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An In Vitro Comparison of the Primary Stability of 2 Tapered Fluted Femoral Stem Designs

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ABSTRACT

Background: Proximal bony deficiencies present a biomechanical challenge to achieving primary stability in revision hip arthroplasty. Long tapered fluted stems have been engineered to span these defects but concerns of early subsidence are well documented. This work aimed primarily to investigate the issue of subsidence with this design using a cadaveric model. A secondary aim was to compare the stability of 2 versions of this design.
Methods: Seven pairs of cadaveric femora were obtained, dual emission x-ray absorpitometry scanned, with calibration radiographs taken for digital templating. Each bone was potted according to the ISO standard for fatigue testing and a Paprosky type 3 defect was simulated. The established cone-conical Restoration Modular (Stryker) system and a novel design with a chamfered tip and flute configuration (Redapt, Smith & Nephew) were examined. Movement at the stem-bone interface was measured using radiostereometric analysis and micromotion transducers.
Results: All restoration stems and 85% of the Redapt stems achieved stability by recognized criteria, micromotion < 150 μm and migration less than 2 mm. A Fisher exact test comparing the proportion of stems which were stable or unstable was not significant, $P = .055$. Mean axial subsidence (SD) was 0.17 mm (0.32) and 0.1 mm (0.131) for the Restoration and Redapt stems respectively.
Conclusion: This study has demonstrated minimal subsidence in the immediate post-operative period using tapered fluted stems. Both designs achieved excellent stability despite simulation of Paprosky type 3 bony defects in the cadaveric model. This geometry appears satisfactory for use in revision surgery in the presence of significant proximal bony deficiencies.

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Severe proximal femoral bony deficits (Paprosky type III and IV) [1] compromise implant stability and contribute to the inferior survivorship observed in revision total hip arthroplasty [2,3]. Revision stems have been designed to bypass proximal defects and gain primary fixation in the intact femoral isthmus. Interest in the use of tapered, fluted, modular, titanium (TFMT) stems for this purpose is growing but there are concerns regarding well documented early subsidence [3–6].

The current literature suggests increased popularity of the TFMT stem design in contrast to cylindrical, non-modular cobalt chrome prostheses [7,8]. Titanium alloy has a lower Young's modulus than cobalt chrome with a suspected improvement in load transfer and reduction in stress shielding [6,9,10]. The taper is thought to provide axial stability whilst the presence of longitudinal flutes in the TFMT prosthesis provides initial rotational stability based on the Wagner philosophy [11].

The main aim of this work was to investigate subsidence in 2 TFMT revision femoral stems implanted in cadaveric femora using micromotion transducers and radiostereometric analysis (RSA). The secondary aim was to compare the stability characteristics of these 2 designs. Both featured a 3° taper but varied in their flute configuration and stem tip geometry.

It was hypothesised that both TFMT stems would produce adequate stability under representative loads to support their use in revision cases with unsupportive proximal metaphyseal bony defects.

Materials and Methods

This study was performed according to Institutional and National Research Ethics Service guidelines using cadaveric bones sourced from a registered charity. 7 matched pairs of cadaveric femora (Anatomy Gifts Registry, Hanover, MD) were sourced according to strict inclusion/exclusion criteria. Specimens with sufficient bone mineral density to reflect the expected adult arthroplasty population were included

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Table 1
Demographic and Bone Mineral Density Data for Cadaveric Bones Used in Investigation. T-Score is Matched to the Healthy Adult Population and Z-Score to the age-Matched Population.

Donor I. D.	Side	Sex	Age	Body mass index (kg/m^2)	Total T-score	Total Z-score	WHO classification [30]
NY 326	L	M	72	24	−1.0	−0.3	Normal
NY 326	R	M	72	24	−1.0	−0.2	Normal
AZ 721	L	F	74	40	−0.3	1.5	Normal
AZ 721	R	F	74	40	−0.3	1.5	Normal
VA 262	L	F	63	37	−2.0	−0.8	Osteopenia
VA 262	R	F	63	37	−2.2	−1.0	Osteopenia
TN 253	L	F	75	18	−1.4	−0.3	Osteopenia
TN 253	R	F	75	18	−1.7	−0.6	Osteopenia
MI 709	L	F	64	31	−2.0	−0.8	Osteopenia
MI 709	R	F	64	31	−1.6	−0.3	Osteopenia
FL 914	L	M	73	26	−0.7	0.1	Normal
FL 914	R	M	73	26	−0.6	0.2	Normal
FL 615	L	M	66	33	−1.1	−0.5	Osteopenia
FL 615	R	M	66	33	−0.8	−0.2	Normal
Totals: mean (SD)			69.6 (4.6)	29.9 (7.4)	−1.2 (0.63)	−0.1 (0.76)	

and exclusion criteria included: a heavy smoking history, previous fragility fracture, gross anatomical deformity of the femur, prior trauma to the femur, history of malignancy, previous surgery to the femur, known history of metabolic bone disease or osteoporosis.

The tissues were delivered on dry ice, thawed overnight and any residual soft tissue removed. Dual emission x-ray absorpitometry scans were performed using Hologic scanners (Bedford, MA) at our institution's Metabolic Bone Unit. The donor demographic and bone mineral density recordings are summarized in Table 1.

Implants

The Restoration Modular system consisted of 2 components, a proximal body portion with a grit-blasted, straight fluted stem (Fig. 1). The titanium alloy (Ti-6Al-4V ELI) cone body is circumferentially plasma sprayed with titanium and then over-sprayed with hydroxyapatite. A 195 mm straight stem was used with a standard 70 mm cone body of smallest diameter (19 mm) to minimise proximal support. A 32 mm (+0) cobalt-chrome head was used for loading.

The three-part Redapt implant (Smith & Nephew, Memphis, TN) consisted of a stem, sleeve and neck (Fig. 2). The stem is manufactured from titanium alloy (Ti-6Al-4V) and is straight, tapered and fluted. In all cases the longest stem (300 mm) was used. A standard off-set neck with a 32 mm (+0) cobalt-chrome head was used. The sleeve component was omitted so as to limit the possibility of proximal support.

There were several notable differences in the designs and geometry of these 2 systems. The overall length of the assembled system was greater for the Redapt (300 mm) versus the Restoration (265 mm). The Redapt stem featured a single 3° taper whereas the Restoration stem had 2 distinct tapers. The flutes (major diameter) formed 2° and the stem shaft (minor diameter) 3°. The distal tip of the Redapt stem featured an anterior-posterior chamfer designed to reduce the risk of insertional fractures that can occur with a straight stem.

The principal difference between the Redapt stem and the Restoration control stem was the novel flute configuration (Fig. 3). The new pattern of flutes ('Rocktite') on the Redapt stem consisted of a multilevel fluted geometry to include major and minor splines. The major splines were designed as the principle contributory factor to axial and

Fig. 1. Restoration revision stem (Stryker).

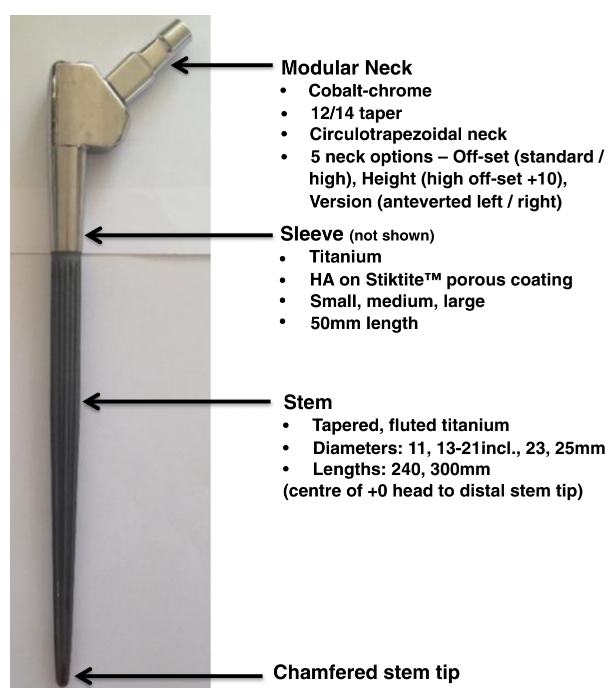

Fig. 2. Redapt revision stem (Smith & Nephew). HA, hydroxyapatite.