of motion after the surgery, it is crucial to perform caudal joint capsule release. The capsule is often contracted due to fibrous changes.

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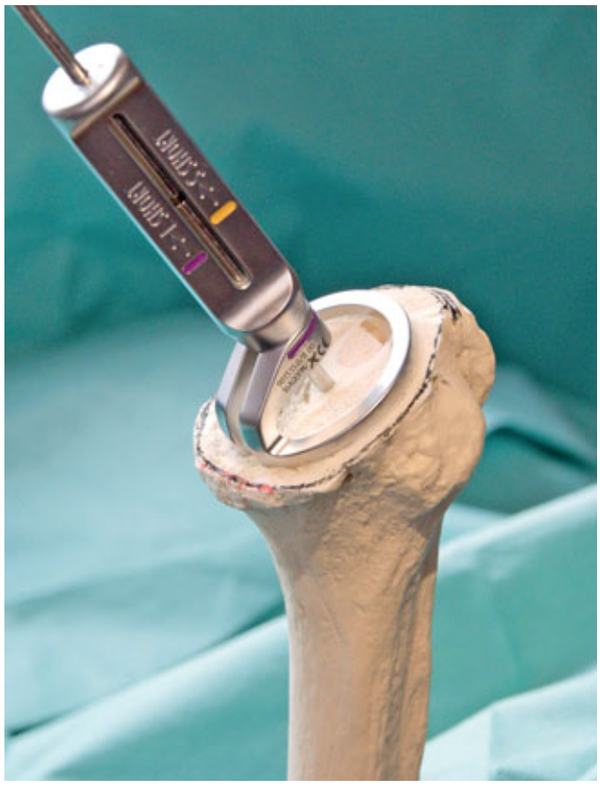

Fig. 4. Application of the sizer to select the reamer diameter and to drill the K-wire.

performed more distally, we inadvertently resect the rotator cuff attachments, meaning the resultant anatomical hemiarthoplasty would be unstable. Alternatively, if the resection is insufficient, the result would be an excessively "tight" shoulder joint with unsatisfactory function.

The next step is the stemless core size selection. There are 4 different sizes with their corresponding sizers to help with selection. The sizer is placed onto the resected surface after removal of the humeral head (Fig. 4). To determine the diameter, the outer ring of the sizer should not reach the inner cortical surface of the metaphysis, while being centric to the resected surface. After selection of the appropriate sizer, K-wire is drilled through the sleeve to the contralateral cortex. The lines on the K-wire shows us the correct size of core. In the case of contralateral cortex perforation, it can lead to incorrect selection of an oversized core.

After the K-wire is inserted. It guides the reamer which creates a bed for the core in metaphyseal bone. The reamers are available in short or standard lengths for each corresponding core size. In our experience, we recommend caution when selecting the longer (standard) size. We often observed that when it was used, the peg came into contact with the contralateral cortex. Some publications even describe cases of periprosthetic fracture (see discussion) as a consequence of this. Due to these facts, we now prefer to use the short core variant (Fig. 5).

A special compactor is then used to create fins for the correct seating of the core. There is a different position of the implant depending on the side being operated on.

A system of trial components can then be used to test the head size. First, the resected head diameter is measured with a provided head gauge. The diameter and of the resected head should be measured; correct size selection is crucial for the final arthroplasty outcome. Once an appropriate trial size is selected, it is attached to the core with an adaptor. There are adaptors that allow for centric placement of the head but also ones with 2 or 4mm of eccentricity. This part of the surgery is also crucial; the head must perfectly copy the contours of the resected cortical bone without extending over the supraspinatus attachment proximally and either copying or extending 1–2mm over the medial edge of the resected humerus. The cortical bone should never be exposed in the region of the medial edge. Thanks to the eccentric

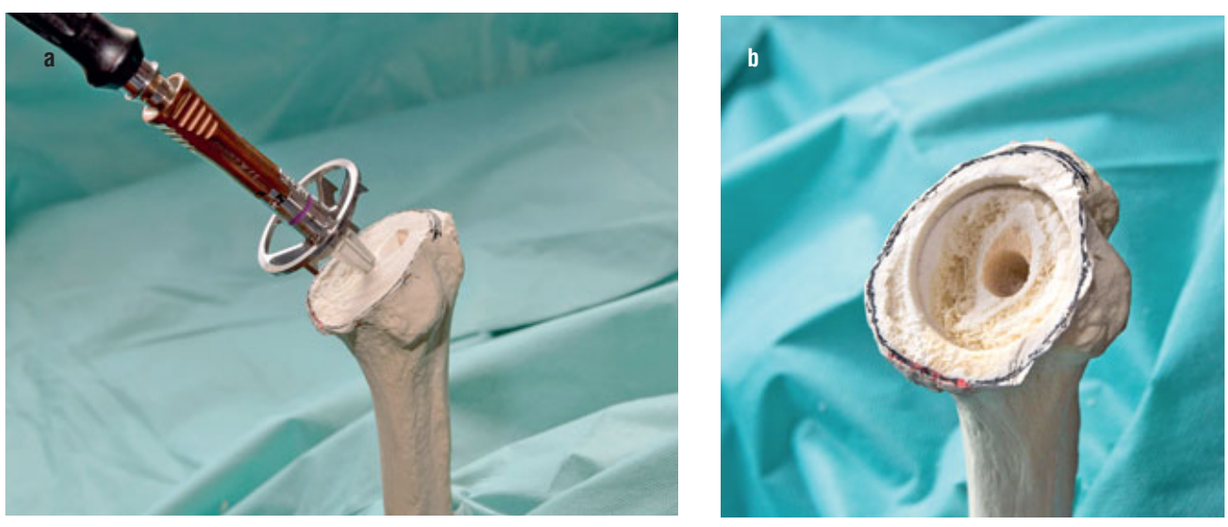

Fig. 5a, b. Reamer for implant bed preparation (a). Prepared implant bed (b). The reamer must not remove the cortical bone (Highlighted in black).

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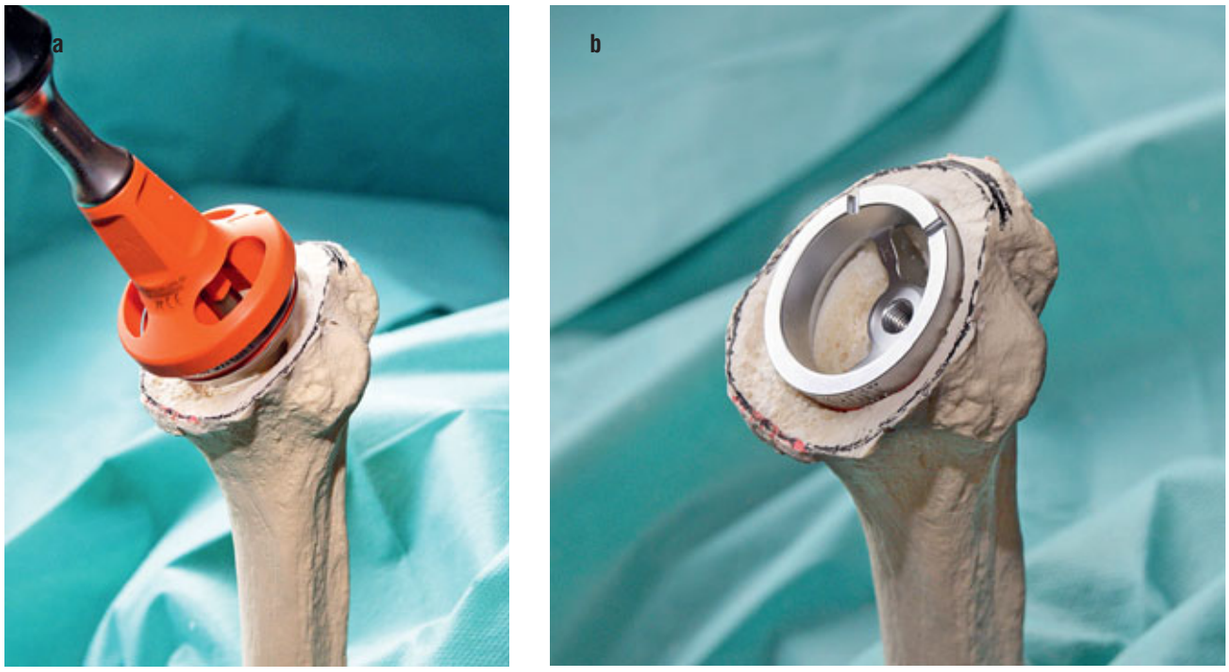

Fig. 6 a, b. Compactor attached to an introducer (a). Isolated compactor in the humeral bone bed which creates grooves for the fins of the original component (b).

adaptors, the position of the head can be adjusted into the optimal anatomic position.

If an anatomic hemiarthoplasty is the implant of choice, a trial reduction is then performed. In general, the surgeon must feel a certain looseness in the joint after reduction. When pulling on the arm, the travel of the head distally in relation to the glenoid should be about a third of the glenoid surface. It is also necessary to ensure that the subacromial space is free enough to allow a finger to be inserted into it. An excessive tension of the soft tissues and impingement of the subacromial space is a major surgical error.

After trialling, the original Stemless core implant (Fig. 8) can be impacted into the metaphyseal cancellous bone. The component is made from a Ti6Al4V alloy with an osteoinductive surface treatment. When im-

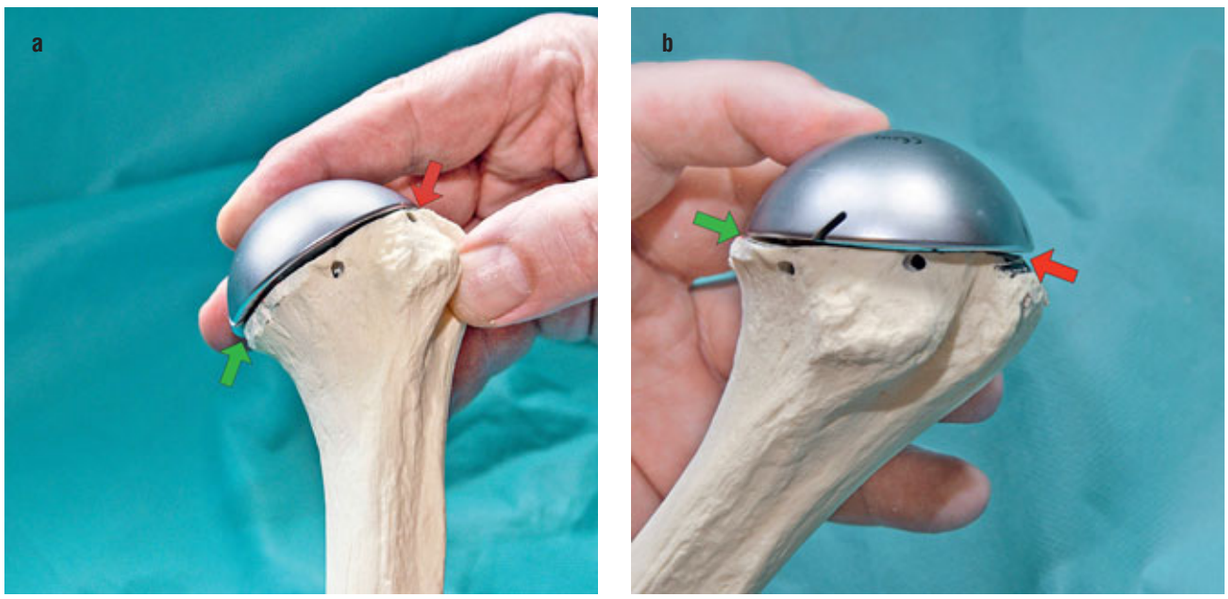

Fig. 7 a, b. Example the head position on a model. Correct position of the head (a): green arrow shows the position of the distal edge, red arrow shows the attachment of the supraspinatus which the head should not exceed. Wrong position of the head (b): head does not reach the edge of the osteotomy (green arrow) and proximally exceeds the supraspinatus attachment (red arrow).

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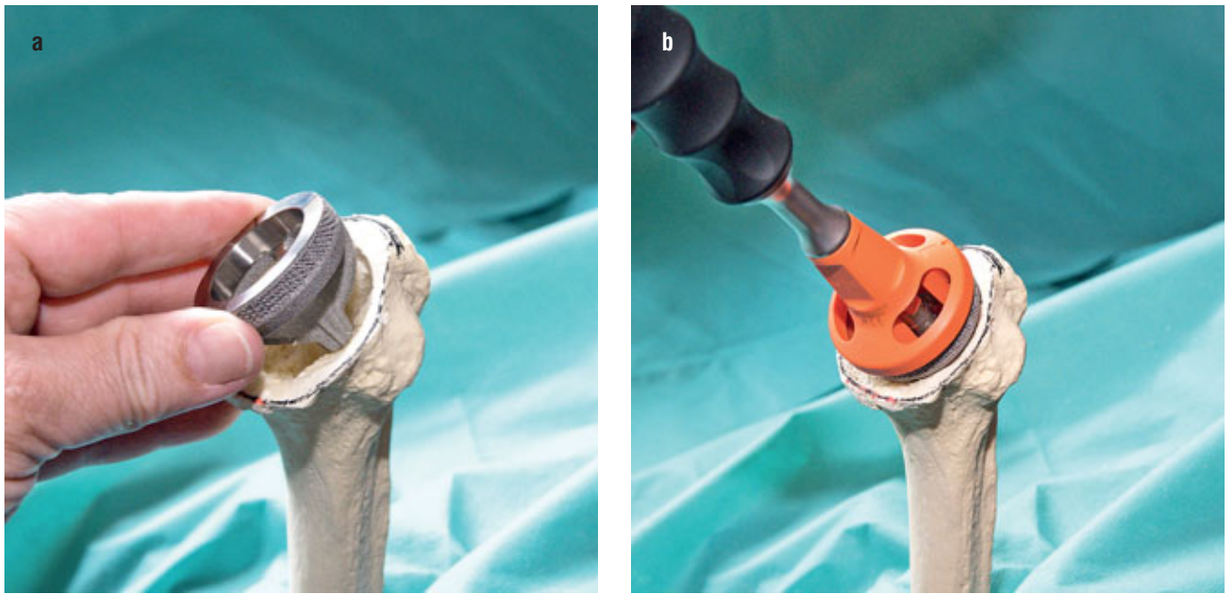

Fig. 8 a, b. Original component impacted into the prepared bed with an introducer.

planted correctly, this component provides excellent primary fixation.

This is followed by the application of an adaptor taper onto the core in an identical position as the trial component. A safety screw is then used to secure the coupling between the adapter taper and the stemless core. The original head (made from CoCrMo with a Ti6Al4V head available for patients with metal allergies) is then impacted onto the adapter taper securing it in place (Fig 9).

Joint reduction is then performed.

The subscapularis muscle should then be securely attached with non-resorbable sutures, ideally transosseous sutures. No less important is the closure of the rotator interval (Space between the cranial edge of the subscapularis tendon and ventral edge of the supraspinatus tendon). If this interval were not closed, the head would migrate through the interval in the cranio-ventral direction. In the final portion of the procedure, a tenodesis of the long head of biceps is done.

While the patient is still in theatre, the arm is fixed in a Dassault style brace. Due to the suture of the sub-

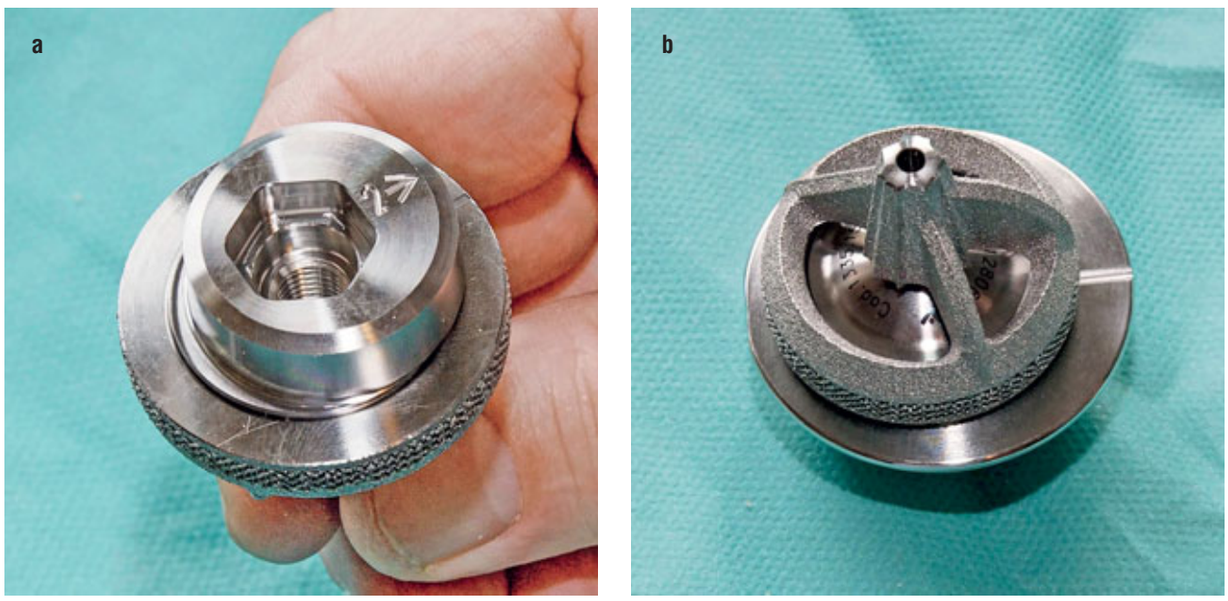

Fig. 9. Adaptor taper system that allows for selecting a precise position of the head in relation to the core. An eccentric variant is visible in the picture.

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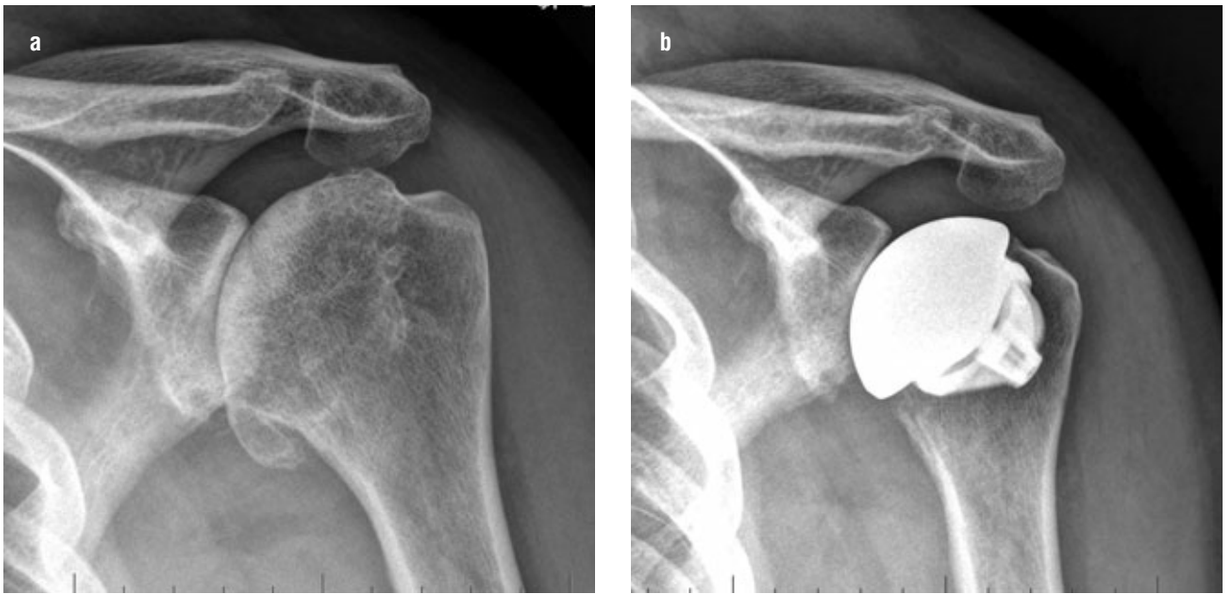


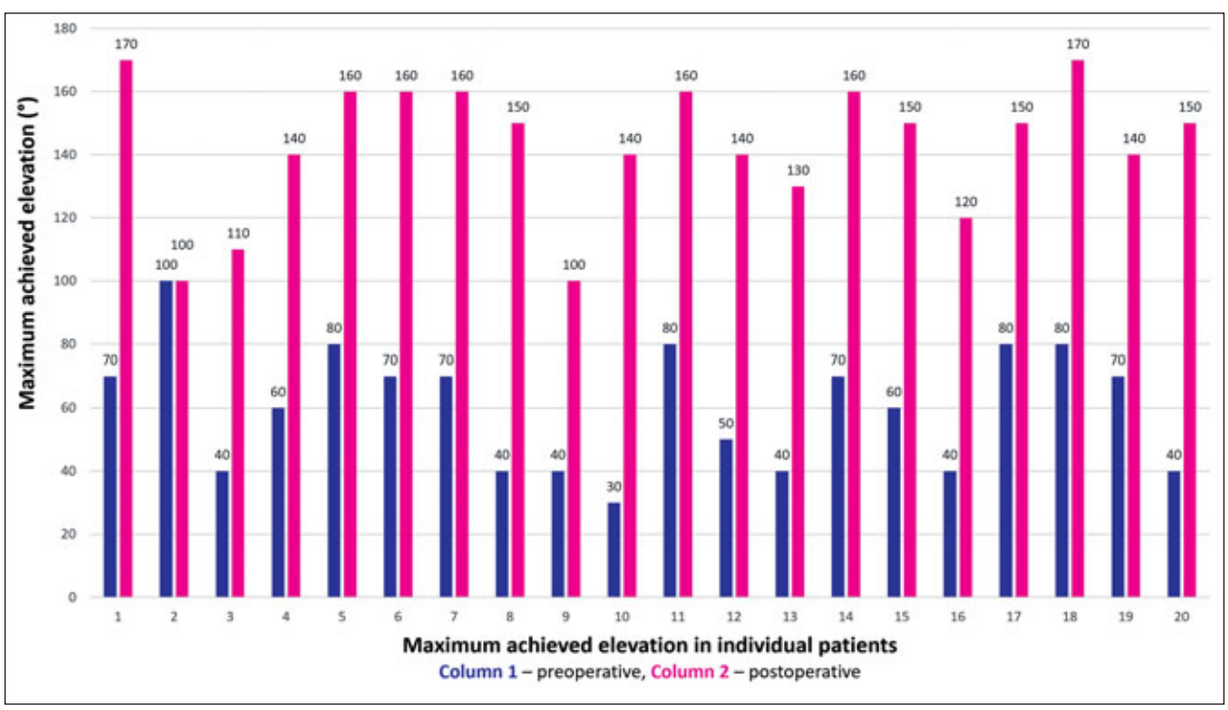
Fig. 10. Pre- and postoperative radiographs of one of the patients.

scapularis tendon, we recommend starting with physiotherapy under the supervision of a senior physiotherapist 3–4 weeks after the procedure.

Patients were followed prospectively from the first procedure. In all cases, preoperative function was evaluated: maximum achievable elevation and classic Constant scoring (6). We also evaluated the pain level according to the visual analogue scale (VAS).

Each patient was followed up during their physiotherapy and then at 3, 6 and 12 months after surgery. At each point the patient was evaluated both clinically and with radiographs (Fig. 10). After this, the patients were followed up once a year. In the study we include data from the latest follow-up, which occurred during 2021 in all patients.

Statistical evaluation was performed using standard statistical parameters (mean, median, minimum, maximum, standard deviation). Statistical significance was evaluated using a paired t-test with the level of statistical significance set at p=0.01.



Graph 1. Maximum elevation in individual patients pre- and postoperatively.

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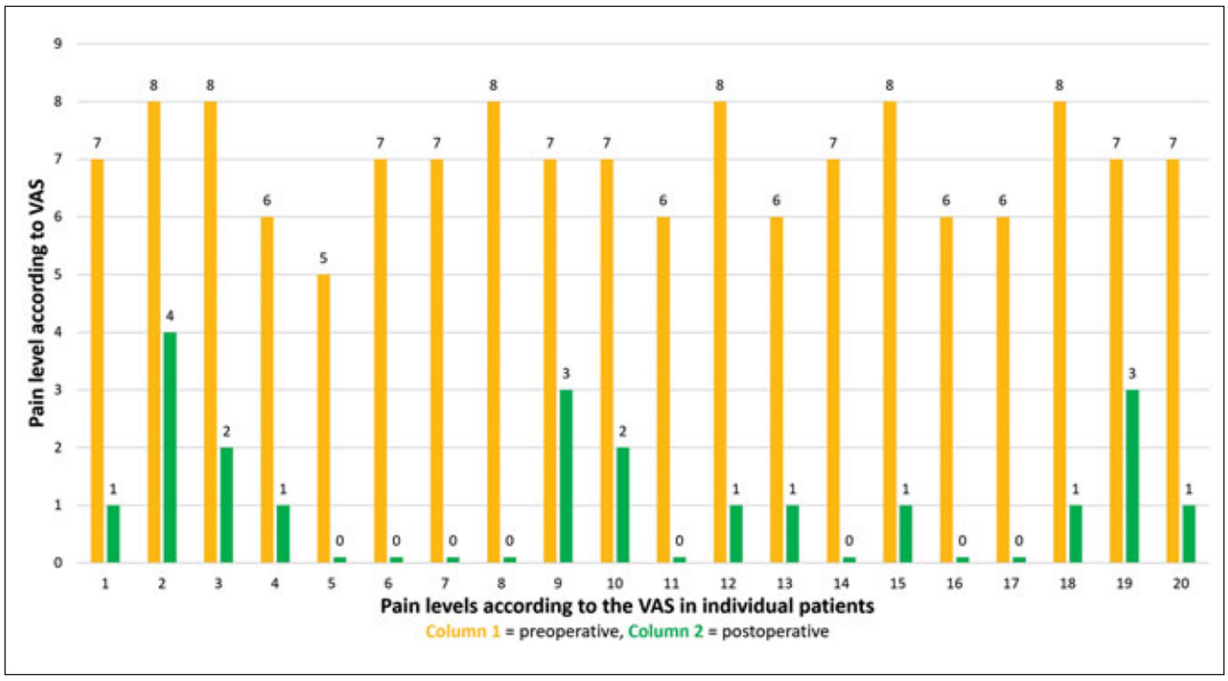

Graph 2. Pain levels according to the VAS in individual patients pre- and postoperatively.

RESULTS

This study evaluates 20 cases of anatomic shoulder hemiarthoplasty in 20 patients (15 men and 5 women)**.** The mean age at the time of surgery was 60.1 years (Range 26–74, median 61.5, SD 12.32).

The mean follow-up duration was 3.01 years (Range 0.32–5.69, Median 2.82, SD 1.56)

The mean preoperative elevation was 60.5° (range 30–100°, Median 65°, SD 18.83). After surgery the mean elevation increased to 143° (range 100–170°, Median 150°, SD 20.76).

The increase in range of elevation is statistically significant with a p value of $p<0.01$. The maximum pre- and postoperative elevation in individual patients is shown in Graph 1.

Pain level according to VAS (Visual Analogue Score) was measured preoperatively with a mean of 6.95 (Range 5–8, Median 7, SD 0.86). The mean postoperative VAS fell to 1.05 (Range 0–4, Median 1, SD 1.02). The decrease in postoperative pain level is statistically significant with a p value of $p<0.01$. The VAS values pre- and postoperatively are shown in Graph 2.

Preoperative mean Constant score was 41.7 (Range 32–54, Median 40.5, SD 5.77). Postoperatively, it increased to a mean of 85.7 (Range 70–96, Median 86, SD 6.83). The increase in the Constant score is statistically significant with a p value of $p<0.01$. Changes in the Constant score before and after surgery are shown in Graph 3.

Complications

There were no major complications (Infection, joint stiffness, major post-surgical pain or instability) in our patient group. In one patient (patient no. 2 in our cohort), there was a slightly higher postoperative pain (VAS 8 preoperatively and VAS 4 after the surgery) with a narrowing of the subacromial space visible on radiographs.

DISCUSSION

The implantation method of the SMR stemless prosthesis follows the trend of maximum bone stock preservation. The fixation of the humeral component is dependent on a specialised short module with a surface optimised for osseointegration. If the patient's bone stock allows for it, this implant leaves the entire humeral shaft intact. An intact humeral shaft is greatly advantageous in cases of humeral periprosthetic fractures, where the treatment is much simpler than if there were a stem implanted inside the humeral canal.

There are several systems that were important milestones in the evolution of humeral shaft preserving component designs. Initially, systems such as Tornier Flex (now Wright Medical, Tennessee, USA), and Biomet Micro and Mini (Warsaw, IN, USA) (4) had a short noncemented stem for fixation.

The introduction of systems where the fixation is ensured only with a metaphyseal component – so called stemless designs- was the next evolutionary step. First of these systems was introduced by Biomet in 2004: **Total Evolutive Shoulder System – TESS** (Biomet, Warsaw, IN, USA) (4, 16). The **Sidus** implant from the same manufacturer was introduced to the European market in 2012.

Another system utilising the "stemless" design is the **Simpliciti shoulder system** (Previously Tornier, now Wright Medical, Tennessee, USA). It was initially in-

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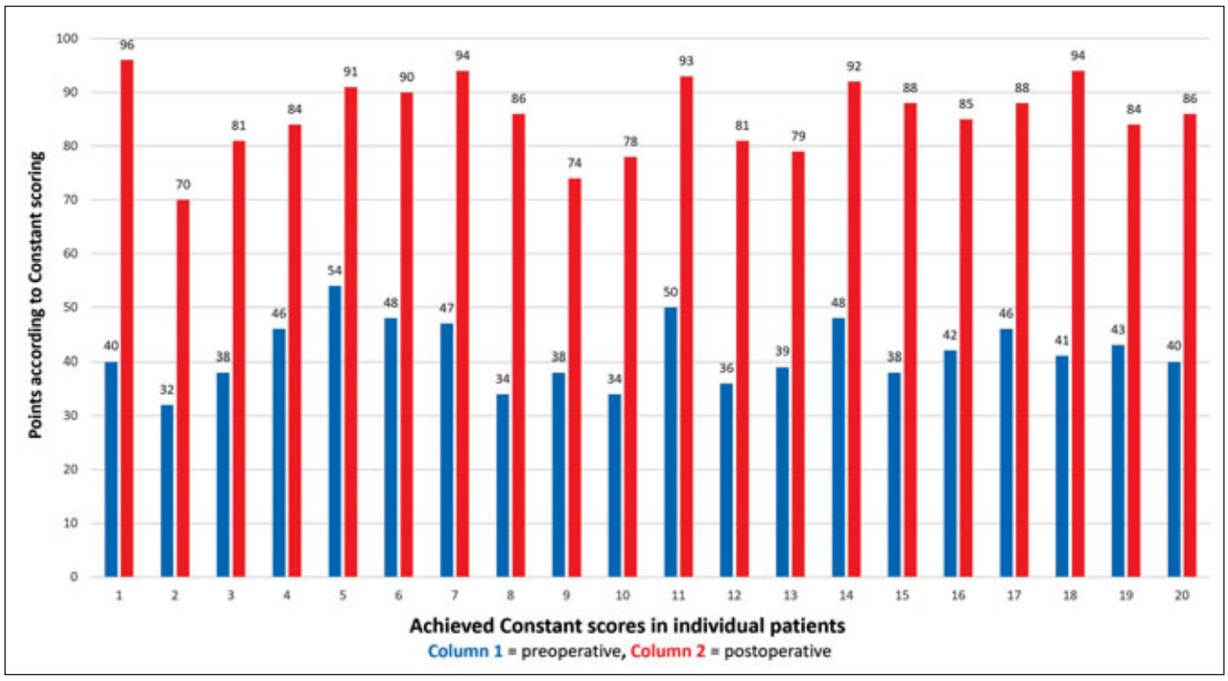

Graph 3. Constant Scores in individual patients pre- and postoperatively.

troduced to the market in France in 2010 when Tornier was still the manufacturer.

The **Eclipse** humeral component is a stemless implant in the Arthrex (Arthrex, Karlsfeld, Germany) company portfolio since 2005 (4).

Similarly, the Mathys (Mathys, Bettlach, Switzerland) company introduced their stemless design, the **Affinis Short** in 2008.

Currently, there are not many publications reporting clinical outcomes of systems utilising the stemless design.

Huguet et al. (10) published their results of the Biomet TESS system in 2010. They evaluated 63 patients after an anatomic arthroplasty with a minimal follow-up of 3 years. Forty-four were anatomic hemiarthroplasties and 19 were anatomic total shoulder artrhroplasties. In long-term follow-up, 8 revisions were performed. Five due to infectious complications, 2 due to rotator cuff failure and 1 due to instability.

Habermayer et al. (9) evaluated 96 Eclipse Stemless Shoulder arthroplasties in 78 patients with a minimum follow-up of 5 years. In half of the cases, a hemiarthoplasty was performed while the other half received an anatomic TSA. In both groups, a decrease of bone mineral density in the metaphyseal region surrounding the implant was observed after 5 years in 50% of cases!

A study with probably the largest patient cohort was presented by Churchill et al (5). It was a multi-centric study of 14 departments in the USA and evaluated the outcomes of the Simplicity Shoulder System (Wright) in 150 patients. The minimum follow-up period was 2 years, and 3 complications were reported: one case each of infection, glenoid component loosening and failure of the subscapularis muscle.

While not objectively measured in this study with VAS scoring, we have nevertheless clearly observed that there was significantly lower postoperative pain in patients after stemless hemiarthoplasty when compared to stemmed implants.

In the surgical technique section, we have highlighted the importance of correct implant head sizing and its positioning relative to the resected humeral surface – in essence respecting the original anatomic conditions. We believe that following this rule is responsible for very good functional outcomes in our patients.

We have never utilised the SMR® Stemless system as an anatomic TSA. This is due to the relatively high number of complications associated with the glenoid component that we have observed in other systems. An example of this occurred in 4 patients with an EPOCA TSA which were performed at our department. These patients showed perfect clinical function with no subjective problems for a period of 3–5 years. After this period, patients started to develop pain, limitation in movement and all required revision surgery. During revision surgery, we found total destruction of the polyethylene insert due to abrasion in all cases, sometimes even of the metalback component (Fig. 11, 12).

Published studies of large groups of various TSA systems with a long (more than 10 year) follow-up show failures of glenoid components in metal-back, cemented all-poly and even peg stabilised designs (2, 3, 14).

Albers et al. (1) presented a study in 2021 analysing 49 SMR stemless arthroplasties. They evaluated their patients 2 years after surgery. No radiolucent lines or loosening was observed in any of their patients. In two cases a revision surgery with conversion to RSA was necessary due to instability at 7 and 8 months post-

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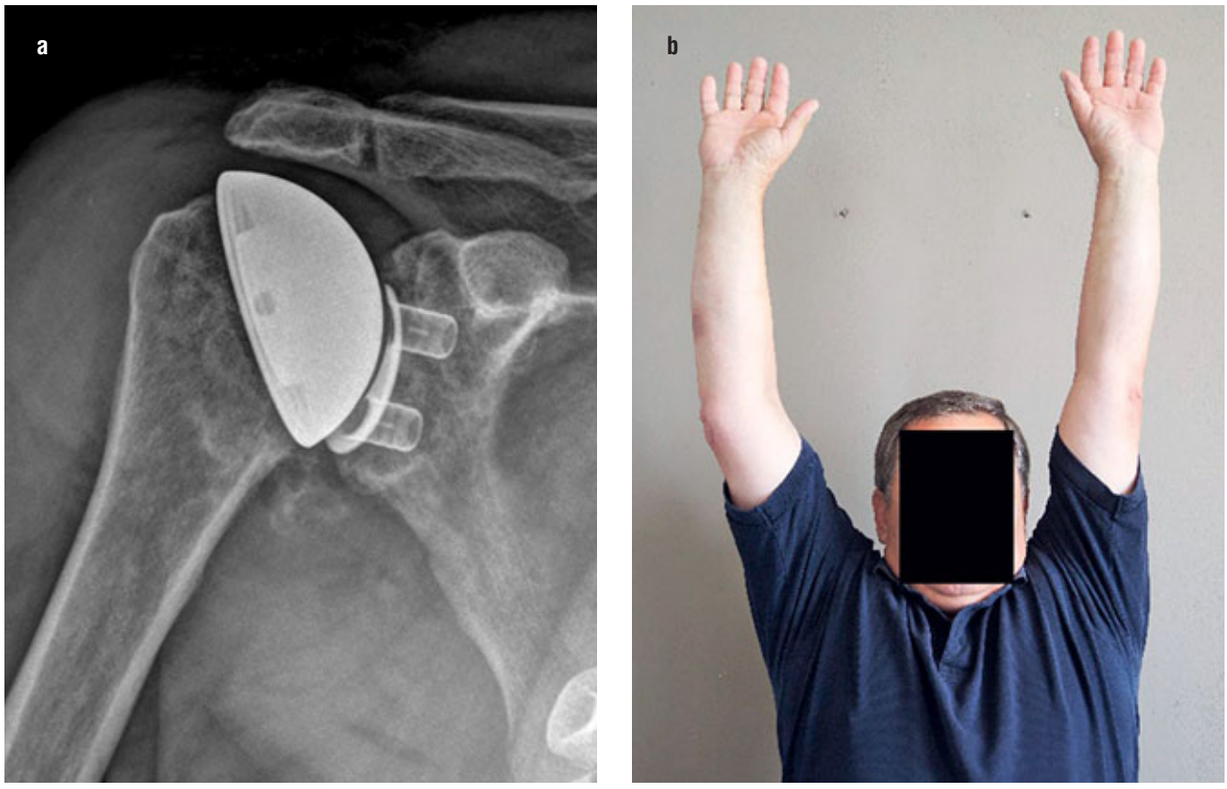

Fig. 11. Patient with optimal function 4 years after EPOCA Synthes anatomic TSA with resurfacing type of humeral component.

surgery respectively. In both cases, **perfect osteointegration of the metaphyseal component was observed**.

In comparison, we observed very good results in 4 cases where an SMR® resurfacing component was used as an anatomic hemiarthoplasty. No signs of loosening were observed in these patients (Fig. 13).

We have not yet utilised the SMR® Stemless system as an RSA either. The reason for this is our long-term experience with the standard SMR® reverse shoulder system which we have utilised in more than 500 cases (14). In our opinion, the forces that occur between the glenoid and humeral components after joint reduction exceed the **primary fixation strength** of the Stemless humeral component. Due to fear of implant loosening, we prefer to use the classic humeral component in cases of RSA.

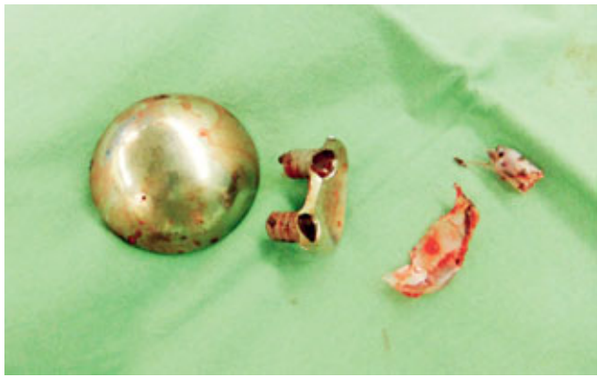

Fig. 12. Same patient where slight pain and a feeling of subluxation gradually developed after 6 years. During revision surgery, complete destruction of the UHMWPE liner and of the metal-back component was found. Treated with conversion to an SMR® RSA.

However, it is an entirely different situation should it be necessary to convert a completely integrated humeral Stemless component to a reverse design. Here, it is possible to easily verify the integration of the Stemless component during the revision surgery. If there is perfect osseointegration, it presents an ideal situation for retaining the humeral component and converting to an SMR® RSA.

The size of our group was influenced by a careful patient selection. As stated before, this implant is highly suited for patients with primary osteoarthritis, possibly also in cases of early-stage humeral head necrosis without rotator cuff insufficiency. If it were to be used in questionable or wrong indications, the number of complications would surely increase.

This corresponds with our observations in our set of 20 patients with a mean follow-up of 3.01 years (Range 0.32-5.69) where we observed no cases of loosening or radiolucent lines around the metaphyseal component.

CONCLUSIONS

Our study confirmed the hypothesis that the SMR® system in the anatomic hemiarthoplasty variant provides

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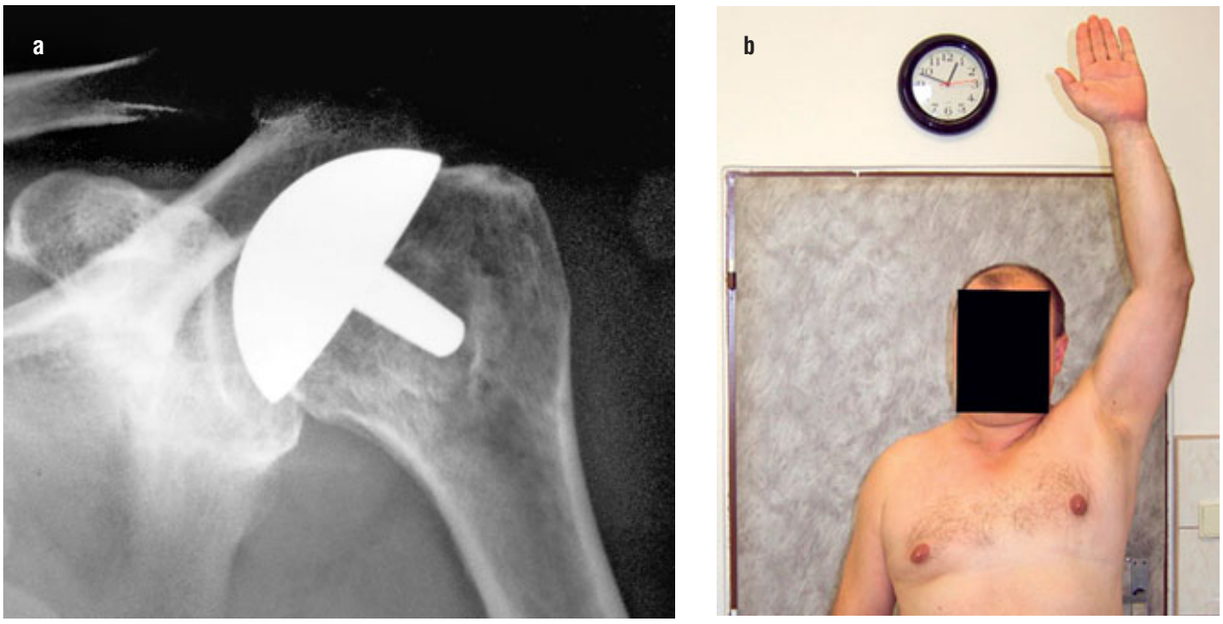

Fig. 13. Patient 8 years after an SMR® resurfacing procedure (heavy manual labourer even after surgery).

very good clinical results. We saw no failures or complications that would imply a deficiency in its design.

The SMR® Stemless system contains a humeral component whose shape and surface coating allows for perfect osseointegration in cancellous bone of sufficient quality. It is however not suitable for use in patients with severe proximal humeral osteoporosis. The mechanism which connects the core and the head allows for orienting them in any position in relation to each other, thereby respecting the patient's anatomy. The system also allows for conversion to a reverse design. The range of humeral head sizes is sufficiently large to select one that is most similar to the diameter of the resected head.

A basic factor in ensuring a good outcome is respecting important details during surgery. Especially important is the precise evaluation of soft tissue changes to the rotator cuff and joint capsule. No less important is evaluating the tone of the tissues after reduction along with ensuring a sufficiently free subacromial space. Following these guidelines is crucial for good function of an anatomic shoulder hemiarthroplasty.

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