Focus On Fixation
PPS® Porous Plasma Spray
Focus On FIXATION

The implant surface area is the only aspect of a prosthesis to actually touch a patient’s bone, meaning the efficacy of the surface coating is an important contributing factor to the long-term stability of cementless arthroplasty.

In determining which implant and surface coating is best for your patients, consider the following:

- How are initial stability and fixation achieved?
- To what degree will osseointegration occur, and when?
- Will the coating successfully inhibit debris migration?

By addressing these issues since its introduction in 1981, Biomet’s PPS® Porous Plasma Spray has achieved outstanding clinical success, as documented by numerous studies. At follow-up, many surgeons have observed extremely low rates of osteolysis and nearly 100% survivorship at over 10 years with PPS® coated prostheses.1, 2, 3, 4

PPS® Porous Plasma Spray

- Creates a mechanical interlock with the substrate, resulting in nearly a two-fold increase in fatigue strength when compared with sintered surface coatings.5
- Provides initial implant stability through a scratch-fit fixation obtained by enhanced surface roughness.
- Maximizes short and long-term ingrowth through random, non-interconnected pores and pore size distribution.
- Creates a barrier to migrating debris particles, reducing the likelihood of osteolysis.4
Focus On *Time-Proven Design & Process*

The application of Biomet’s titanium porous plasma spray coating is a computer controlled process subject to strict manufacturing tolerances for particle size, voltage current and gas pressure. The resulting rough, mechanically bonded circumferential coating aids in short and long-term fixation and greatly reduces the risk of osteolysis through its non-interconnected pore structure. The figure below details engineering characteristics that contribute to Biomet’s PPS® Porous Plasma Spray’s continuing clinical success.

**Biocompatible Titanium Alloy**

Titanium alloy has been shown to be highly biocompatible and enhances osseointegration.

**Titanium Substrate**

The substrate is never heated during the application of the PPS® Porous Plasma Spray, resulting in a very high fatigue strength.

**Mechanical Bond**

PPS® Porous Plasma Spray bonds mechanically, not metallurgically, to the substrate, resulting in a high retention of substrate fatigue strength.

**Random Pore Size**

A variable pore size distribution range between 100 and 1,000 microns aids in both short and long-term fixation.

**Rough, Porous Surface**

Irregularly shaped particles create a proud surface, which allows a scratch-fit during implantation for initial stability.

**Non-Interconnected Pore Structure**

A non-interconnected pore structure effectively blocks routes for debris migrating distally along the length of the implant.
All prostheses are subjected to extremely high loads once implanted, particularly in weight-bearing joints. Biomet uses specialized manufacturing procedures to optimize substrate quality and implant strength, allowing for long-term viability.

**Substrate Preparation**

To combat notch sensitivity (a phenomenon where small surface imperfections on the substrate can adversely affect fatigue strength), Biomet prepares the substrate surface to maximize fatigue strength and ensure strong mechanical bonding.

**Shot Peening**—Bombarding the titanium substrate with small beads induces compressive stress deep within the surface, increasing fatigue strength and reducing notch sensitivity.

**Grit Blasting**—The substrate’s roughened surface aids in the mechanical interlocking between the implant and the PPS® Coating.

**Titanium Alloy Coating**—Within the plasma chamber, irregularly shaped titanium alloy powder is projected at high speeds through a high temperature plasma arc, striking the substrate in a semi-molten state. The molten outer shell of each particle flows over the grit-blasted roughened substrate surface and solidifies, resulting in a strong mechanical interlock with the substrate.

**Bead Blasting**—The finished prosthesis is bead blasted to remove any loose coating particles.

**Result of Plasma Spray Process**

Maintaining an implant’s inherent fatigue strength allows for a stronger prosthesis that is better able to withstand daily patient demands with lower risk of breakage to provide for increased longevity.

Biomet’s proprietary plasma spray application is unique in comparison to competitive methods due to the fact that only the titanium alloy powder is heated, not the substrate of the implant. “With the sintering or diffusion bonding techniques, the mechanical strength of the substrate is reduced by 50% or more...Plasma spray techniques allow the substrate material to retain 90% or more of the fatigue strength characteristics reported for uncoated titanium alloy implants.”

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**Fatigue Strength Comparison**

<table>
<thead>
<tr>
<th>Description</th>
<th>PSI at 10 Million cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porous Plasma Spray CoCrMo</td>
<td>79</td>
</tr>
<tr>
<td>Porous Plasma Spray Ti</td>
<td>63</td>
</tr>
<tr>
<td>Sintered Bead Cast CoCr</td>
<td>40</td>
</tr>
<tr>
<td>Sintered Bead Ti</td>
<td>30</td>
</tr>
<tr>
<td>Diffusion Bonded Fiber Mesh</td>
<td>30</td>
</tr>
</tbody>
</table>

Pounds per square inch in 1000s

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Titanium PPS® Porous Plasma Spray being applied through a heated plasma arc.
Focus On **Scratch-Fit**

Biomet’s **PPS® Porous Plasma Spray** is unique among surface coatings in its ability to attain immediate post-operative fixation. Unlike smooth beads and fiber mesh, the surface of plasma spray on a microscopic level is very rough, resulting in markedly higher coarseness and surface interlocking (Fig. 1).

**Achieving Immediate Fixation**

All surface coatings may have varying degrees of surface roughness to the touch; however, roughness makes a difference in fixation at the microscopic and cellular level. **PPS® Porous Plasma Spray**’s microscopic roughness is the result of irregularly shaped pores, inducing osseointegration by creating a “scratch-fit” between the porous coating and the cortical bone during prosthesis insertion. This scratch-fit action causes the rough titanium surface to scrape the walls of the femoral canal, filling the small pores with bone and providing excellent initial stability. Implants with a smooth surface profile (such as sintered beads) have limited microroughness.

![Biomet’s superior clinical results with cementless prostheses are a direct result of the immediate fixation achieved through titanium alloy PPS® Porous Plasma Spray.](image)

A study comparing the scratch-fit stability of acetabular shells with three different porous coatings concluded that **PPS® Porous Plasma Sprayed** cups were twice as strong in resistance to rim failure as the beaded or fiber mesh cups.21
Focus On *Pore Size Distribution*

Optimal fixation may be achieved as a result of an ideal pore size distribution attained through the **PPS® Porous Plasma Spray** application process (Figs. 3 & 4).

**Successful Osseointegration with PPS® Porous Plasma Spray**

The engineering design of an implant’s surface coating seeks to maximize cortical bone contact through a moderately proud profile and a wide distribution of pore sizes to encourage full osseointegration. In keeping with these principles, Biomet’s proprietary application process distributes multiple coats of porous titanium alloy over the substrate, creating layers of varying pore sizes intended to maximize osseointegration. The circumferential coating also sits high enough off of the substrate to provide stable scratch-fit fixation.

Increasingly, surgeons are encouraging patients with Biomet’s **PPS® Porous Plasma Sprayed implants** to weight-bear immediately post-op, which attests to the value of scratch-fit fixation.²²

**Fixation with Beads**

In the case of large beads, the smooth beaded surface and large interconnected pores may fail to provide initial stability and a barrier to debris migration, which could potentially lead to micromotion, early loosening or dislocation.²³ Other sintered bead surfaces (Fig. 5) composed of only very small pore sizes may result in questionable long term fixation.³ According to one study, “The strength of the interfaces [bone-to-prosthesis] formed by the PPS® coated specimens exceeded [sintered bead] porous coated specimens by 81%.”²⁴ Similarly, the smooth surface of wire mesh combined with its large pore structure could fail to achieve successful initial fixation (Fig. 6).²³

**Biomet’s PPS® Porous Plasma Spray vs. Other Plasma Sprays**

The fabrication process of Stryker Arc Deposition (Fig. 7) is similar to Biomet’s in that it entails shooting titanium particles through a plasma flame but not in a fashion conducive to porosity, fixation and long-term stability. The Food & Drug Administration prohibits Stryker from marketing Arc Deposition as “promoting biological ingrowth” because it is a non-porous coating.²⁵
Focus On *Preventing Osteolysis*

**PPS® Porous Plasma Spray** is designed to prevent debris from migrating distally, minimizing the greatest threat to implant longevity: osteolysis.

**Non-Interconnected PPS® Porous Plasma Spray**

PPS® Porous Plasma Spray, by its design, has no defined pathways through which particle debris can travel due to its non-interconnected pore structure. Together, the seal between the titanium substrate and non-interconnected circumferential porous coating creates a barrier to particulate debris migration that helps reduce osteolysis and improve long-term fixation (Fig. 8).

Most modern coatings are fully circumferential; however, a fully circumferential coating may not guard against osteolysis, particularly if the coating’s pore structure is interconnected, such as in sintered beads (Fig. 9).

This may result in a greater risk of particulate matter passing unobstructed proximally to distally.²⁶

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The construct of Biomet’s non-interconnected PPS® Porous Plasma Spray is critical to the long-term performance of the prosthesis.

**Fig. 8**: 50x photomicrograph of the non-interconnected pores of PPS® Porous Plasma Spray

**Fig. 9**: 50x photomicrograph of the interconnected pores of a sintered bead coating
Biomet’s Osteocoat® HA coating provides for accelerated bony ingrowth.

A 2001 JBJS study demonstrated that Hydroxyapatite stimulates osteoblastic activity for optimal initial stability when applied over the top of the clinically proven PPS® Porous Plasma Spray.29

The following characteristics of Hydroxyapatite composition have a considerable impact on its clinical success.30

**Features of Biomet’s OsteoCoat® HA Coating**

- **Pore Size**: Hydroxyapatite enhances PPS® Porous Plasma Spray’s proven clinical effectiveness by its thin surface coating (~ 75 microns) designed to enhance bony ingrowth. The resultant post-ingrowth pore size of plasma spray is entirely unaffected by the HA coating. When Hydroxyapatite is broken down and replaced by the body, the underlying titanium PPS® Porous Plasma Spray coating may be integrated to an even greater extent.

- **Crystallinity**: Crystallinity is a measure of a substance’s structural homogeneity. Although there is no recognized ideal crystallinity, an HA coating with a very high crystallinity is resorbed slowly, generating slow osseointegration. However, a very low crystallinity value results in rapid resorption, preventing the body from generating a meaningful bone producing response. Biomet’s HA coating employs a crystallinity value greater than 50% but less than 70%, which allows the coating to perform as intended within the body.

- **Purity**: HA is most effective when it is highly refined and contains very few extraneous substances. Biomet maintains a very high purity (95%+) for all HA products. The remaining phases are calcium phosphates.

- **Thickness**: The process of breaking down HA and replacing it with natural bone can take months, but the immediate post-operative period is perhaps the most critical in determining success. An extremely thick HA coating (>100 microns) will act the same as a thin coating; however, the body is unlikely to resorb it fast enough to fully interdigitate bone with the prosthesis. Biomet applies a 75 micron layer over PPS® Porous Plasma Spray to maximize the body’s natural bone-producing response and fully leverage the power of rapid fixation.
Focus On *Unparalleled Clinical Results*

**Mallory-Head**
Porous Primary Hip Stem

- **99.5% survivorship**
  12 year follow-up
  188 hips

- **99.9% survivorship**
  10-13 year follow-up
  307 hips

- **98.2% survivorship**
  Patients aged 40 years and younger
  7.6 year average follow-up
  249 hips

- **97.3% survivorship**
  10.1 year average follow-up
  76 hips

**Taperloc**
Hip Stem

- **99.6% survivorship**
  12 year follow-up
  4,750 hips

- **98% survivorship**
  8-12 year follow-up
  114 hips

- **100% survivorship**
  Rheumatoid arthritis patients
  5 year follow-up
  50 hips

- **95% survivorship**
  Obese patients
  14.5 year average follow-up
  100 hips

**Bi-Metric**
Porous Primary Hip Stem

- **100% survivorship**
  10.4 year average follow up
  105 hips

- **100% survivorship**
  Juvenile chronic arthritis patients
  9.6 year average follow-up
  77 hips

- **100% survivorship**
  12.2 year average follow-up
  104 hips
References
