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ORIGINAL ARTICLE

Total Hip Stem Classification System

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Abstract

The aim of this paper is to review the influx of short stems for total hip arthroplasty. Not all short stems are created equal concerning fixation points for implant stability and length of engagement of the device in the proximal femur. Some devices are stabilized in the head, neck, metaphysis and metaphysis/diaphysis. Depending on stabilization and engagement area different short stems can have different indications, contraindications and clinical outcomes. As a result of our findings JISRF developed a classification system based on implant stabilization point and overall stem length.

Keywords*: short stems, head stabilized, neck stabilized, metaphyseal stabilized, metaphyseal diaphyseal stabilized*

Introduction

The use of short stems is growing. Initial short and mid-term follow up studies of a number of these stems suggest that stable, durable fixation and excellent clinical outcomes can be achieved. As a result, a very large number of short stem designs are available. However, there does not exist a classification system [1,2,3,4] for uncemented short stem implants that would allow comparisons of clinical and radiographic results. The purpose of this paper is to propose an updated classification system based upon the length of the stem and the method by which the stem seeks to achieve stability.

A number of advantages have been argued to justify the design and clinical usage of short stems [5,6]. Elimination of femoral proximal-distal mismatch, tissue preservation (hard & soft), facilitation of less invasive surgical exposures, less invasive surgical violation into the femoral canal, less violation into the trochanteric bed, improved proximal bone remodeling, less intraoperative blood loss, less postoperative rehabilitation, less instrumentation and less inventory cost [7,8].

All of these advantages are worthwhile if they can be proven to be benefits to the clinical outcome and increased survivorship of the device. The real question is can these shorter length devices obtain long-lasting stability of the implant without diaphyseal anchoring [9].

Figure 1. A variety of short stems are available in the global market.

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The influx of short stem designs can be confusing as a result of many different design philosophies. Learmonth in 2009 attempted to broadly divide conservative implants into three categories: [3]

1. Femoral Neck Implants:
   These are the most conservative of the short-stemmed prostheses. A wedge shaped cylindrical implant is impacted into the femoral neck to provide initial stability. Long-term stability is then provided by bone ingrowth. It is important to have reasonable bone quality and relatively normal anatomy of the proximal femur.

Figure 2. Example: The Silent Stem.

2. Stems Engaging the Lateral Cortex:
   Engaging the lateral cortex resists the turning moment generated on weight bearing and improves the stability of conservative prostheses in the coronal plane. The implant is designed to load the medial cortex of the femoral neck.

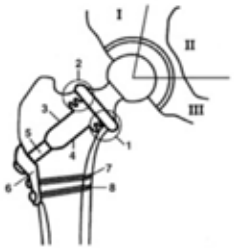

Figure 3. Example: The Thrust Plate Implant.

3. Stems Using the Lateral Trochanteric Flare:
   Engagement of the lateral flare on the prosthesis to the corresponding region of the greater trochanter aids in both torsional and axial stability of the implant.

Figure 4. Example: The Mayo Stem.

We have found this classification too broad in its description and it does not address the sub-classifications of designs. The Joint Implant Surgery and Research Foundation (JISRF) advocate a stem classification system by primary stabilization contact regions to help identify, differentiate, and catalog short-stemmed total hip replacements. This classification system should help clarify the design principles inherent with each type and provide some guidance when researchers and other investigators are reporting on the outcomes of the various implant styles. The basic categories of classification include the following: head stabilized, neck stabilized, metaphyseal stabilized, and conventional metaphyseal/diaphyseal stabilized.

The classification system is officially structured as follows:

1. Head Stabilized
   - A. Hip Resurfacing
   - B. Mid-Head Stem
2. Neck Stabilized
   - A. Short Curved Stems
   - B. Short Lateral Engaging Stem
   - C. Neck Plugs or Neck Only
3. Metaphyseal Stabilized
   - A. Taper Stems
   - B. Bulky/Fit and Fill Stems
4. Conventional Metaphyseal/Diaphyseal Stabilized

Some of these devices are not available in the United States (U.S.) and some are new with regard to clinical performance. As a result this paper makes no assumption as to clinical outcome or benefits to certain product features. This is intended to point out certain trends for hip reconstruction and provide a base for development of the "JISRF Stem Classification System".

Figure 5. Stabilization Zones for Classification System.

Trends

Conservative approaches to hip development (devices and surgical approaches) are the main focus in total hip arthroplasty at the moment [3,10]. The recent Metal on Metal concerns has reduced current alternate hard on hard bearing development [11]. The focus is on improved polyethylene material matting with improved ceramic heads and more conservative stem designs.

Recent reports with certain convention style stems have raised concerns over the use of modularity at this neck stem junction. Neck stem modular tapers are being used in six of the twenty-five devices we reviewed with success. It is important to remember not all modularity is created equal. Application of modularity in certain designs like neck sparing have, significantly reduced stresses at the modular neck stem junction compared to both conventional monoblock and modular designs [12,13].

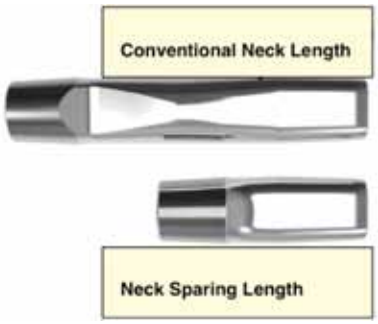

Figure 6. Comparison of Modular Necks (Standard Neck vs. Neck Sparing Design).

The European experience, with certain styles of conservative designs, is years ahead of our experience in the U.S., so it is reasonable to look towards Europe for both trends and early to mid-term clinical results [14].

JISRF Stem Classification System

HEAD-STABILIZED PROCEDURES (JISRF CLASSIFICATION 1A & 1B)

Head-stabilizing procedures are classified as either hip resurfacing or mid-head resection (e.g., Birmingham Mid Head Replacement (BMHR).

Hip Resurfacing (Jisrf Classification 1A)

This procedure is bone conserving as most of the femoral head is retained. The femoral head is shaped to accept a low-wear metal sphere, and most devices feature a stem component for alignment guidance.

Figure 7. Example of Hip Resurfacing

Mid-Head Resurfacing (JISRF Classification 1B)

This device was developed as an alternative to traditional hip resurfacing for patients whose femoral head structure or bone quality was inadequate for resurfacing.

Figure 8. Example of Mid-Head Resection Resurfacing

NECK-STABILIZED PROCEDURES (JISRF CLASSIFICATION 2A, B & C)

In his now classic paper, "Why Resect the Neck," published in a 1986 issue of the Journal of Bone and Joint Surgery, Michael Freeman was the first to advocate for sparing the neck. [36] Since the 1980s, Freeman has developed a number of neck-sparing stems to be used with and without bone cement. However, his stems have featured a conventional straight-length stem

Short Curved Neck-Sparing Stem (JISRF Classification 2A)

Recently, new designs are following in Pipino's Biodynamic™ stem style of saving the femoral neck. These designs feature a short curved stem that finds its stabilization contact region in the femoral neck and saves considerable bone in the medial calcar region. In addition, the curvature of the stem prevents violation of the lateral trochanteric region. The shorter stem also reduces blood loss by not reaming the femoral canal distally. These style stems generally have a variable stem length between 90 and 135 mm. This might not appear much shorted than conventional cementless stems (110 to 150 mm) however, the shorter curved neck sparing stems penetrate on average one to two centimeters less distally in the femoral canal.

Figure 9. Example of TSI™ Neck Preserving Short Curved Stem

One important factor to remember about neck sparing stems is the increase risk factor for mechanical impingement especially with retained osteophytes attached to the femoral neck. In addition if you cannot get to a 32mm head diameter we would recommend a dual mobile style versus using a smaller fixed head diameter. Alternatively, a different stem design may be indicated in these smaller patients.

Figure 10. Example Post-op view of Proxima Stem

Short Lateral Flare Engaging Stem (JISRF Classification 2B)

The authors have seen lateral flare engaging conventional cementless stems such as the Revalation® Stem (JISRF Classification 4), but we have only seen one short neck-preserving stem that engages the trochantic lateral falre (Proxima™ Implant).

Neck Plugs or Neck Only Implants (JISRF Classification 2C)

Several modified neck-sparing designs have recently been introduced that are only inserted into the femoral neck region. These have been referred to as "neck plugs or neck only" and are limited to international clinical experience. They appear to be a hybrid design between the short curved neck-sparing stem and the mid-head device by McMinn (BMHR). Surgeons who have been interested in hip resurfacing and robotics appear to be drawn to this design style. While results are short-term, interest appears to be growing with the decline of hip resurfacing.

Figure 11. Example of TSI™ Neck Plug

Models of neck plugs in development or currently on the on the market include the Silent Hip from DePuy, launched in 2009; the Primoris Neck Replacement from Biomet; the Spiron™ Hip by ARGE Medical Technics; the CUT™ Stem by Orthodynamics; and the TSI™ Hip by Concept Design & Development, LLC. All of these devic-

es have a common theme: engagement in the femoral neck and a 12/14 head neck taper. As many of these models are still in development, details on precise specifications and early clinical results are available for only three models of neck plugs: the Spiron™ Hip, the CUT™ Stem, and the Silent™ Hip.

SHORT METAPHYSEAL STABILIZED STEMS (JISRF CLASSIFICATION 3A AND 3B)

Short metaphyseal stabilized stems comprise the largest segment of short stems in the United States, compared with the neck-stabilized stems that dominate the European market. The first generation of short stems in the United States were truncated conventional tapered stems. This may be due in part to the nature of design and surgical technique. This style stem uses the same neck resection as conventional cementless stems and does not require an additional learning curve or modification of surgical technique. It also does not require any additional engineering modifications at the proximal portion of the stem. Some early reports from Europe on metaphyseal stems are beginning to recommend a higher neck resection to reduce stem subsidence and torsional instability.

Tapered Stems (JISRF Classification 3A)

Figure 12. Example of short metaphyseal style tapered stem.

One common design of short metaphyseal stabilized stems is the coronal wedge taper. Typically, this implant design is a modified version of a conventional stem length. The implant provides a tight wedge taper in the coronal plane and is relatively flat in the sagittal plane. The flat-plane design allows the surgeon to adjust stem version as needed. Coronal wedge taper stems provide a very tight wedge taper fit between the lateral femoral cortex and the medial femoral neck. This requires removal of the lateral femoral neck cortex. Most wedging occurs at the meta-diaphyseal junction of the proximal femur. Medial to lateral cortical contact is essential. The anterior to posterior fill is not anatomic. Consequently, the anterior and posterior surfaces are primarily in contact with cancellous bone.

Bulky or Fit and Fill Stems (JISRF Classification 3B)

Figure 13. Example of short metaphyseal style bulky stem.

These stems often feature anatomical shaped stems (left and right) with a percentage of anterversion (6º to 12º) built into a monoblock neck/stem configuration. They fit and fill most of the metaphyseal area. Some designs feature an enhanced lateral flare for enhanced stability.

Pitfalls and Liabilities of Short Stems

EXAMPLE: CONVENTIONAL METAPHYSEAL / DIAPHYSEAL STABILIZED STEMS (JISRF CLASSIFICATION 4)

Figure 14. AML® Stem

Use of short stem technology for primary THA comes with caveats. Shorter stems are generally less stable at initial press fit (compared with their longer stem counterparts). Surgeons, therefore, will compensate by forcing a "tighter" initial press fit. Surgical technique that emphasizes a robust press fit can lead to proximal femoral fracture. We have empirically seen this phenomenon with a variety of short stem designs. Conversely, if the surgeon adopts a less aggressive press fit technique to mitigate the risk of proximal neck fracture, the short stem may settle and become mechanically loose because the stem is less inherently stable to rotational loads compared with longer stem implants. This ultimately narrows the "sweet spot" for press fit technique. For some surgeons, learning the sweet spot for a particular short stem may entail a long learning curve. When considering short stem implants, one should, at a minimum, consider implanting these devices in an instructed cadaver course scenario.

Short stem designs that rely mostly on femoral neck fixation are susceptible to failure if the femoral neck is thin and osteoporotic. Rotational hip stress combined with cantilever bending forces can overstress the native neck bone, leading to bone fatigue. As a result, the hoop stresses that keep the implant stable are lost and the stem loses mechanical fixation and settles. To mitigate this problem, the authors believe all short stems must be limited in weight bearing for 4 to 6 weeks. A 50% weight load to the implant is recommended. This will give the femoral neck enough time to heal and biologically bond to the prosthesis. With the push towards ultra-short lengths of stay and "rapid recovery" protocols, this point must be continually emphasized to the health care team and patient.

Conclusion

Short femoral stems have been of interest to surgeons and implant designers for decades. Many varieties of short stem (JISRF classification 2 and 3) have been introduced over the years with the goal of reducing the soft tissue dis-

section associated with standard metaphyseal-diaphyseal stabilized (JISRF classification 4) length stems. Some short stems are also bone sparing, by preserving the medial femoral neck, the lateral femoral neck, or both.

Figure 15. Example of bone saving Gruen Zones with a Short Curved Neck Preserving Stem

The broad category of short stems actually encompasses several subtypes. The JISRF classification is recommended as a means to accurately assess the clinical performance of these subgroups. Neck/stem modularity plays an important role in some short stem implant systems in order to facilitate anatomic restoration. Avoidance of complications at the modular junction is a function of specific design parameters, especially when considering dissimilar metals. Short stems can be successfully implanted via all standard approaches to the hip, including anterior, lateral, and posterior approaches.

Short stems can facilitate surgical technique for THA. Specifically, when one is using Direct Anterior Approach (DDA), the neck-sparing curved design significantly facilitates cases of stem insertion. Less trochanteric levering reduces the risk of proximal femur fractures. Furthermore, with larger-sized patients, proximal extension of the incision is avoided. When utilizing a posterior hip approach, surgeons must note that a true neck-sparing implant provides a distinct advantage for soft tissue closure. Specifically, the capsular envelope is not extensively removed. This allows for a more robust closure of the posterior hip capsule, which may translate to improved posterior hip stability. Furthermore, since a majority of the femoral neck is preserved, the short external complex is successfully closed in a consistent fashion. This adds an additional soft tissue layer that is protective.

Short stems have a definite role in modern total hip arthroplasty, as greater emphasis is being placed on soft-tissue and bone-sparing techniques and as refinements continue in the understanding of proximal femoral fixation and the biomechanics of head/neck and neck/stem modularity.

Metaphyseal short stems have significantly less surface contact area compared with conventional length stems and as a result, they might have less torsional and axial resistance. Neck-retaining short stems provide additional axial and torsional stability and reduced stress at the implant bone interface and may be a consideration in the more active patient profile. Bone quality and the patient's physical activity should be considered prior to the selection of short-stem devices. Short stems both of older generations and new can and do work. Many short stem designs have considerably different style features that may alter bone remodeling. Bony adaptation around new implants might have different time frames before these changes occur. Only detailed follow-up will render the results.

Knowing the design and the required technique is vital in order to fit the device properly to the patient. The variations of short stems available call for caution in their overall use until there is better understanding of how dependent these stems are on individual stem features, bone quality, and surgical techniques. Overall, the authors are cautiously optimistic and continue advocating their selective use.

Figure 16. Post-op x-ray comparing conventional cementless stem to a short curved neck preserving style stem.

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