The introduction of titanium alloys in ophthalmic microsurgical instruments

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Soon after the founding of the Microsurgical Instrumentation Research Association (MICRA) in 1971, it was decided to investigate the possible use of titanium and its alloys in the production of surgical instruments suitable for use with the microscope. After an analysis of surgical instruments available at that time, it was clear to us that modifications to existing designs were required. Most surgical instruments are manufactured from high-quality stainless steel often requiring hardening by heat treatment, and thereby presenting difficulties in the manufacture of precision instruments. These technical difficulties tend to make precision instruments in this material very expensive. With the increasing use of the surgical microscope, surgeons demand even more delicate instruments, making the technical problems still greater.

Requirements for an instrument material

A study carried out by MICRA showed that significant improvements in instrument design could be effected by more careful selection of the materials used, with better methods of machining and heat treatment.

The requirements were:
1. That the material used for instrument manufacture should be capable of being worked to the various complex shapes needed, yet retain the necessary accuracy, hardness and surface finish, while also being free from fatigue failure or stress or other cracking during useful life.
2. It must be resistant to corrosion or wear under conditions normally encountered in surgery or instrument care, and particularly must not be affected by body fluids.
3. The material should be capable of repeated sterilization by any of the normal methods, including very high temperatures, without cumulative detrimental effect.
4. A finished instrument should be light in weight and of adequate strength, and be so designed that it is comfortable to use.
5. An instrument used with a microscope under high intensity illumination should have a matte or non-reflecting surface finish.
6. The instrument should be undamaged and unchanged when exposed to any form of radiation and preferably should be non-magnetic, with a low thermal conductivity and a low specific heat.

Titanium and its alloys

Pure titanium or oxygen-hardened titanium has been in use in surgery for some time, but as this material lacks some of the physical properties listed, it is of limited use only for the manufacture of surgical instruments. Many new alloys have been developed, particularly for use in the aircraft industry, and the MICRA investigators gave careful consideration to all new materials commercially available which could meet the requirements described. It was decided that the most suitable is 6AL-4V, which has a high tensile strength and, provided that no attempt is made to improve the mechanical characteristics by heat treatment, the material remains stable after normal working and machining. The Table shows the information on the list of alloys which appear to be of most practical significance.

Titanium alloy has the further advantage that it is easily anodized to produce a thin layer of transparent titanium oxide on the surface of the instrument, and in this way the surface can be given colour. The advantage of this is that optical reflections are modified, an important factor when working under the brilliant illumination needed for microscope work. The anodized surface in addition is much harder than the metal itself.

Design considerations

The methods by which titanium alloys are worked are quite different from those employed with
Table  Average mechanical properties of titanium at NTP

<table>
<thead>
<tr>
<th>Material type</th>
<th>Ultimate tensile strength (tonf/in²)</th>
<th>0·1 per cent proof stress (tonf/in² min)</th>
<th>Percentage elongation (min)</th>
<th>Young's modulus E (tonf/in³)</th>
<th>Density (tonf/in³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pure Soft (CPS)</td>
<td>26 max</td>
<td>13</td>
<td>30</td>
<td>7·200</td>
<td>0·163</td>
</tr>
<tr>
<td>Pure Medium (CPM)</td>
<td>30–40</td>
<td>18</td>
<td>20</td>
<td>7·200</td>
<td>0·163</td>
</tr>
<tr>
<td>Pure Hard (CPH)</td>
<td>35–45</td>
<td>25</td>
<td>18</td>
<td>7·200</td>
<td>0·163</td>
</tr>
<tr>
<td>6 AL–4 V</td>
<td>58–75</td>
<td>57</td>
<td>8</td>
<td>7·100</td>
<td>0·161</td>
</tr>
<tr>
<td>11 Sn–5 Zr</td>
<td>70–80</td>
<td>58</td>
<td>10</td>
<td>7·100</td>
<td>0·175</td>
</tr>
</tbody>
</table>

Conversion factors: 1 lbf/in² ≈ 6·9 kN/m²; tonf/in³ ≈ 15·4443 MN/m³

stainless steel. A special knowledge of working methods is essential for any instrument designer to enable him to produce instruments which can successfully be reproduced, and which will be reliable in operation. The MICRA organization, in which surgeons and engineers work together, has proved an ideal arrangement for the successful designing of new and improved instruments. It must be realized that the traditional hand methods of manufacture are not suitable for the working of titanium. Much of the work in the production of these instruments must be done by machine so that the use of highly skilled craftsmen is reserved for those stages of manufacture such as final finishing, adjustment, and inspection which need to be carried out by hand. It will readily be seen that such a production method requires a close cooperation between the designing surgeon and engineer.

Conclusion

Over the past five years MICRA has supervised the development and later production of a small range of titanium instruments for use in ophthalmic microsurgery, which has now been extended into a full range of instruments for anterior segment microsurgery. The expertise so gained has since enabled other workers in the United States of America to produce a comprehensive range of instruments for use in neurosurgery. It is our conviction that this material has proved itself superior to stainless steel, and its use will continue to expand.