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# Wear analysis of explanted conventional metal back polyethylene glenoid liners

Gyorgy Kocsis*, Charlie J. Payne, Angus Wallace, Donal McNally

*University of Nottingham, Nottingham, NG7 2RD, United Kingdom*

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ABSTRACT

*Introduction:* Glenoid component wear and loosening is the Achilles heel of total shoulder replacement. Analysis of failed, revised implants might give an insight into the causes of component failure. Volumetric assessment of conventional total shoulder replacement glenoid liner wear rate and scanning electron microscopy was accomplished in this study for the purpose. Coherence scanning interferometry (white light scanner) 3D images were acquired. This method requires no physical contact, ionising radiation or extensive surface preparation.

*Methods:* Twenty-four Nottingham total shoulder replacement system metal - back glenoid liners were explanted from revision shoulder arthroplasty cases. A Phase Vision Quartz DBE 800 scanner was used to scan the explanted polyethylene liners. The images of worn liners were registered to the reference image. Differences in wear and wear rate were quantified and central and non-central wear groups were distinguished. The Central wear group had a polyethylene wear rate of $115 \pm 55$mm3/year (mean $\pm$ SD). The non-central group showed a wear rate of $112 \pm 42$ mm3/year (mean $\pm$ SD), which was not significantly different from the central wear group ($p = 0.426$) Polyethylene liners showing edge wear from unstable shoulder replacements showed a wear rate of 545 $mm^3$/year.

Scanning electron microscopy images showed that the polyethylene was wearing in laminar flakes which indicated fatigue wear.

*Conclusion:* The volumetric wear rate was found to be more than twice as fast as in the case of total hip replacement with the acetabular liner made of the same type of polyethylene. Use of coherence scanning interferometry is proposed for wear analysis.



## Introduction

Glenoid component wear and loosening is the Achilles heel of total shoulder replacement [1]. Analysis of failed, revised implants may give an insight into the causes of component failure.

Polyethylene wear has often been suspected of causing osteolysis and implant failure [8–12]. Determining an average wear rate therefore could be useful, but so far few accurate in vivo wear rates have been published in conjunction with total shoulder arthroplasty [13], though in vitro data are available [14–16].

Complex wear patterns as well as implant material creep may lead to defects that are difficult to characterise. The shape, the depth, the volume of the defect as well as the deformation and the characteristics of the worn bearing surface are potentially important. Several techniques have been used to quantify dimensional changes of worn implants. Stylus based measurements (coordinate measuring machines) are based on physical contact with the implant, [2] and can lead to surface scratching and other damage. Fluid-displacement method is suggested to be the most accurate way to determine the volume of material worn away from the implant [3], but does not give any information about the location of the wear. Microcomputed tomography has also been shown to be an accurate way to investigate worn implants [4–6].

Here a simple way for 3D scanning of ex vivo implants, using coherence scanning interferometry is proposed. Also known as white light scanners, these machines provide a method of acquiring 3D images of objects without contact, ionising radiation or extensive surface preparation. A series of fringe patterns are projected onto the object and a high resolution camera is used to capture images of the fringe patterns. Light waves collected by the high resolution camera undergo constructive or destructive interference and this superposition principle is used to calculate changes in surface topography across the object. Scanners can

* Corresponding author.
*E-mail addresses:* msxgk@nottingham.ac.uk (G. Kocsis), charliepayne6@gmail.com (C.J. Payne), angus.wallace@rcsed.ac.uk (A. Wallace), donal.mcnally@nottingham.ac.uk (D. McNally).

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**Fig. 1.** The Nottingham total shoulder arthroplasty system.

be configured for varying measurement volumes. As a guideline, feature accuracy is approximately 1/20,000 of the body diagonal of the measurement volume [7].

Scanning electron microscopy was also performed to characterise the wear of the polyethylene glenoid liner.

Here a simple method is proposed for wear analysis of implants, and wear patterns of an anatomical polyethylene glenoid liner are described, as well as wear rate for the glenoid liner and worn surface properties based on scanning electron microscopic images.

**Table 1**
Survival times of explants. The cases where the explanted liner was larger than size 3 (sizes 4 or 5) were excluded from the analysis due to lack of an unworn, new liner as control.

| Case No | Implant survival in months | Reason for exclusion |
|---|---|---|
| Case 1 | 209.3 | Included |
| Case 2 | 53.83 | Included |
| Case 3 | 11 | Included |
| Case 4 | 6.43 | Included |
| Case 5 | 49.7 | Included |
| Case 6 | 126.6 | Included |
| Case 7 | 18.57 | Size 5 liner |
| Case 8 | 121.17 | Included |
| Case 9 | 52.03 | Included |
| Case 10 | 67.53 | Included |
| Case 11 | 79.1 | Included |
| Case 12 | 191.67 | Included |
| Case 13 | 66.2 | Size 4 liner |
| Case 14 | 111.77 | Included |
| Case 15 | 120.9 | Size 4 liner |
| Case 16 | 26.83 | Deformed d/t autoclave |
| Case 17 | 111.9 | Included |
| Case 18 | 43.37 | Size 4 liner |
| Case 19 | 18.7 | Included |
| Case 20 | 35.9 | Included |
| Case 21 | 45.77 | Included |
| Case 22 | 43.1 | Included |
| Case 23 | 97.67 | Included |
| Case 24 | 37.47 | Included |
| Case 25 | N/A | Improperly labelled |
| Case 26 | 86.67 | Included |
| Case 27 | 66.47 | Included |
| Case 28 | 61.43 | Included |
| Case 29 | N/A | Improperly labelled |
| Case 30 | 60.83 | Included |
| Case 31 | N/A | Improperly labelled |
| Case 32 | 94.07 | Included |

## Materials and methods

An anatomical (or conventional) total shoulder system with a metal back glenoid (Nottingham Total Shoulder Arthroplasty System, Biomet UK, Bridgend, UK) was investigated. The Nottingham Total Shoulder Arthroplasty System consists of a humeral stem and a metal head on the humeral side, and a metal glenoid baseplate with a clip-on polyethylene glenoid liner (Fig. 1).

A titanium alloy glenoid baseplate (A) is inserted and screwed onto the bony glenoid after bone preparation. The titanium alloy humeral stem (B) has a taper fitting onto which a cobalt chrome alloy head is mounted. An Ultra High Molecular Weight Polyethylene (UHMWPE) liner or bearing component (C) is clipped into the glenoid baseplate to articulate with the head component (D). This UHMWPE socket was designed to be fully congruent with the head component. The design of the baseplate and liner was intended to ensure that the liner is clipped solidly and irreversibly onto the metal glenoid baseplate.

Using a 3D white light scanner 32 explanted polyethylene glenoid liners were examined, from 32 consecutive revision arthroplasty operations. These were all Nottingham total shoulder system UHMW polyethylene glenoid bearings, anatomical by design, explanted at various stages after implantation (Table 1). The polyethylene used for these components is not highly cross-linked since, at the time of design, the use of highly cross-linked polyethylene was not widespread.

The explanted arthroplasty components were washed following explantation using surgical hand scrubs to decontaminate them and kept away from sunlight in plastic bags – except for one component which was sterilised in an autoclave. Implant survival times are shown in Table 1. The cohort was not divided into groups based on reasons for revision because statistical analysis of subgroups with small number of cases could have led to misleading conclusions.

New, unused polyethylene glenoid liners for reference use were provided by the manufacturer.

3D scanning of the explanted glenoid liners used a Phase Vision Quartz DBE 800 scanner, calibrated according to German VDI/VDE 2634 standard (2002) [17]. To enhance the scan quality, commercially available developer spray (Ardrox 9D1B, Chemetall, Frankfurt am Main, Germany) on both control and explanted liner surfaces were used, as per standard methodology. The wear volume was calculated using a reference 3D image of an unused liner which was then compared to that of worn liner. A new, unused Size 3 polyethylene glenoid liner was scanned 5 times. Out of the 5 reference glenoid liners the one closest to the mean weight was selected for the purpose. From the five scanned 3D images of this liner, the mean volume was calculated and the image that was closest to the calculated average was used as the reference surface. The manufacturing accuracy was within the accuracy of the measuring method, as shown by the finding that the unworn parts of the explanted liners compared well with the reference liner manufactured many years later, during the 3D image analysis.

Thirty-two explanted glenoid liners were scanned using the whitelight scanner. Most of these explants were Size 3 in thickness. One size 5 explant and three size 4 explants were excluded from the volume analysis as no unused sizes 4 and 5 glenoid liners were available to be scanned as a reference. One case, although scanned, was excluded from the analysis because it was autoclave-sterilised after explantation, and it sustained a deformity that would have made data interpretation difficult. Three explants were not labelled properly on explantation and were unidentifiable. Three further implants were identified with the help of manufacturer implant despatch data. This left 24 explants to analyse.

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