



Transforming lives with Zircon



Zircon is probably best known for its extensive use in modern ceramics — from elegant tableware to bathrooms and kitchens. Due to its high refractive index, it's highly regarded for making ceramic tiles and sanitaryware whiter and brighter.

Yet, there is another type of zircon-based ceramic which may be less known but is essential in life-enhancing orthopaedic applications.

Ceramics have been used in joint replacement surgery (arthroplasty) of arthritic hips and knees since the 1970s.⁴¹ In prosthetic hip and knee bearings, ceramic surfaces offer the significant benefit of drastically reduced wear rates and excellent long-term biocompatibility, which can increase the longevity of prosthetic hip and knee joints.¹

The last 25 years have seen the development and increasing use of another zircon-based advanced implant material for hip and joint bearing surfaces made from oxidised zirconium, known commercially and patented as OXINIUM.

How have joint replacements evolved?

Joint replacement is a highly successful operation that relieves pain and improves mobility. In the US alone, approximately 790,000 total knee replacements and over 544,000 hip replacements are performed annually.¹

By their very nature, hip and knee replacements demand a high-performance material that can deliver proven clinical performance and meet the expectations of patients for reduced pain and increased activity.

The traditional type of hip replacement, for example, with its origins in the 1950s and 60s, is a metal ball on a stem fixed into the femur (thigh bone) and a plastic liner - typically in a metal shell - replacing the socket in the pelvis. In older patients, this type of hip replacement is unlikely to wear out within their lifetime.

However, younger, more active patients are often advised to have a hip replacement made from harder-bearing surfaces, such as ceramic-on-ceramic.²

OXINIUM, developed by medical technology company Smith+Nephew, is a ceramicised metal that offers the best of both worlds for bearing surfaces - providing the wear resistance of ceramic and the durability of metal.

It can be used in partial knee, total knee, primary hip, revision hip and revision knee joints.

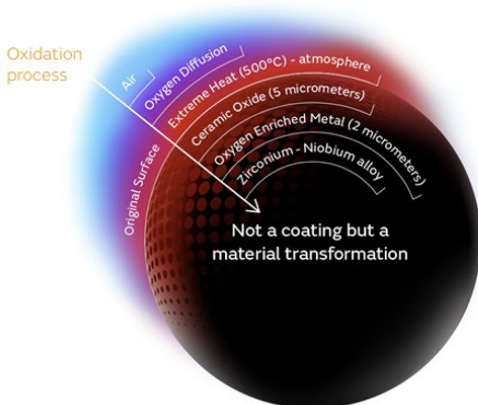
What is the material science behind ceramicised metal?

An OXINIUM implant is composed of an oxidised zirconium (OxZr) alloy. The original metal surface is transformed through heating in air at over 500°C to create a 5µm thick ceramicised oxide.³

Ceramicised metal is a uniform surface transformation, providing the implant with the durability of metal, the wear of a ceramic bearing, and fretting/corrosion resistance that, according to Smith+Nephew, is better than both.⁴⁻⁶

How is OXINIUM Technology manufactured?

The zirconium alloy core undergoes a transformation at its surface, upon heating, to form a ~5µm thick ceramicized surface.



The way the ceramicised metal is manufactured is unique, creating a ceramic oxide surface that is fully integrated with the zirconium alloy of the implant. In contrast to other materials used in arthroplasty, the ceramicised metal is not an externally applied coating, which in severe cases can peel off, delaminate and cause problems, particularly on the surface of bearings.

In testing OXINIUM's resilience, Smith+Nephew carried out 45 million simulated wear cycles, tested in hip simulators, without any measurable loss in oxide thickness. This is nine times the industry standard.⁷

What are the benefits of using ceramicised metal for joint replacements?

As the number of cases and age of patients increases, orthopaedic applications demand a high-performance implant material.

Corrosion, strength, wear and metal composition can all impact implant survivorship and quality of the implant.^{8,9}

Since its introduction, the OXINIUM technology has been used in more than two million procedures over 25 years in 120 countries and when combined with Smith+Nephew's implant designs has seen proven clinical performance in a range of patients.¹⁰⁻¹⁷

According to Smith+Nephew, OXINIUM has several key properties that differentiate it from other bearing materials:

- Reduces wear and is twice the surface hardness (versus cobalt chrome)^{18, 19}
- Delivers the strength of a metal without the concern of surface phase transformation and brittle fracture that has been observed in ceramic materials^{20 - 22}
- Lower observed mechanically assisted crevice corrosion^{23, 24}
- Contains virtually undetectable levels of nickel, cobalt and chromium^{25, 26}
- 4,900 times more abrasion resistance than cobalt chrome after 10 million cycles of pin-on-disc lab testing using bone cement²⁷
- Goes beyond basic biocompatibility as it may also have a reduced impact on the inflammatory response, as demonstrated by a lower pro-inflammatory cytokine expression in cells exposed to OXINIUM Technology (versus CoCrMo and Ti alloy)^{28,29}



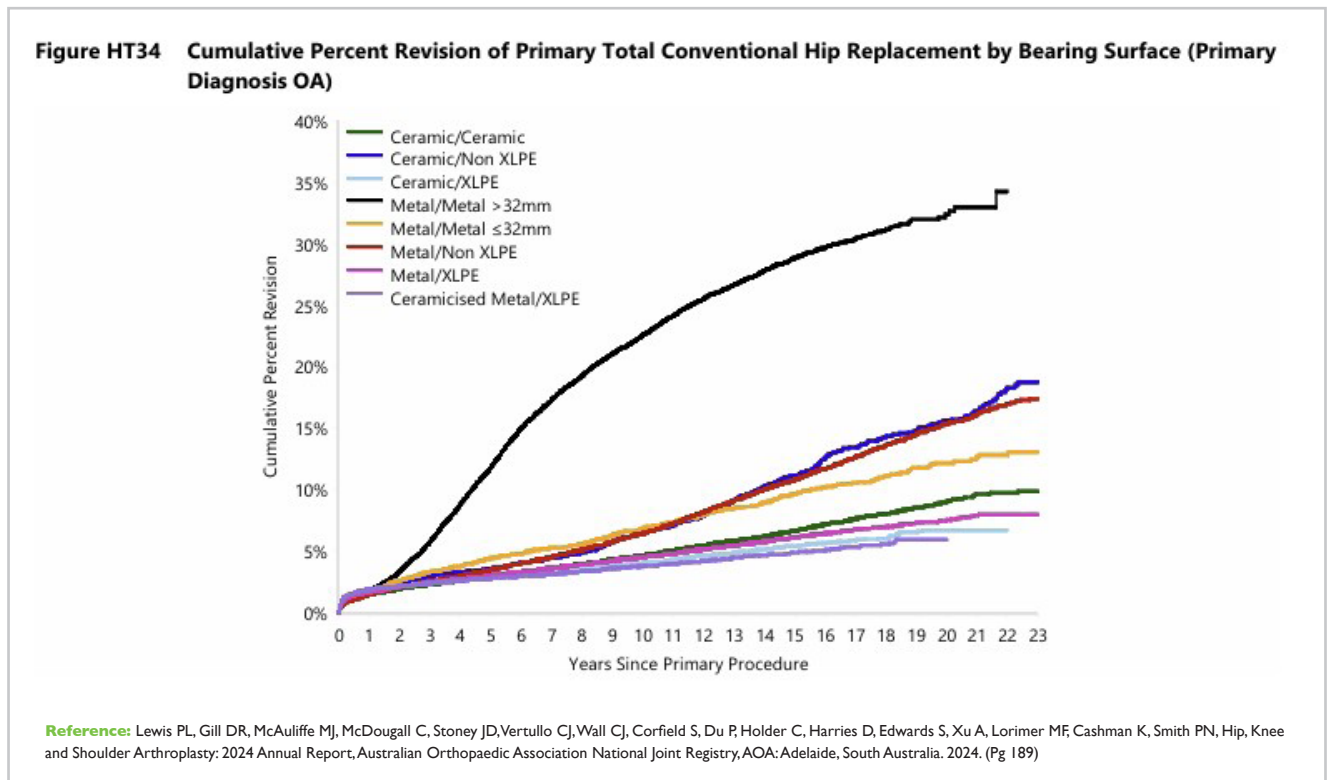
In terms of clinical performance data multiple national and regional hip registries have demonstrated that ceramicised metal combined with highly crosslinked polyethylene has the lowest rate of revision surgery in total hip replacement.^{35, 43, 44, 45}

In total knee arthroplasty, implants powered by OXINIUM perform at A/A* levels according to ODEP (Orthopaedic Data Evaluation Panel) up to 13 years, providing excellent survivorship (the length of time a joint replacement will last).³⁶

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The Australian joint registry is one of the largest and most respected joint registries in the world. Its 2024 report demonstrated that the ceramicised metal on a highly crosslinked polyethylene bearing in hip replacement surgery had the lowest revision rates of all bearing combinations at 20 years. It showed a 38% reduction in revision rates compared to metal on highly crosslinked polyethylene.³⁵

Smith+Nephew also cite the economic benefits of using ceramicised metal in arthroplasty for both hip and knee implants - including lower readmission rates, lower lengths of hospital stay and a greater likelihood of discharge to home (after controlling for patient demographics with propensity matching).

However, there are also broader macro-economic considerations of getting people back on their feet sooner and for longer with implants that perform better and last longer. For instance, if people can get back to healthy, active living, they can work and contribute to society, which is of great value to local and national economies. And an implant with assured longevity and less prone to revision will reduce healthcare costs by avoiding follow-up primary care appointments, and repeated hospital visits and assessments.

How widely is ceramicised metal used in orthopaedic surgery?

Perhaps less well-known than other implant materials, OXINIUM ceramicised metal implants have been used in arthroplasty for over 25 years.

Smith+Nephew introduced OXINIUM in 2001 as...

“a new material that improves performance and increases the service life of total joint replacement systems”.

Whilst its benefits are proactively communicated, ceramicised metal is seemingly most widely used in countries that follow evidence from joint registries. For example, the Australian Joint Registry has sub-categorised ceramicised metal since 2010, distinguishing it from the other types of ceramic and metal femoral heads, highlighting its strong performance.

Similarly, in the UK, the 2021 National Joint Registry covering England, Wales, Northern Ireland, the Isle of Man and Guernsey published an independent research piece sub-stratifying ceramicised metal and evidencing its successful performance. As a consequence, the use of ceramicised metal implants has increased by 91% from 2021 to 2024, according to Smith+Nephew sales data.

Professor Edward Davis, a recognised expert and consultant in arthroplasty, first used an OXINIUM femoral head in a hip replacement surgical procedure over 19 years ago.

“When you use an implant in a hip or knee replacement, you need the assurance that it’s hard-wearing, biocompatible, and unlikely to fracture. You want to avoid, where possible, the need for patients to be re-operated on.

“One of the main advantages of ceramicised metal I’ve seen is its bearing properties. It has an incredibly smooth surface, high wettability, and a low coefficient of friction, making it very wear-resistant. It’s also bio-inert, and incites a lower inflammatory response, which means it’s more biocompatible and, therefore, better for the patient.

“Ceramicised metal also has a main advantage in that it does not fracture, which is particularly beneficial when you attach the ceramicised ball to a taper in the case of a hip replacement. All these factors contribute to reducing the need for a patient to have a hip redone which is what the clinician and the patient ultimately wants.”

... adds Professor Davis.

Ceramicised metal beyond the femoral head - what's next?

It seems the role of zirconium-based ceramicised metal in arthroplasty is only likely to expand.

Modern dual mobility constructs (a ball within a ball) have shown to reduce dislocation and revision resulting from dislocation for both primary and revision hip arthroplasty.^{37,38} However, loss of the articulation between the inner femoral head (Intraprosthetic Dissociation or IPD), increased metal ions, and intraoperative issues continue to be areas of potential improvement.^{39,40}

Smith+Nephew has developed what it defines as the 'next generation dual mobility design', built on its patented OXINIUM technology and learnings from dual mobility technology. It's called OR30, a dual mobility cup.

Rigorous testing by Smith+Nephew included two clinical studies and more than ninety individual pre-clinical tests that has yielded more than twenty peer-reviewed abstracts and journal articles. The end result is a device that is designed to increase stability, incorporate design elements that have a proven clinical history, and simplify the surgical experience.

This will be another zirconium application that will gather momentum in the future!

Zircon and its derivatives, including zirconium, play a critical role in many applications that we rely on in our day-to-day lives. While often unseen and not known about, zircon contributes greatly to many sustainable applications. In this case, zirconium-containing OXINIUM, really does have the power to transform lives enabling recipients to experience pain-free movement and return to their active and fulfilling lives. With an ever-ageing population, the number of people needing hip and knee replacements is increasing and so, likely, will the use of OXINIUM.

Further reading

Information on hip replacements

[Hip Replacement - The National Joint Registry \(njrcentre.org.uk\)](http://njrcentre.org.uk)

Information on OXINIUM

[OXINIUM – Oxidized Zirconium](#)

[Moment of change brochure](#)

[Interactive collection of evidence – Oxinium Oxidized Zirconium Materials Science](#)



References

1. Joint Replacement Surgery (rheumatology.org)
2. Hip Replacement - The National Joint Registry (njrcentre.org.uk)
3. Hunter G, Dickinson J, Herb B, et al. Creation of oxidized zirconium orthopaedic implants. *Journal of ASTM International*. 2005;2:1-14.
4. Hunter G, Dickinson J, Herb B, et al. Creation of oxidized zirconium orthopaedic implants. *Journal of ASTM International*. 2005;2:1-14.
5. Long M, Riestler L, Hunter G. Nano-hardness Measurements of Oxidized Zr-2.5Nb and Various Orthopaedic Materials. Abstract presented at: 24th Annual Meeting of the Society for Biomaterials. April 22-26, 1998, San Diego, California.
6. Parikh A, Hill P, Hines G, Pawar V. Wear of conventional and highly crosslinked polyethylene liners during simulated fast walking/jogging. Poster presented at: 55th Annual Meeting of the Orthopaedic Research Society, 2009. Poster no. 2340.
7. Parikh A, Hill P, Pawar V, Sprague J. Long-term Simulator Wear Performance of an Advanced Bearing Technology for THA. Poster presented at: 2013 Annual Meeting of the Orthopaedic Research Society. Poster no. 1028.
8. Fernandez-Fernandez R, Cruz-Pardos A, Garcia-Rey E. Revision Total Hip Arthroplasty: Epidemiology and Causes. In: Rodríguez-Merchán E. *Revision Total Joint Arthroplasty*. Springer, 2020.
9. Lewis PL, Robertsson O, Graves SE, et al. Variation and trends in reasons for knee replacement revision: a multi-registry study of revision burden. *Acta Orthopaedica*. 2020. DOI: 10.1080/17453674.2020.1853340.
10. Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) Hip, Knee & Shoulder Arthroplasty: 2020 Annual Report.
11. Davis ET, Pagkalos J, Kopjar B. Bearing surface and survival of cementless and hybrid total hip arthroplasty in the National Joint Registry of England, Wales, Northern Ireland and the Isle of Man. *Journal of Bone Joint Surgery*. 2020; 5(2):pe0075.
12. Peters RM, Van Steenberg LN, Stevens M, Rijk PC, Bulstra SK, Zijlstra WP. The effect of bearing type on the outcome of total hip arthroplasty. *Acta Orthopaedica*. 2018;89(2), 163-169.
13. Atrey A, Ancarani C, Fitch D, Bordini B. Impact of bearing couple on long-term component survivorship for primary cementless total hip replacement in a large arthroplasty registry. Poster presented at: Canadian Orthopedic Association; June 20–23, 2018; Victoria, British Columbia, Canada.
14. Civinini R, Matassi F, Carulli C, et al. Clinical Results of Oxidized Zirconium Femoral Component in TKA. A Review of Long-Term Survival. *HSS Journal*. 2017;13:32-34.
15. Civinini R, Carulli C, Matassi F, Lepri AC, Sirleo L, Innocenti M. The Survival of Total Knee Arthroplasty: Current Data from Registries on Tribology. *HSSJ*. 2017;13:28-31.
16. The Orthopaedic Data Evaluation Panel (ODEP). www.odep.org.uk. Accessed June 1st, 2021.
17. Laskin RS. An oxidized Zr ceramic surfaced femoral component for total knee arthroplasty. *Clin Orthop Relat Res*. 2003;416:191-196.
18. Papannagari R, Hines G, Sprague J, Morrison M. Long-term wear performance of an advanced bearing technology for TKA. ORS 2011 Annual Meeting, Poster N. 1141.
19. Parikh A, Hill P, Pawar V, Sprague J. Long-term Simulator Wear Performance of an Advanced Bearing Technology for THA. ORS 2013 Annual Meeting. Poster No. 1028.
20. Hunter G, Dickinson J, Herb B, et al. Creation of oxidized zirconium orthopaedic implants. *Journal of ASTM International*. 2005;2:1-14.
21. Evidence Analysis Report EA/RECON/POLAR3/007/v1. 11th December 2020.
22. Medel, F.J., Shah, O and Kurtz, S.M. Retrieval Analysis of Contemporary Alternative Femoral Head Materials: Oxinium and Biolox Delta. 55th Annual Meeting of the Orthopaedic Research Society, 2009; Poster No. 2300.
23. Aldinger P, Williams T, Woodard E. Accelerated Fretting Corrosion Testing of Zirconia Toughened Alumina Composite Ceramic and a New Composition of Ceramicised Metal Femoral Heads. Poster presented at: 2017 Annual Meeting of the Orthopaedic Research Society. Poster no. 1037.
24. Smith+Nephew 2016. OR-16-127.
25. ASTM International Standard Specification for Wrought Zirconium-2.5 Niobium Alloy for Surgical Implant Applications (UNS R60901) Designation: F 2384 – 10.
26. ASTM International Standard Specification for Wrought Cobalt-28 Chromium-6 Molybdenum Alloys for Surgical Implants (UNS R31537, UNS R31538, and UNS R31539): Designation: F1537-20.
27. Hunter G, Long M. Abrasive wear of oxidized Zr-2.5 Nb, CoCrMo, and Ti-6 Al-4 V against bone cement. Abstract presented at: Sixth World Biomaterials Congress, 2000
28. Hallab NJ, McAllister H, Jacobs JJ, Pawar V. Zirconium-alloy and zirconium-oxide particles produce less toxicity and inflammatory cytokines than cobalt-alloy and titanium-alloy particles in vitro, in human osteoblasts, fibroblasts and macrophages. Annual Meeting of the Orthopaedic Research Society (ORS), 2012. San Francisco, CA.
29. Dalal A, Pawar V, McAllister K, Weaver C, and Hallab NJ. Orthopedic implant cobalt-alloy particles produce greater toxicity and inflammatory cytokines than titanium alloy and zirconium alloy-based particles in vitro, in human osteoblasts, fibroblasts, and macrophages. *J Biomed Mater Res Part A* 2012; 100A:2147-2158.
30. Parikh A, Hill P, Pawar V, Sprague J. Long-term Simulator Wear Performance of an Advanced Bearing Technology for THA. Poster presented at: 2013 Annual Meeting of the Orthopaedic Research Society. Poster no. 1028.
31. Papannagari R, Hines G, Sprague J, Morrison M. Long-term wear performance of an advanced bearing technology for TKA. Poster presented at: 2011 Annual Meeting of the Orthopaedic Research Society. Poster no. 1141.
32. Aldinger P, Williams T, Woodard E. Accelerated Fretting Corrosion Testing of Zirconia Toughened Alumina Composite Ceramic and a New Composition of Ceramicised Metal Femoral Heads. Poster presented at: 2017 Annual Meeting of the Orthopaedic Research Society. Poster no. 1037.
33. Smith+Nephew 2016. OR-16-127.
34. OXINIUM-Hip-Brochure.pdf
35. Lewis PL, Gill DR, McAuliffe MJ, McDougall C, Stoney JD, Vertullo CJ, Wall CJ, Corfield S, Du P, Holder C, Harries D, Edwards S, Xu A, Lorimer MF, Cashman K, Smith PN. Hip, Knee and Shoulder Arthroplasty: 2024 Annual Report, Australian Orthopaedic Association National Joint Registry, AOA: Adelaide, South Australia. 2024. Australian Orthopaedic Association National Joint Replacement Registry 2024
36. The Orthopaedic Data Evaluation Panel (ODEP). www.odep.org.uk. Accessed June 1st, 2021.
37. Reina, N; Pareek, A; Krych, AJ; Pagnano, MW; Berry, DJ; Abdel MP. "Dual-Mobility Constructs in Primary and Revision Total Hip Arthroplasty: A Systematic Review of Comparative Studies." The Journal of Arthroplasty, 34, 2019, pp. 594-603
38. Nam, D; Salih, R; Brown, KM; Nunley, RM; Barrack RL. "Metal Ion Levels in Young, Active Patients Receiving a Modular, Dual Mobility Total Hip Arthroplasty." The Journal of Arthroplasty, 32, 2017, pp. 1581-1585
39. Addona, JL; Gu, A; De Martino, I; Malahias, MA; Sculco, TP; Sculco PK. "High Rate of Early Intraoperative Dislocations of Dual Mobility Implants: A Single Surgeon Series of Primary and Revision Total Hip Replacements." The Journal of Arthroplasty, 34, 2019, pp. 2793-2798
40. Di Laura, A; Hothi, H; Battisti, C; Cerquiglini, A; Henckel, J; Skinner, J; Hart, A. "Wear of dual-mobility cups: a review article." International Orthopaedics, 41, 2017, pp. 625-633
41. Ceramics for Prosthetic Hip and Knee Joint Replacement - Rahaman - 2007 - Journal of the American Ceramic Society - Wiley Online Library
42. Smith+Nephew POLAR3 clinical evidence summary February 2024, pg. 6
43. National Joint Registry, UK, 2021 report
44. Peters RM, Van Steenberg LN, Stevens M, et al. The effect of bearing type on the outcome of total hip arthroplasty. *Acta Orthopaedica*. 2018; 89(2):163-169. 6. Atrey A, Ancarani C, Fitch D, Bordini B.
45. -Impact of bearing couple on long-term component survivorship for primary cementless total hip replacement in a large arthroplasty registry. Poster presented at: Canadian Orthopedic Association; June 20–23, 2018; Victoria, British Columbia, Canada.