The S-ROM Stem: Versatility of Stem/Sleeve Combinations and Head Options

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abstract

The S-ROM stem (DePuy Orthopaedics Inc., Warsaw, Ind) is a modular cementless hip implant that has a modular proximal sleeve that mates with a fluted stem. Various sleeves, stem lengths, diameters, proximal body types, and heads can be configured into 10,398 combinations. Independence of the sleeve and stem version permits correction of excessive anteversion found in types of dysplasia and the retroversion deformities found in revision total hip arthroplasty (THA). The fluted distal segment provides stability if a corrective osteotomy is required. The stem is a versatile tool in primary or conversion hip arthroplasty with unusual deformity and in revision THA.

Since the S-ROM stem's introduction in 1984, it has become a versatile tool in facilitating management of complex primary total hip arthroplasty (THA) and femoral revision (Figure 1). The modular stem/sleeve/head interchange creates varying stem lengths and diameters, proximal body heights and offsets, proximal sleeve diameters, and calcar spout sizes. The S-ROM stem gives surgeons the ability to independently set anteversion of the sleeve and stem, providing an "off-the-shelf" custom femoral stem that accommodates anatomical variation.

IMPLANT DESIGN

The S-ROM stem is a descendant of the Sivas stem, which was introduced in the Soviet Union in 1956 and was available in the earliest metal-on-metal design. A version of the Sivas stem called the SRN stem was manufactured by the U.S. Surgical Company in 1975. The SRN stem had modifications such as distal flutes, a proximal sleeve/stem morse taper connection, and a distal coronal slot. In 1982, the SRN stem was reincarnated as the S-ROM stem by Joint Medical Products. Over the next 3 years, innovations included a fully polished distal stem, modular heads, and a modular sleeve with a spout and concentric steps.

The S-ROM stem consists of at least three parts, including the stem, sleeve, and head. An optional modular trochanteric bolt is available for the calcar replacement stems only (Figure 2). The S-ROM stem is designed to achieve proximal bone ingrowth only; fully-coated stems are not available. The design philosophy is to achieve proximal ingrowth and loading to create a physiologic pattern of bone stresses that reduces stress-shielding. Although the stem is not porous coated distally, it is designed to maximize the intramedullary fit proximally and distally to minimize micromotion and enhance bone ingrowth. Ohl et al. performed a biomechanical

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study to document the stem’s contribution of proximal sleeve fixation and distal stem fixation to overall stability. The study involved placing S-ROM stems in cadaver femora and taking rotational stability measurements. Three groups were included in the study: a group inserted with tight fixation proximally and distally, a group over-reamed proximally (relying on distal fixation only), and a group over-reamed distally (with only the sleeve providing rotational stability). Rotational stability was 66, 35, and 33 Newton-meters respectively. In comparison, a cemented primary stem has 71 Newton-meters. Approximately 22 Newton-meters are required for most daily activities.2

The provision for bone ingrowth is provided by the proximal sleeve (Figure 3). The sleeve is 4 cm long, is covered by beads or hydroxyapatite, and has ZTT steps to convert hoop stresses to compressive axial stresses.

The bone is prepared by a “broachless” milling system, which is less traumatic when dealing with the compromised bone stock encountered in revision surgery. First, the distal canal is machined with straight or flexible reamers. The upper metaphysis is then machined with conical reamers. The calcar reamer is used to prepare a bed for the sleeve spout, with orientation dependent upon the bony anatomy (Figure 4).

The interior of the sleeve provides a Morse taper connection to the stem. In vivo, the taper is loaded in compression, which minimizes micromotion and provides rotational stability for up to three times a patient’s body weight.3 In addition, the proximal half of the sleeve has a spout designed to fit into the metaphyseal flare of the upper femur. This spout adds a lateral extension to the cylindrical sleeve. The eccentric shape helps provide rotational stability. Because the stem and sleeve have complete rotational independence, the sleeve may be impacted into the metaphysis in a degree of version (anteverted, retroverted, or with the spout placed into the greater trochanter). The stem may then be inserted into normal physiologic anteversion as it mates with the sleeve (Figure 5).

For the most common sized stems, four outer sleeve diameters and two or three spout lengths are available for each sleeve outer diameter. For patients without a
metaphyseal flare, a small cylindrical SPA sleeve is available (Figure 6). Most stems have 13 sleeves, which allow them to mate (10 "spouted" sleeves and three "non-spouted" SPA sleeves), whereas the smallest stems may have only five sleeves with which to mate (four spouted sleeves and one SPA sleeve) (Figure 7).

The stem sizes vary from short to straight, elongated. Elongated stems may be curved or straight. All standard diameter sleeves have distal flutes that increase the distal root diameter by 1.25 mm and are designed to enhance rotational stability. The distal stem is polished to prevent distal bony ongrowth. The smallest stem diameters are 6 mm, 7 mm, or 8 mm and are available in only the short length and standard offset. Stems that are 9 mm or longer may have standard or increased offset, elongated and calcar replacement bodies, or long curved distal segments in addition to short straight distal segments. Stems that are 9 mm or longer also increase in diameter at 2-mm increments, up to 21 mm. For each of these diameters, one short, straight stem (130-175 mm) and one long, straight stem (205-230 mm) are available along with three long curved stems (205-230 mm, 255-275 mm, and 300-325 mm).

In addition to the selection of diameters and lengths, choices for proximal body height and offset are available. The proximal body lengths are 30 mm, 36 mm, 42 mm, and 57 mm (the "36+21" calcar replacement body). The proximal body length is measured diagonally along the femoral neck starting at the top of the sleeve (Figure 8). Stems that are 9 mm or wider may also have increased offset, which permits increasing the soft tissue tension and stability without increasing leg length. Depending upon the stem, offsets of +4, +6, +8, or +12 are available.

**NOMENCLATURE**

The S-ROM stem is described in terms of its distal diameter and proximal diameter (interior of the sleeve), i.e. 15 mm × 20 mm. The stem is then attached, increasing the dimensions to 15 mm × 20 mm × 225 mm. The proximal body is described by the height and extra offset (if present). Therefore, the proximal bodies are 30, 30+4, 36, 36+6, 36+8, 36+12, 42, calcar replacement (36+21), or calcar replacement +4 lateralization (for the 11-mm diameter stem), and +8 lateralization (for the 13-21 mm diameter stems).

The spouted sleeves are labeled B, D, F, or F "oversize." The sleeves are 3 mm, 5 mm, 7 mm, and 9 mm larger, respectively, than the inner diameter of the sleeve (Figure 9). The A sleeves (SPA) are cylindrical and do not have a spout. A small and large spout are available for each of the other sleeves. The F and F
oversize sleeve have an extra large spout in addition to the small and large spout. The spouts extend from the cone 9.5 mm, 13.5 mm, and 17.5 mm, respectively (Figure 10). Therefore, a sleeve listed as “20 F-large” mates with any 15 mm × 20 mm stem and has a size F outer diameter with a large spout. When the S-ROM stem was introduced in 1984, sleeves were intended to be available in sizes A through F. However, this range of sleeves was determined to be unnecessary, and only sizes A, B, D, and F were introduced.

**Stem Insertion**

Preoperative planning is essential to avoid mismatch between the distal stem and the proximal body. If the discrepancy between the distal stem and the proximal body is too great, then a different implant or fixation strategy (distal ingrowth or impaction grafting) should be considered. A discrepancy may occur if the canal distal to the old prosthesis bed is small but the proximal canal is patulous. If it is beneficial to use an S-ROM stem despite a discrepancy, then custom-made sleeves or intercalary spacers can be used to accommodate bigger sleeves with the appropriate distal stem diameter. The S-ROM stem should not be used if insufficient proximal bone is present to permit firm intraoperative anchorage of the sleeve.

The first step of stem insertion is determining the distal diameter and stem length. Surgeons should select the shortest stem that will provide solid intramedullary fixation and bypass compromised bone. Line-to-line reaming may be used with straight stems with the option of over-reaming by 0.5 mm in hard bone (the flutes provide 0.75 mm of fixation). Flexible reamers are used for curved stems, usually over-reaming by 1-2 mm to allow atraumatic passage of the long curved stem.
Upper metaphyseal reaming is performed with the tapered reamers until a good apposition of bone to the sleeve is present. The calcar is then machined to a small, large, or extra large spout. The reamer handles have witness marks to anticipate the center of rotation once the implant is inserted.

The trial sleeve is inserted, followed by the straight stem. Before inserting the curved stem, it may be necessary to pre-assemble the sleeve and stem in the proper orientation because the stem may need more freedom of rotation than the sleeve interior permits as the stem tip negotiates the bow of the femur (Figure 11). This point is even more important when the real stem is inserted, since it is even larger. If a mismatch exists between the desired anteversion and the version permitted by the bow, then it may be necessary to over-reach further with the flexible reamers.

If a longer length is needed after using the longest head, then a surgeon can seat the implant slightly proud by going up to the next largest sleeve diameter. Surgeons should keep most of the sleeve opposed to bone.

A trochanteric bolt (available only with the calcar replacement body) (Figure 12) may be used if the trochanter was not united, or if a trochanteric osteotomy or slide was necessary for exposure. Alternatively, a trochanteric bolt can be used if the trochanter is intact, but additional rotational stability is desired in compromised bone. The bolt acts as a proximal interlock.

The neck of the prosthesis has an 11/13-mm taper and can accommodate 22-mm heads (cobalt chrome) in one length, 28-mm heads (cobalt chrome or ceramic) in five lengths, 32-mm heads (cobalt chrome or ceramic) in five lengths, or 36-mm heads (cobalt chrome or ceramic) in six lengths.

**IMPLANT REMOVAL**

The stem can be removed with minimal bone disruption. Because the distal stem is polished, ingrowth should occur on the sleeve only. The stem-sleeve Morse taper can be disrupted by inserting the extraction chisel into the 1-2 mm gap between the top of the sleeve and the bottom of the proximal body. The sleeve is then extracted by breaking up the porous interface and inserting the sleeve extractor (Figure 13).

**RESULTS**

**Primary THA**

Christie et al.⁴ reported the results of 175 hips in 159 patients who underwent primary THA with an S-ROM stem. Follow-up averaged 5.3 years (range: 4-7.8 years). Radiographs revealed that 98% had stable bone ingrowth, 1% had stable fibrous ingrowth, and 0.6% had unstable fibrous ingrowth. Osteolytic lesions occurred in 7% of hips, but no lesions were noted distal to the sleeve.

Tanzer et al.⁵ reported the results of 59 patients in whom primary S-ROM stems were used, with a mean follow-up of 101 months (range: 72-145 months). All patients showed evidence of bone ingrowth, and no revisions were required. A degree of disuse atrophy was seen in 78% of patients, and a degree of proximal femoral osteolysis was seen in 42% of patients.

Park et al.⁶ reported the results of 20 patients who underwent bilateral THA with an S-ROM stem. One hip received a porous-coated sleeve and the other hip received a hydroxyapatite-coated sleeve. Follow-up was for at least 4 years. No medium-term advantage to a hydroxyapatite-coated sleeve was evident.

**Revision THA**

Cameron⁷ reported the results of 62 revisions with a long calcar stem and 29 revisions with a short primary stem, with an average follow-up of 3.5 years.
Clinical Examples

Case One
A 40-year-old woman had a loose hemiarthroplasty for many years. The involved side had 4 cm of shortening. Secondary to the long-standing loosening, the upper femur was remodeled into excessive retroversion. Revising this retroversion with a one-piece stem would have been difficult due to the version mismatch (Figure 1).

Case Two
A loose-cemented stem was revised in a 54-year-old man. Osteolysis was present at the base of the greater trochanter, which fractured with minimal stress upon stem removal. Stem stability was achieved with the sleeve/stem combination, and the greater trochanter was reattached with the trochanteric bolt (Figure 2).

Case Three
A 40-year-old patient underwent hip arthroplasty for arthritis secondary to developmental dysplasia of the hip. Because of the patient's age, it was desirable to use a cementless implant. However, anatomic anteverision of 80° made it difficult to use a one-piece stem without placing the stem in excessive anteverision (Figure 3).

Case Four
A 46-year-old man had undergone a hybrid hip replacement 4 years earlier. The stem loosened above a femoral malunion secondary to a motor vehicle accident that occurred when the man was 18 years old. An S-ROM stem was used, permitting reconstitution of length and stable fixation proximally. The long fluted stem provided intramedullary fixation for the corrective midshaft osteotomy (Figure 4).

Figure 1: Preoperative anteroposterior (AP) radiograph demonstrating stem loosening and subsidence (A). Intraoperative view of the sclerotic canal of the proximal femur, which has remodeled into retroversion throughout the years (B). The sleeve has been inserted into a retroverted position in which it fits best into the canal (C). The stem is in a normal amount of anteverision. Postoperative radiograph revealing a stable construct with restoration of length (D).

Figure 2: Preoperative AP radiograph demonstrating a loose cemented stem (A). Intraoperative fracture of the greater trochanter following stem extraction (B). Repair with the trochanteric bolt, the cables were added to prevent crack propagation during stem insertion (C). Postoperative radiograph 2 years later, demonstrating a stable stem and healed trochanter (D).

(range: 2-6 years). No stem reoperations were performed in the short length group, and eight reoperations were performed in the longer stem group as a result of femoral complications. No reoperations were performed for aseptic loosening.

Chandler et al performed 30 revisions in 29 patients with massive proximal bone loss using an S-ROM stem as part of an allograft-prosthetic composite. The sleeves were cemented to the allograft. Union was obtained in 28 patients at an average of 28-months' follow-up.

Chandler et al reported the results of 52 revisions in 48 patients, with an average
Figure 3: Preoperative radiograph demonstrating arthritis of both hips secondary to dysplasia. The right hip also has excessive anteversion (A). The sleeve is inserted in 80° of anteversion, whereas the stem is inserted in 15° of anteversion (B). Postoperative radiograph demonstrating implant stability and correction of deformity (C).

Figure 4: AP and lateral radiographs demonstrating a loose cemented stem with uncorrected varus and flexion deformities of the femur secondary to a previous motor vehicle accident (A,B). Post-revision radiographs demonstrating correction of loosening, shortening, and deformity using a long calcar stem and a step-cut midshaft ostectomy (C).

Follow-up of 3 years (range: 2-6 years). Structural bone grafts were required in 44% of patients due to profound bone loss. Significant loosening was present in 9.6% of patients.

Cameron\textsuperscript{10} reported the results of 100 femoral revisions, with a 2-8 year follow-up. All patients had Paprosky type III bone loss. The failure rate was 5.8%.

Smith et al\textsuperscript{11} reported the results of 66 revisions, with 2-5 year follow-up (average, 3.4 years). Seventy-nine percent of the revisions had bone ingrowth, 11% were fibrous, and 8% were radiographically loose. Two re-revisions for sepsis were
performed. Survivorship at 5 years was 96.4% with re-revision as the endpoint.

Bono et al12 reported the results of 63 revisions in 62 patients. All patients had Paprosky type II or Paprosky type III bone loss. At an average follow-up of 5.9 years, the rate of aseptic loosening was 6%.

Christie et al13 reported the results of 129 patients, with an average follow-up of 6.2 years (range: 4-7 years). Patients with Paprosky type IV bone loss were excluded. The aseptic loosening rate was 2.9%. Evidence of bone ingrowth occurred in 92.2% of patients.

Cameron14 reported on 320 revisions, 109 with short stems and 211 with long stems. Average follow-up was 7 years (range: 2-12 years). There were no aseptic loosenings in the short-stem group, compared to 1.4% in the long-stem group. No osteolysis was seen distal to the sleeve.

Bolognesi et al15 performed a prospective, randomized study with the S-ROM stem in which patients undergoing femoral revision randomly received a hydroxyapatite-coated sleeve or a porous-coated sleeve. Overall survivorship was 95%. Radiographic evidence of bone ingrowth was present in 96% of femora with Paprosky type I or Paprosky type II defects, and in 81% of femora with Paprosky type III defects.16 Hydroxyapatite coating did not affect Paprosky type I or Paprosky type II defects, but was effective in Paprosky type III defects (100% ingrowth with hydroxyapatite-coating versus 63% without).8

**SUMMARY**

The S-ROM stem has features that allow surgeons to handle the anatomic variability seen in unusual primary THA (eg, juvenile rheumatoid arthritis, developmental dysplasia of the hip), conversion THA following fracture or osteotomy, or revision THA. The various stem diameters and lengths, proximal body heights and offsets, sleeve diameters and calcar spout lengths, and head lengths and diameters provide 10,398 combinations, resulting in an "off-the-shelf" custom implant. Although it is desirable to minimize the degree of modularity and the potential generation of wear debris, anatomic obstacles may dictate the use of a stem with myriad permutations, such as the S-ROM.

**REFERENCES**