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The evolvement of cementless stems: Risks and rewards

*Joshua S. Bingham, MD, Adam Hart, MD, and Matthew P. Abdel, MD**

Department of Orthopedic Surgery, Mayo Clinic, 200 First Street S.W, Rochester, MN 55905

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ABSTRACT

Cementless fixation is the most common form of femoral fixation in North America for primary total hip arthroplasty (THA). While many contemporary designs are available, the goal of all cementless femoral stems is to achieve initial mechanical stability by interference press-fit, thereby obtaining long-term stability through osseointegration. In general, cementless femoral component designs vary based upon material composition, type and extent of biologic ingrowth surface, and geometry.

1. Introduction

Total hip arthroplasty (THA) is one of the most successful surgical procedures [1]. Over the past several decades, cementless femoral fixation for primary THAs has become increasingly common in North America [2]. It is estimated that nearly 90% of all primary THAs performed in the United States are cementless [3]. In the Australian National Joint Replacement Registry, the use of cementless femoral fixation has also increased from 51.3% in 2003 to 63.3% in 2015 [4]. During that same time period, cemented fixation declined from 13.9% to 3.7%. Despite the increasing popularity of cementless femoral fixation, it is not without risk. Failure of osseointegration and periprosthetic fractures are associated with a 1–3% failure rate within two years of surgery [5]. Intraoperative fractures are significantly more likely with cementless fixation compared to cemented fixation, especially in patients with risk factors such as female gender, age greater than 65, osteoporosis and Dorr C canals [6]. Despite these risks, cementless fixation continues to gain popularity likely related to the shorter surgical times, potential for biological fixation, and the long-term survival rates reported in the literature.

It is important to note that not all cementless femoral components are the same. In fact, there is great variation in the composition, type, and extent of biologic ingrowth surfaces, as well as geometry of different cementless femoral components. Each design has unique advantages and disadvantages. While some cementless femoral components are indicated for the general population, some are more specific and tailored for complex primary THAs [such as developmental dysplasia of the hip (DDH), post-traumatic arthritis with intraoperative concern for femoral version (and thus hip stability), or revision procedures where distal fixation is needed (such as those with periprosthetic fractures or lack of proximal metaphyseal bony support)].

In 2000, Berry [7] first described the evolution of cementless femoral components based upon distinct geometries that govern where fixation is obtained. This was further modified in 2011 by Khanuja et al [3] to include six general types of cementless femoral components based upon the shape and location of fixation. These stem types include single wedge (Fig. 1), double wedge with metaphyseal filling (Fig. 2), tapered (Fig. 3), cylindrical fully coated (Fig. 4), modular (Fig 5), and anatomic designs (Fig. 6, Table). Within each stem type, certain implant designs have shown excellent long-term

*Corresponding author:
E-mail address: abdel.matthew@mayo.edu (M.P. Abdel).

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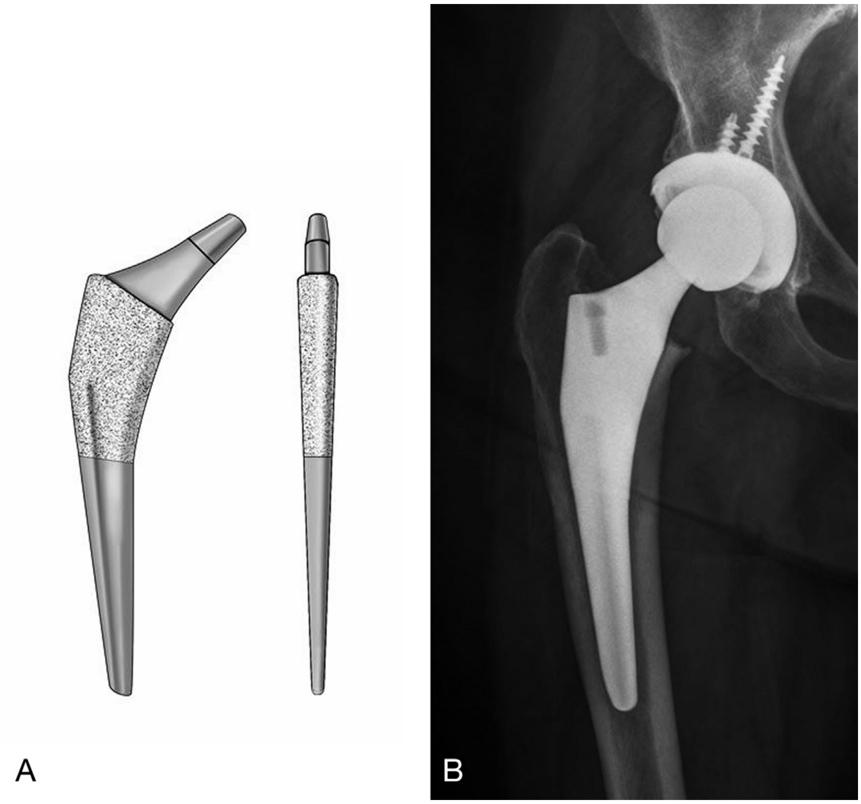

Figure 1 – (A) Illustration of a single wedge or type 1 stem. (Reprinted with permission from the Mayo Clinic.) (B) Radiographic example of a single wedge stem (Accolade II; Stryker, Mahwah, NJ) with proximal porous coating that is flat in the anterior-posterior plane and narrows in the medial-lateral plane distally.

survivorship, while other specific implant designs have had higher than expected failure rates. Of note, one class of stems that has shown early failures due to adverse local tissue reactions (ALTR) is that of dual-modular necks [8]. On the other hand, modular fluted tapered stems continue to produce excellent long-term data in complex primary THAs, as well as difficult revision THAs [9].

Although cementless femoral fixation in THA has become the preferred choice in North America, it is important to know the many design variations available. Understanding the potential risks associated with each stem design allows the operative surgeon to select the ideal component for each patient based on individual bony morphology. This chapter will discuss the composition, surface coating, stem geometries, and current trends in cementless femoral fixation.

2. Cementless stem composition

Since the first cementless stems were developed in the late 1970s, various materials have been utilized [10]. Cementless femoral stems have been manufactured from titanium aluminum vanadium alloy (TiAlV), cobalt-chrome molybdenum alloy (CoCrMb), stainless steel, and even low-elastic modulus composites. However, only TiAlV and CoCrMb stems are commercially available today, and the vast majority of cementless femoral stems utilized are TiAlV. There is extensive clinical evidence to support TiAlV as the material of choice over CoCrMb for cementless femoral stems. TiAlV has a lower modulus of elasticity, which is closer to the elastic modulus of cortical bone. The higher modulus of elasticity of CoCrMb stems has resulted in a higher rate of stress shielding and stem related thigh pain [11].

TiAlV is biocompatible, and is an excellent material to promote osseointegration [12,13]. Although the composition of cementless femoral stems is important, and TiAlV seems to be superior to other alloys currently available, it is not the only factor in producing a successful cementless femoral stem. Stem design and surface coating also play critical roles in successful osseointegration and long-term survival.

3. Cementless stem surfaces

Various cementless stem surfaces, whether they are an ongrowth or ingrowth in nature, are utilized in order to obtain osseointegration of the femoral component. Regardless of the specific surface, adequate osseous contact and initial stability are critical to minimize micromotion. Micromotion $<20\,\mu m$ leads to lamellar bone formation and osseointegration, while micromotion $>150\,\mu m$ results predominantly in fibrous tissue formation and failure to obtain successful osseointegration [14–16].

3.1. *Ongrowth cementless surfaces*

Ongrowth surfaces are manufactured by either plasma spraying or grit blasting implant surfaces. Plasma spraying utilizes