The Science of Ceramics in Hip Joint Replacements

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Medical implants are helping many people around the world enjoy improved quality of life. While the material used in the implant will vary depending on factors such as the age of the patient, their activity level, and the preference of the surgeon performing the operation, it is ceramic material that has proved time and time again to offer the strongest, most hard-wearing, and versatile solution. Ceramic materials have been used for artificial joints since the 1970s, yet the need for smaller medical implants with more complicated structures has created exciting new opportunities for those manufacturing ceramic solutions for the medical market. As a result, detailed and complex ceramic components are becoming increasingly specified for a wide range of applications, including hip joints, feed-thrus, and implantable devices, as the technology continues to demonstrate a range of competitive advantages when compared with other material types.

Ceramics are increasingly the material of choice in medical applications due to their biocompatibility and resistance to chemicals in the human body. Further, ceramic materials have been proven to offer vastly superior resistance to wear when compared to their metal and polyethylene (PE) counterparts.

A key application for ceramic materials in the medical sector is hip joint replacement. The use of ceramics in hip arthoplasty began in France in 1970, when Professor Pierre Boutin pioneered the use of alumina implants. Further developments led to the introduction of ceramic actebular cups, which could be implanted in the pelvic bone to bear against a ball head that is attached to the femur by a prosthetic stem.

Together, the ceramic actebular cup and ball head create what is known as a wear couple, where the two parts move against each other when a person is in motion. The modular design of the hip joint replacement can incorporate a number of different material combinations between the cup insert and the ball head, including metal-on-metal, metal-on-PE, ceramic-on-PE, and ceramic-on-ceramic. While metal is still widely used in wear couples, recent reports have shown that potential health risks can be caused by tiny metal particles breaking away from the implants and leaking into the blood. This can cause significant discomfort, damage muscle and bone, and potentially lead to long-term disability. Metal and polyethylene wear couple combinations can be problematic, as wear on the implant can generate PE particulate debris, which can lead to osteolysis—a condition where bone is eroded faster than it can be repaired. This, in turn, weakens the bone surrounding the implant and can cause the part to become loose, requiring a surgical procedure to remedy the situation. Ultimately, wear couples that use ceramic for both parts have proven to offer the most effective solution, due to the wear resistance characteristics of modern ceramic materials, and will improve the patient’s quality of life as a result.

These issues were illustrated in a 2012 study, where researchers from the University of Bristol analyzed information from more than 400,000 hip replacements recorded in the National Joint Registry of England and Wales.[1] It showed that, overall, 6.2% of metal-on-metal hip replacements had failed within five years. Larger implants were also linked to an increased risk in patients with metal-on-metal implants, with the researchers finding that each 1.0-mm increase in size represented a 2% increase in the possibility of the patient requiring corrective surgery, as a result of the joint becoming loose, dislocating, or wearing. Conversely, ceramic implants actually performed better as the size of the component increased.

Typically, ceramic components can be expected to last for more than 20 years, with some ceramic components boasting a wear rate of just 0.032 mm per three million cycles. Consequently, there is almost no chance of inflammation or bone loss, while the biocompatibility of ceramic materials means they do not trigger any kind of chemical reaction when inserted into the body. This is due to the material’s strong chemical bonding and high purity composition.

Advances in ceramic technology are continuing to have significant influence on the types of components used in medical applications. The latest generation of ceramic materials offers improved strength and more versatile size options. For example, diamond-like carbon coating is being utilized in applications to offer an extremely strong, low-friction wear surface that outperforms alternatives currently available on the market in terms of longevity and wear resistance.

Not only are ceramics being used for implants fitted in the body, but an extensive range of surgical devices, instrumentation, and diagnostic equipment too, offering further opportunities for those working in the medical sector. As ceramic technology continues to develop, the opportunities for the material in medical applications will grow as well, resulting in a range of high-performance and durable solutions that help enhance quality of life, enabling greater independence for patients.

For more information, visit www.morganadvancedmaterials.com [1].

[1] The Lancet, 'Failure rates of stemmed metal-on-metal hip replacements: analysis of data from the National Joint Registry of England and Wales' http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(12)60353-5/abstract [2]

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