CERAMICS IN TOTAL JOINT ARTHROPLASTY

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CERAMICS FOR HIP ARTHROPLASTY

Alumina ceramics (Al₂O₃) were introduced more than 30 years ago as a candidate material for bearing surfaces in total hip replacement (THR). The goal was to improve the performance and longevity of THR by virtue of ceramic’s inertness and low-wear properties. In the 70s alumina appeared ideal for the modular, femoral ball concept, which increases the surgeon’s flexibility in THR. In the pioneer times monolithic ceramic acetabular cups have been used. In the mid 80s this concept was replaced by ceramic liners (inserts) that are fixed in a metal shell by taper fixation. Today alumina femoral heads are used in combination with polyethylene (PE) cups and ceramic cups. Up to now approx. 3 million alumina heads and more than 200.000 alumina liners have been used worldwide. The mostly used alumina is BIOLOX® forte by CeramTec.

Medical-grade alumina is a standardised material, the first standard was the German DIN 58835 edited in 1979. In 1981 the international ISO 6474 was edited. It was revised in 1994. The American standard ASTM F 603 was edited in 1963 and re-approved in 1995.

Based on clinical results in North America, Japan, and Western Europe there is consensus that ceramics reduce the wear rate when comparing to the standard wear couple metal-on-PE [1].

<table>
<thead>
<tr>
<th>Femoral head</th>
<th>Acetabular cup</th>
<th>Typical wear rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>metal</td>
<td>PE</td>
<td>&gt; 0.2mm / year</td>
</tr>
<tr>
<td>alumina</td>
<td>PE</td>
<td>&lt; 0.1mm / year</td>
</tr>
<tr>
<td>zirconia</td>
<td>PE</td>
<td>&lt; 0.1mm / year</td>
</tr>
<tr>
<td>alumina</td>
<td>alumina</td>
<td>approx. 5µm / year</td>
</tr>
<tr>
<td>zirconia</td>
<td>alumina</td>
<td>Not available</td>
</tr>
</tbody>
</table>

Table 1: In vivo wear rate of alumina ceramics in THR

More than 10 years ago zirconia (ZrO₂) was introduced. There are various medical-grade zirconias: Mg-PSZ (= partially stabilised zirconia, stabiliser MgO) was the first zirconia offered in USA by Biopro. It is approved for PE-cups. Y-TZP (=tetragonal polycrystalline zirconia, stabiliser Y₂O₃) offers better strength.

Zirconia is an attractive material because of its better mechanical strength and fracture toughness, but there is some controversial discussion ongoing.

The wear rate zirconia-on-PE is in the same order as then one for alumina-on-PE [1].

NOVEL CERAMICS

In 2000 a novel ceramic bio composite material was introduced: AMC (= alumina matrix composite) [2,3] combines the hardness of alumina (>70% Al₂O₃), the toughness of Y-TZP. Due to the additives Cr₂O₃ and SrO [3] it was possible to achieve a mechanical strength and fracture toughness as high as the one of Y-TZP and tribological properties as good as the one of alumina. Tests according to EN 30993 prove that AMC is bio inert [4]. AMC’s colour is mauve due to Cr₂O₃.

Clinical studies with AMC femoral heads articulating against alumina cups are ongoing in USA. The IDE study is approved by the FDA. AMC offer options for total knee replacement and small joints.

SIMULATOR TESTS

To get approval for marketing implants wear tests have to be performed. When investigating retrieved ceramic implants it is observed that the wear pattern and the wear rate are different when comparing to the results of hip or knee simulator tests. This is due to effects that cannot be mimicked, e.g. scratched surfaces, torque and momentum due to wrong positioned implants, impingement, subluxation, and dislocation.

CONCLUDING REMARKS

The special properties of ceramics have made this one of the most promising solutions to the challenging problems presented by young and active patients. The success of ceramics in joint replacement is based on interdisciplinary R&D with engineers and surgeons.

REFERENCES