Information Management System with RFID tag embedded into Polyethylene Insert in Knee Arthroplasty

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Disclosures:

Introduction: In total knee arthroplasties, there are risks of revision due to polyethylene wear or aseptic loosening in the long-term follow-up. The information such as model, type and size of joint prosthesis is necessary at the time of revision surgery. It is sometimes difficult to acquire of the information due to the elimination and consolidation of hospitals and patients’ change of address.

Radio frequency identification (RFID), which can read and record data on its IC chips using a contactless reader, is widely used for traceability and goods management of commodity distribution.

The purpose of the study was to examine whether RFID can apply to total knee joint prostheses by embedding RFID tag into Ultra-high molecular weight polyethylene (UHMWPE).

Methods: The RFID tags, [1] µ-Chip (Hitachi Co., Ltd, Tokyo, Japan), [2] FerVID family (Fujitsu Co., Ltd, Tokyo, Japan), were embedded into the anterior side of GUR 1050 UHMWPE inserts (Fig.2). The UHMWPE inserts were molded by compression molding at the maximum temperature of 220°C and the maximum compressive force of 245 kgf/cm².

The transmission output of interrogator (952 MHz-band; DOTR-920, Tohoku Systems Support Co., Ltd, Miyagi, Japan) was set to 1W (maximum output). The interrogator was set at the distance of 40 mm away from RFID tag, and Received Signal Strength Indicator (RSSI, Fig.1) was measured 500 times. The histogram of RSSI data was approximated by Gaussian distribution and its median value was defined as a communication sensitivity of a RFID tag (Fig.3).

Next, the UHMWPE inserts with the RFID tag were implanted in a formalin fixed cadaveric knee, and the communication sensitivity of the RFID tag was measured by the same method as the above. The tibial base plate was made of Ti-6Al-4V, and femoral component was made of Co-Cr-Mo or Ti-6Al-4V (Nakashima Medical Co., Ltd, Okayama, Japan) (Fig.4).

Results: The measured communication sensitivities and maximum communicable distances of the RFID tags embedded into UHMWPE are shown in Table 1.

The communication sensitivities of the RFID tags embedded into UHMWPE could be all detected. When the UHMWPE insert was implanted in a cadaveric knee, the communication sensitivity of [1] µ-Chip reduced from -60.3 dBm to -72.6 dBm, (the attenuation ratio = the sensitivity of implanted tag/ the sensitivity of tag; 1/17) and the sensitivity of [2] FerVID Family reduced from -38.0 dBm to -55.4 dBm, (the attenuation ratio; 1/55). The communication sensitivities of the RFID tags in the Ti-6Al-4V femoral component were lower than that in the Co-Cr-Mo component.

Furthermore, the maximum communicable distance of the RFID tags were all shortened in a cadaveric knee. The communicable distances of [1] µ-Chip changed from 200 mm to 70 mm or 50 mm, and the distance of [2] FerVID Family changed from 310 mm to 100 mm.

Discussion: In this study, we clarified that the RFID tags embedded into UHMWPE could work correctly. Absorptions of radio waves through skin and subcutaneous tissue, and reflections of radio waves due to the metal components caused the reduction of the communication sensitivity and the shortening of the communicable distance of the RFID tag embedded into the UHMWPE insert in a cadaveric knee. Although the communication sensitivities of the RFID tags were decreased in cadaveric knee, the communicable distance of [2] FerVID family was 100 mm. Thus, the RF tag can be available in the living body.

We are planning to carry out clinical trials to test this management system in knee arthroplasty.

Significance: This is the first study of information managements of knee arthroplasties by RFID.

We investigated that a RFID tag embedded into UHMWPE could work correctly in this study. RFID can be useful for information management system in knee arthroplasty.

Acknowledgments: None

The communication sensitivity and maximum communicable distance

<table>
<thead>
<tr>
<th>RF tag in UHMWPE</th>
<th>in cadaveric knee</th>
<th>femoral component</th>
<th>Sensitivity of RF tag (dBm)</th>
<th>communicable distance (mm)</th>
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<tbody>
<tr>
<td>[1] μ-Chip</td>
<td>-</td>
<td>-</td>
<td>-60.3</td>
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<td>[1] μ-Chip</td>
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<td>[1] μ-Chip</td>
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<td>50</td>
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<td>[2] FerVID Family</td>
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<td>-</td>
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<td>[2] FerVID Family</td>
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\[
\text{RSSI (dBm)} = 10 \log_{10} \left( \frac{\text{received power (mW)}}{1 \text{ mW}} \right)
\]  

(1)

Fig. 1 Received Signal Strength Indicator (RSSI).

Fig. 2  RFID tags embedded into UHMWPE inserts. The range of UHF-band tags was from 860 MHz to 960 MHz.
(A-B) Before embedded: (A) μ-Chip (60 mm×1.5 mm), (B) FerVID family (40 mm×6 mm)
(C-D) After embedded: (C) μ-Chip, (D) FerVID family
Fig. 3  The histogram and Gaussian distribution of 500 RSSI data. In the case, the communication sensitivity is -51.9 dBm.

Fig. 4  Method of measuring sensitivity
(A) The UHMWPE insert with a RFID tag in cadaveric right knee ([2] FerVID Family).
(B) Measuring the communication sensitivity of the RF tag by the interrogator.