Design Rationale
A vast amount of clinical data supports the use of an extensively porous coated cylindrical stem in revision hip arthroplasty. ECHELON™ combines this proven philosophy with distinctive design features that address key clinical issues in revision surgery. These features set ECHELON apart from other stems in its class by offering a superior combination of fixation, range of motion, versatility and simplicity.

The ECHELON product line is a comprehensive revision system. In addition to porous coated implants, cemented implants are also available. The cemented components are designed for implantation with the same set of instruments as the porous stems, thereby allowing the surgeon to easily select the optimal method of fixation during surgery.
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System overview

The unpredictable nature of revision surgery is particularly challenging to the orthopaedic surgeon. Often times, the situation is difficult to assess prior to removal of the previously implanted hardware. For this reason, a variety of implant options with regard to surface treatment, sizing, and calcar platforms comprise the ECHELON® Revision Hip System.

Cementless Implants

Extensively porous coated cylindrical stems have demonstrated excellent long-term clinical results in revision hip arthroplasty. ECHELON stems are made of cobalt chrome, which allows for extensive porous coating of the prosthesis due to the notch sensitivity of titanium.

ECHELON porous coated stems are available with straight and bowed distal geometries to accommodate the natural femoral anatomy, and in lengths ranging from 190 to 260mm.

ECHELON POROUS PLUS® HA

190mm stems are provided with porous coating to the tip of the implant for situations where the extent of the proximal defect mandates additional porous coating. A 50 micron hydroxyapatite layer is applied onto the porous surface.
Cemented Implants

In cases where the bone stock is not optimal for cementless fixation, a cemented revision prosthesis is available. ECHELON™ cemented implants are available in lengths of 175, 225, and 300mm. The 300mm implant is bowed to accommodate the natural bow of the femur. Specific design features contribute to success at the implant/cement interface such as:

- **Double Taper Proximal Geometry** – limits shear stresses and promotes compressive stress transfer between the cement and implant.
- **Proximal Anterior/Posterior Groove** – increases rotational stability without increasing cement stresses.
- **Trapezoidal Distal Cross Section** – improves resistance to rotation.

Calcar Platforms

Revision hip surgery is often accompanied by deficient bone stock or severe bone loss in the proximal femur. ECHELON cementless and cemented implants are available with a standard collar, +15mm and +30mm calcar platforms. A calcar replacement revision stem is indicated for use in the presence of a proximal defect of the femur.

Note: Cemented implants also available in 300mm length.
Short and long term fixation

Initial stability of an implant is an important factor in the clinical success of a femoral prosthesis. The ECHELON™ Revision Hip System is comprised of both porous-coated implants for fixation by bone ingrowth and matte-finish implants for use with cement. For each method of fixation, key features assist in optimizing short and long-term fixation.

Cylindrical stem geometry
For cementless revision hip arthroplasty, a cylindrical femoral prosthesis is often preferred for achieving necessary distal fixation. The proximal portion of the host femur is usually deficient and fit and fill of the diaphysis is essential for initial and continued stability of the implant.

Proximal flare
The proximal body is designed to work in conjunction with distal fixation. ECHELON porous implants have a 3° proximal anterior/posterior flare to improve proximal fill, without preventing implant seating. In addition, a 0.5mm press-fit is achieved between the broach and the implant, providing an interference fit and enhancing initial fixation. The 0.5mm press-fit and flare work together to transfer stresses to the host bone, thereby reducing the risk of resorptive proximal bone remodeling, which is often associated with cylindrical distal fixation stems.

ECHELON has a 3° proximal anterior/posterior flare to improve proximal fill, without preventing implant seating.
Distal flutes provide immediate implant fixation and rotational stability. Immediate rigid fixation and rotational stability contribute to long-term fixation and success of the implant, whereas micromotion can result in loosening and ultimately failure of the prosthesis.³

NOTE: ECHELON POROUS PLUS® HA is fully porous coated, and then coated with 50 microns high shear strength hydroxyapatite. There are no flutes on this implant.

Sizing
ECHELON™ implants are available in 1mm increments to minimize bone removal and provide optimum canal fill. A consistent observation in the results of cementless implants has been the dramatic improvement in clinical outcomes with use of components that are available in a greater range of sizes. This allows for a closer match between the component and the host bone’s endosteal geometry. The clinical effects of mismatches between implant and bone geometries appears to contribute to micromotion at the bone-implant interface.⁸

ROUGHCOAT® Porous Coating
Circumferential rough porous coating of sintered beads (ROUGHCOAT) increases the friction between the implant and bone, improving implant stability and providing a porous surface for bone ingrowth. This helps reduce the initial movement of the prosthesis and results in implant stability, which contributes to a lower incidence of pain.¹⁰

Distal flutes increase rotational stability by providing immediate fixation upon implantation. Immediate rigid fixation and rotational stability contribute to long-term fixation and success of the implant, whereas micromotion can result in loosening and ultimately failure of the prosthesis.³

NOTE: ECHELON POROUS PLUS® HA is fully porous coated, and then coated with 50 microns high shear strength hydroxyapatite. There are no flutes on this implant.
Short and long term fixation

In revision total hip replacement, intimate contact between the femoral component and the host bone is much more difficult to achieve than in primary total hip replacement. Proximal bone loss and procedures such as an extended trochanteric osteotomy reduce proximal support, forcing the surgeon to rely on initial distal fixation for bone ingrowth.

ECHelon™ POROUS PLUS HA™ may be advantageous when an extended trochanteric osteotomy has been performed or there is deficient proximal bone. The added porous coating will allow for a minimum of 4-6 cm of scratch fit past a proximal bone deficiency, while the properties of the hydroxyapatite coating are consistent with those that have been clinically successful.

Hydroxyapatite coating

Through clinical studies, important HA properties and their respective values that characterize a clinically successful coating have been identified.

These properties are:

- Thickness
- Purity
- Calcium to Phosphorous (Ca/P) ratio
- Crystallinity

Thickness

A thick HA coating is more likely to have a lower attachment strength than a thinner one. As a result, it is more likely to crack and delaminate under fatigue loads. Conversely, a very thin coating will dissolve and disappear quickly. The optimum thickness has been shown to be 50 microns. The HA coating applied to ECHelon POROUS PLUS HA is 50 microns.
**Ca/P Ratio**

This ratio is the relative amount of Calcium to Phosphorous found on the coating. It is used to distinguish HA from other minerals with similar composition. HA has a Ca/P ratio of 1.67. The HA coating applied on ECHELON® stems has a Ca/P ratio of 1.67.

**Purity**

An HA coating should have a minimal amount of impurities. The source of impurities can be the manufacturing method. Because of the special method used, the HA powder applied on ECHELON stems is more than 99% pure.

**Crystallinity**

HA can be in crystalline form or amorphous (non-crystalline). Amorphous HA tends to dissolve faster, a coating with high crystallinity dissolves slower. An optimum amount of crystallinity is required in order for a part of the coating to slowly dissolve. FDA guidance recommends a minimum of 62% crystallinity. The HA coating applied on ECHELON stems has an average crystallinity of 68%.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Clinically Successful Value</th>
<th>FDA or ASTM Requirements</th>
<th>Smith &amp; Nephew HA</th>
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<tr>
<td>Thickness</td>
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<td>NA</td>
<td>50 Microns</td>
</tr>
<tr>
<td>Ca/P Ratio</td>
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</tr>
<tr>
<td>Crystallinity</td>
<td>68%</td>
<td>62%</td>
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</tbody>
</table>
The restoration of proper hip biomechanics is one of the key objectives of hip arthroplasty. Design characteristics of the prosthesis can have a significant impact on the outcome of the procedure. Distinctive design features of ECHELON™ implants maximize range of motion and restore offset so as to minimize the following:

- Increased poly debris that could lead to osteolysis
- Subluxation and possible joint dislocation
- Prosthetic loosening
- Dislodgement of a modular acetabular liner

**Circulotrapezoidal neck**

Optimizing neck geometry increases range of motion. The circulotrapezoidal neck on the ECHELON stem is designed to provide a greater range of motion than a circular neck. By using more material in the medial/lateral direction where fatigue requirements are higher, and less material in the anterior/posterior direction where demands are smaller, the range of motion is maximized.

The circulotrapezoidal neck was first used on the SPECTRON™ Total Hip System, which has 20 years of excellent clinical results.

**Anteversion**

It is not necessary to build anteversion into the neck of the stem to maximize range of motion. In a computer simulation study (right), results indicated that built-in anteversion does not increase range of motion – it merely shifts the location of the range of motion. With proper neck, taper, and acetabular liner geometry, a neutral stem neck can provide a greater range of motion than a stem with a circular neck and built-in anteversion.

*The circulotrapezoidal neck was first used on the SPECTRON Total Hip System, which has 20 years of excellent clinical results.*
Progressive offset

Femoral offset is an important clinical requirement of proper joint function. The advantages of increasing femoral offset after hip arthroplasty are reported to include increased range of motion, better mechanical advantage for the abductors and decreased instability because of improved soft tissue tension.15

When offset is not restored, medialization of the femur can occur, resulting in impingement and possible instability.17 Furthermore, when offset is not restored at the time of surgery, laxity of the soft tissues can occur, resulting in weakness and possible dislocation.

ECHELON® Revision stems incorporate offset greater than standard offset primary stems, and the amount of offset increases as the stem size increases.

Optimized 12/14 Taper

The size of a taper connection affects range of motion. ECHELON stems have an optimized 12/14 taper that is buried inside the femoral head for increased range of motion compared to other taper designs. A large taper that is exposed beyond the femoral head may impinge on the cup, thereby limiting range of motion. Skirted heads also have a negative impact on range of motion. Head sizes range from -3 to +16, with the need for a skirt only on sizes +12 and higher.

In a clinical study, the dislocation rate at a minimum of two years follow-up was 15.4% for a stem with a 14/16 taper, a circular neck cross-section, a fixed 42mm offset, and an anteverted neck compared to 4.3% with the ECHELON Revision stem.19

<table>
<thead>
<tr>
<th>Neck offset (mm)</th>
<th>Head size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem size</td>
<td>-3</td>
</tr>
<tr>
<td>11-12</td>
<td>38</td>
</tr>
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<td>13-17</td>
<td>43</td>
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<td>18-20</td>
<td>48</td>
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</tbody>
</table>

Large exposed tapers or skirted heads decrease prosthesis range of motion up to 40 percent.17

In a clinical study, the dislocation rate at a minimum of two years follow-up was 15.4% for a stem with a 14/16 taper, a circular neck cross-section, a fixed 42mm offset, and an anteverted neck compared to 4.3% with the ECHELON Revision stem.19
Versatility and simplicity

In the case of revision surgery, risks are greater, and the demands placed on a system are therefore greater. It is imperative that a prosthesis address a variety of situations and concerns, while offering a reproducible implantation technique. ECHELON™ design features work to simplify the procedure and optimize the clinical result by reducing associated risks such as fracture upon insertion, thigh pain and proximal bone resorption.

Optimized medial curve

The medial curve was determined by a radiographic study of over 100 patients. It starts at a higher location than competitive designs to avoid impingement and risk of fracture upon insertion.

Coronal slot

The coronal slot in ECHELON implants accomplishes the following three objectives:

- Reduce overall stem stiffness
- Ease stem insertion
- Reduce risk of fracture

Stem stiffness is correlated with stress shielding, and therefore a reduction in overall stem stiffness could reduce the rate of resorptive remodeling of the femur. A flexibility analysis comparing ECHELON to AML revealed that ECHELON was less stiff in both the anterior/posterior and medial/lateral aspects.¹⁸

NOTE: ECHELON Porous Plus HA does not have a coronal slot.

In a cadaver study, a distally slotted, fluted stem design was found to generate lower bone strains during insertion than a solid fully coated stem of the same geometry. This translates into a lower risk of fracture during insertion.¹⁵, ¹⁹

Reaming

Sharp reamers are available in 0.5mm increments to allow for the option to ream line to line or under-ream by 0.5mm for desired press-fit. Rigid reamers are used to prepare the femur for implants of 175-190mm, while thin shaft elliptical reamers are used for implants of 225-300mm.

Broaching

ECHELON broaches feature a tooth pattern that has been ground on a five axis machine. This tooth arrangement helps move bone chips up and out of the femoral canal which makes bone preparation straightforward and facilitates cleaning.

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NOTE: ECHELON Porous Plus HA does not have a coronal slot.
Polished bullet tip

ECHELON® implants feature a polished bullet tip distal to the flutes. This design geometry prohibits impingement upon the femoral cortex, and therefore reduces stress between the implant tip and the femoral bone. Eliminating contact altogether at the tip further reduces the risk of thigh pain with ECHELON. Thigh pain is found to be a result of micromotion at the interface between the distal stem and the bone. Finally, the tip is polished to avoid bone on growth.

Instrumentation and technique

ECHELON instrumentation is designed to work specifically with ECHELON implants. Instruments are precise and provide added control and surgical options.

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Broaching

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Stem insertion

ECHELON implants and trials feature a threaded driving platform with a slot for rotational implant control during insertion.


References
