Hydroxyapatite Coating on the Femoral Stem in Primary Total Hip Arthroplasty

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Since the mid 1980s, hydroxyapatite coating on femoral implants has been used to enhance bone attachment to the implant surface. Porous or mesh coating facilitates bone ingrowth. In contrast, bone ongrowth predominates when a grit-blasted surface is used. However, with the addition of hydroxyapatite to a porous or grit-blasted surface, bone ingrowth, ongrowth, and chemical bond attachments are present. The osteoconductive nature of hydroxyapatite encourages more ongrowth along the implant surface.

**MATERIAL PROPERTIES**

The Ca/Po$_3$ ratio of hydroxyapatite (Ca$_{10}$[PO$_4$]$_6$(OH)$_2$) is 1.67:1, resulting in a biocompatible, hexagonal, crystalline structure. Hydroxyapatite is osteophilic and demonstrates no local or systemic tissue toxicity. Previous canine femoral studies have demonstrated that hydroxyapatite can exist for up to 10 years in its bulk form. Furthermore, it has the advantage of preferential bone deposition compared to smooth titanium surfaces alone.

Hydroxyapatite does not reduce the strength of the metal substrate, nor does it allow dissolution of underlying elements of the implant material. Mechanical properties at the hydroxyapatite-prosthesis interface are characterized by variable hydroxyapatite coating thickness. Excessively thick coats of hydroxyapatite (>200 μm) may result in delamination, whereas thin coats (<50 μm) induce resorption. Investigations involving tensile, bending, torque, and fatigue testing have previously reported that 50 μm is considered an optimal thickness.

We use the Osteonics Omnifit stem (Stryker Howmedica Osteonics, Allendale, NJ) with proximal hydroxyapatite coating on a grit-blasted titanium surface. The hydroxyapatite-coated proximal portion of the stem also has normalization steps that transform hoop stresses to compressive loads, resist medial migration and subsidence, and allow for more efficient load transfer. A satin finish (Ra=67 μm) is present distal to the hydroxyapatite coating.

**CLINICAL APPLICATION**

The use of hydroxyapatite-coated implants in total hip arthroplasty (THA) has many advantages. Hydroxyapatite coating increases ongrowth and attachment to bone and leads to an even distribution of bone over the implant’s surface. In turn, this decreases the amount of micromotion between the bone and implant, and may result in reduced subsidence, conversion of fibrous ingrowth to bony ongrowth, and decreased osteolysis by limiting access of polyethylene wear debris to the femur.

The rate and strength of fixation with hydroxyapatite-coated implants may be greater as well. One canine study reported a more rapid microstructure bond between bone and implant (6 versus 12 weeks) for implants coated with hydroxyapatite over those without. The same investigator later reported up to three-fold greater strength at the bone-implant interface in implants with hydroxyapatite versus those without.

Decreased micromotion has been previously documented at the bone-implant interface, and decreased fibrous membrane formation in implants with hydroxyapatite coating was reported as well.

Hydroxyapatite has also been reported to be beneficial in the space between bone and cementless implant. One study documented bone-implant biofixation with as much as a 2000 μm (2 mm) gap between the hydroxyapatite-coated implant and bone versus the accepted gap reduction to 300 μm with microstructured coating alone. The ability to establish intimate bone-implant contact has, in some cases, enabled the stem to be explanted and leave behind an intact endosteal surface (Figure 1).

Hydroxyapatite coating may result in formation of a barrier to free ion release from implant metal. A chemical bond is formed between hydroxyapatite and the implant material, greater for titanium than for cobalt chromium. Further, in consideration of implant wear and long-term survival, data have suggested that hydroxyapatite coating of implants inhibits peri-implant migration of polyethylene particles to a greater degree than grit-blasted implants alone by creating a seal of tightly-bonded bone.

**RESULTS**

A recent study in a canine model comparing osseous response to identical titanium implants with varying surface finishes reported bone apposition in various groups as 3% (polished), 23%
(grit-blasted), 74% (hydroxyapatite coated), and 59% (masked titanium layer—negates chemical-hydroxyapatite bond). These results demonstrate that chemistry is an integral component of hydroxyapatite-coated implants, but that surface topography is the dominant factor in bone apposition.

Survival data for the Osteonics Omnifit stem is now available, and indicate excellent clinical results and 98.7% stem survival at 10-13 years. Favorable results at minimum 11-year follow-up were reported more recently, demonstrating 97% stem survivorship.

These results agree with previous investigations in single and multicenter trials. At our institution, in 100 consecutive hips using hydroxyapatite-coated femoral stems at 11-14 years, the mean Harris Hip Score was 90.1, and 91% reported no or mild hip pain. Two complications, each from sepsis (treated with intravenous antibiotics), and periprosthetic fracture (stem retained) resulted. The stem revision rate was 1% overall, resulting from aseptic loosening of a single stem at 6.5 years.

CONCLUSION

Based on radiographic observation and multicenter clinical outcome up to 14 years, hydroxyapatite appears to be superior to grit-blast alone as a surface finish on cementless implants in THA. Specifically, provision of hydroxyapatite coating provides a reliable, fast incorporation of surrounding bone, minimizes surrounding osteolysis, facilitates cortical hypertrophy, and results in a low mechanical failure rate.

REFERENCES