References

Adultdata, 1988, The handbook of adult anthropometric and strength Measurements, data for design safety, United Kingdom, Department of Trade and Industry.

ASTM D2990, see page 67, 1990, *Tensile, compressive and flexural creep and creep rupture of plastics.*

ASTM D5606-97, see page 202, 2002, Standard test method for determining extreme pressure properties of lubricating greases using high frequency, linear ossilating (SRV) machine Barbour PSM, Barton DC, Fisher J 1995, 'Influence of Contact Stress on The Wear of UHMWPE for Total Replacement Hip Prostheses', *Wear*, Vol. 181 - 183, 250 – 257.

Bajaria SH, Bellare A 1998, 'Deformation, morphology, and wear behaviour of polyethylene used in orthopaedic implants', *Medical Plastics and Biomaterials Mag.*

Bergmann G, Graichen F, Rohlmann A 1993, 'Hip loading during walking and running, measured in two patients', *J Biomech*, Vol. 26(8), 969 – 990.

Bergmann G, Kniggendorf F, Graichen F, Rohlman A 1995, 'Influence of shoes and heel strike on the loading of the hip joint', *J Biomechanics*, Vol. 28, 817 – 827.

Bennet D, Orr JF, Baker R, 1996, 'The influence of shape and sliding distance of movement loci of the femoral head on the wear of the acetabular cup', *Dep of Mech and Manufacturing Engineering,* Queens Univeristy of Belfast.

Boresi AP, Sidebottom OM 1985, *Advanced mechanics of materials*, Fourth Edition, Wiley.

Buford A, Goswani T, 2004, 'Review of wear mechanisms in hip implants: Paper I-General', *Materials & Design* Vol. 25, 385 – 393.

Bragdon CR, Jasty M, Kawate K, McGrory BJ, Elder JR, Lowenstein J, Harris WH, 1997, 'Wear of retrieved cemented polyethylene acetabula with alumina femoral heads', *J Arthro*, Vol. 2, 119 – 125.

Calonius O, Saikko V 2002, 'Slide track analysis of eight contemporary hip simulator designs'*, J Biomechanics*, Vol. 35, 1439 – 1450.

Charnley J, Halley DK 1975, 'The rate of wear in total hip replacement', *Clin Orth and Rel Res*, Vol. 112, 170 – 179.

Charnley, J. 1979, *Low friction arthroplasty of the hip - Theory and practice.* Published by Springer Verlag, Berlin, Introduction.

Claus A, Sychterz CJ, Hopper RH, Engh CA 2001, 'Pattern of osteolysis around two different cementless metal backed cups', *J Arthro,* Vol. 16(8), 177 – 182.

Clarke IC, Gustafson A. Subrata S, Campbell P 1996, 'Hip simulator ranking of polyethylene wear', *Acta Orthop Scand*, Vol. 67(2), 128 – 132.

Costa L, Bracco P 2001, 'Analysis of products diffused into UHMWPE prosthetic components in vivo*', Biometerials*, Vol. 22, 307 – 315.

Davidson JA, Gir S, Paul JP 1988, 'Heat transfer analysis of frictional heat dissipation during articulation of femoral implants', *J Biomed Mater Res*, Vol. 22(A3), 281 – 309.

Davidson D, Graves S, Batten J, Cumberland W, Fraser J, Harris J, Morgan D, Morris P, Wood D, Cooper J, Simpson S 2002, 'Australian Orthopaedic Association National joint replacement registry'. *Annual Report*, Adelaide AOA .

Davidson D, Graves S, Batten J, Cumberland W, Fraser J, Harris J, Morgan D, Morris P, Wood D, Cooper J, Simpson S 2003, 'Australian Orthopaedic Association National Joint Replacement Registry'. *Annual Report*, Adelaide AOA.

Dowson D, Taheri S, Wallbridge NC 1987, 'The role of counterface imperfections in the wear of polyethylene', *Wear*, Vol. 119, 277 – 293.

Dumbleton JH, Manley T, Avram AE 2002, 'A literature review of the association between wear rate and osteolysis in total hip arthroplasty'. *J Arthro*, Vol. 17(5), 649 – 661.

Du Plessis TA, Grobbelaar CJ, Marais F 1977, 'The improvement of polyethylene prostheses through radiation crosslinking', *Radiat Phys Chem*, Vol. 9, 647 – 652.

Eggli S, Brun S, Gerber C, Ganz R 2002, 'Comparison of polyethylene wear with femoral heads of 22 mm and 32 mm: A prospective, randomised study', *J Bone Joint Surg*, Vol. 84(B), 447 -451.

Engh CA, Bobyn JD 1985, 'Biological fixation in total hip arthroplasty', *Slack Orthopaedics*, Vol. 16.

Engineering material handbook, Vol. 2 1987, ASM International, 167 – 1702.

Fisher J, Chan KL, Hailey JL, Shaw D, Stone M 1995, 'Preliminary study of the effect of aging following irradiation on the wear of ultra high molecular weight polyethylene', *J Arthroplasty*, Vol. 10, 689 – 692.

Fourie EF, Burger NDL 1999, 'Ultra high molecular weight polyethylene (UHMWPE), an engineering approach', SA Bone and Joint, Vol. 9 no 3, 163 – 164.

Foguet P, Hashmi F, Lawrence T. 2003, 'Case Report: metaphyseal osteolysis around a titanium reconstruction nail', *Int J care Injured*, Vol. 34, 374 – 377.

Gold Technology no 2*, June 1990 and Workshop notes, SA Mint.*

Grobbelaar CJ, Weber FA, Spirakis K 1999, 'Clinical experience with gamma irradiation crosslinked polyethylene - A 14 to 20 year follow-up report', *SA Bone and Joint*, Vol. 9 no 3, 140 – 147.

Haraguchi K, Sugano N, Nishii, Sakai T, Yoshikawa H, Ohzona T, 2001, 'Influence of polyethylene and femoral head surface quality on wear, A retrieval study', *Int Orthopaedics*, Vol. 25, 29-34.

Havelin LI, Furnes O, Espehaug B 2003, 'The Norwegian Arthroplasty Register', *Annual Report.*

http://www.aesculap.de/ — last accessed November 2004.

http://www.centerpulse-orthopedics.com/uk/en/Home/Home — last accessed November 2004.

http://www.ceraver.fr/anglais/sommaireang.htm — last accessed November 2004.

http://www.depuy.com/ — last accessed November 2004.

http://www.geocities.com/hip_replacements/history — last accessed November 2004.

http://www.healthsystem.virginia.edu/UVAHealth/adult_arthritis/anatomy.cfm — last accessed November

http://www.principalmetals.com/glossary/odoc.htm — last accessed November 2004.

http://science.nhmccd.edu/biol/tissue/areolar.html — last accessed November 2004

http://www.thehipdoc.com/history.htm — last accessed November 2004.

http://www.uct.ac.za/microbilogy/sdspage.htm - last accessed November 2005.

http://www.utahhipandknee.com/history.htm - last accessed November 2004.

Huo MH, Cook SM 2001, 'What's new in hip arthroplasty', *J Bone Joint Surg*, 83A, number 10, 1598 – 1610.

Hutchings IM 1992 *Tribology, Friction and wear of engineering materials*, Arnold.

ISO TR 9325 1989, '*Implants for surgery - Partial and total hip joint prosthesis - Recommendations for simulators for evaluation of hip joint prosthesis'.*

ISO 12891-3, 2000, *'Retrieval and analysis of surgical implants, Part 3, Analysis of retrieved polymeric surgical implants'.*

ISO 14242-1, 2002, '*Implant for surgery - Wear of total hip joint prosthesis, Part 1: Loading and displacement parameters for wear testing machines and corresponding environmental conditions for test*' .

ISO 14242-1, 2002, *'Loading and displacement parameters for wear testing machines and corresponding environmental conditions for test'.*

Jasty M, Goetz DD, Bragdon CR. 1997, 'Wear of polyethylene acetabular components in total hip arthroplasty: An analysis of one hundred and twenty eight components retrieved at autopsy or revision operations', *J Bone and Joint Surg*, Vol. 79-A:349-358.

Kazuo Hirakawa, Thomas W Bauer 1997, 'Effect of femoral head diameter on tissue concentration of wear debris', *J Biomed Mater Res*, Vol. 36, 529 – 535.

Kesteris U, Hardinge K, Ilchmann T, Wingstrand H, 2003, 'Polyethylene wear in prosthetic hips with loose components', *J Artho*, Vol. 18, 10-15.

Klapach AS, Callaghan JJ, Goetz DD, Olejniczak JP, Richard RC 2001, 'Charnley total hip arthroplasty with use of improved cementing techniques: A minimum twenty-year follow-up study', *J Bone Joint Surg*, 83A, number 12, 1840-1848.

Kukureka SN, Chen YK, Liao P, Rao M. 1995, 'The wear mechanisms of acetal in unlubricated rolling-sliding contact', *Wear*, Vol. 185, 1 – 8.

Kummer B 1976, '*Biomechanics of the hip and knee joint, advances in artificial hip and knee joint technology*', Springer Verlag, 24 – 52.

Lee KY, Pienkowski D. 1998, 'Compressive creep characteristics of extruded ultrahigh molecular weight polyethylene', *J Biomed Mater Res*, Vol. 39, 261 – 265.

Lewis G 2001, 'Properties of crosslinked ultra high molecular weight polyethylene', *J Biomaterials*, Vol. 22, 371 – 401.

Li S, Burstein AH 1994, 'Current Concepts Review. Ultra high molecular weight polyethylene. The material and its use in total joint replacement', *J Bone and Joint Surg*, Vol. 76 A(7), 1080 – 1090.

Livermore J, Ilstrup D, Morrey B 1990, 'Effect of femoral head size on wear of the polyethylene acetabular component', *J Bone and Joint Surg*, Vol. 72A, 518 – 528.

Lu Z, McKellop H 1999, 'Potential thermal artifacts in hip joint wear simulators', *J Biomed Mater Res (appl Biomater)*, Vol. 48, 458 – 464.

Mallchau H, Herberts P, Garellick G, Söderman P, Eisler T 2000, 'Prognosis of total hip replacement, update of results and risk ratio, analysis for revision and re-revision' *Swedish National Hip Arthroplasty Register* 1979 – 2000.

Maloney W, Smith RL, Schmalzried TP, Chiba J, Huene D, Rubash H 1995, 'Isolation and characterization of wear particles generated in patients who have had failure of a hip arthroplasty without cement', *J Bone and Joint Sur*, Vol. 77(A), 1301 - 1310.

Manley MT, D'Antonio J, Capello WN, Edidin AA 2002, 'Osteolysis: A Dissease of Access to Fixation Interfaces', *Clin Orthop,* Vol. 1(405), 129 – 137.

Masaoka T, Clark IC, Yamamoto K, Tamura J, Williams PA, Good VD, Shoji H, Imakiiri A 2003, 'Validation of volumetric and linear wear measurements in UHMWPE cups - a hip simulator study', *Wear*, Vol. 254, 1 - 8, 2003.

Material data sheet, UHMWPE, Poli HiSolidur, 1999.

McCoy TH, Salvati EA, Ranawat CS, Wilson PD 1988, 'A fifteen-year follow-up study of one hundred charnley low-friction arthroplasties', *Orthop Clin North Am*, Vol. 19, 467 – 476.

McKellop H, Shen F. Lu B, Campbell P, Salovey R 1997, 'Effect of sterilization method and other modifications on the wear resistance of UHMWPE acetabular cups, in polyethylene wear in orthopaedics', *Implants Workshop, Minneapolis, Society of Biomaterials*, 20 – 31.

McKellop H, Shen F, Lu B, Campbell P, Salovey R 2000, 'Effect of sterilization method and other modifications on the wear resistance of acetabular cups made of ultra high molecular weight polyethylene: A hip simulator study', *J Bone Joint Surg*, Vol. 82(A), 1708 – 1725.

Mendenhall S 2000, 'Putting joint replacement in historical perspective - Compared to other surgeries, TJR has remained a successful and cost effective procedure', *Orthopaedics Today.*

Meng Deng R, Latour A 1998. 'Study of creep behaviour of ultra high molecular

weight polyethylene systems', *J Biomed Mater res*, Vol. 40, 214 – 223.

Moratoglu OK, Bragdon CR, O'Connor AS, Jasty M, Harris W 1999, 'A novel method of cross-linking ultra-high-molecular-weight polyethylene to improve wear, reduce oxidation, and retain mechanical properties', J of Arthoplasty, Vol 16, 2, 149 – 160

Moratoglu OK, Greenbaum BA, Bragdon CR, Jasty M, Freiberg AA, Harris WH 2004, Surface analysis of early retrieved acetabular polyethylene liners, A comparison of conventional and highly crosslinked polyethylenes, J of Arthoplasty, Vol 19, 1, 68 - 77

Norton MR, Yarlagadda R, Anderson GH 2002, 'Catastrophic failure of the elite plus total hip replacement, with a hylamer acetabulum and zirconia ceramic femoral head', *J Bone Joint Surg*, Vol. 84(B), 631 – 635.

Oakley AP, Matheson JA, Rapid 2003, 'Osteolysis after hip arthroplasty in paget's disease'*. J Artho,* Vol. 18(2), 204 – 207.

Oonishi H, Kuno M 1997, 'The optimum dose of gamma radiation-heavy dose to low wear polyethylene in total hip prostheses', *J of Mat Science in Med*, Vol. 8, 11-18.

Orishimo KF, Hopper RH, Engh CA 2003, 'Long term in-vivo wear performance of porous coated acetabular components sterilized with gamma irradiation and in air or ethylene oxide', *J Arthro*, Vol. 18, 546 – 552.

Parr, Jack E 1995, 'Effects of sterilization methods on ultra high molecular weight polyethylene (UHMWPE)*', Basic Science Conference.*

Paul JP 1976, '*Loading on normal hip and knee joints and on joint replacements, advances in artificial hip and knee joint technology'*, Springer Verlag, 53 - 70.

Pietrabissa R, Raimondi M, Martino E 1998, 'Wear of polyethylene cups in total hip arthroplasty: A parametric mathematical model', *Med Eng and Phys*, Vol. 20(3), 199 – 210.

Ries MD, Scott L 2001, 'Relationship between gravimetric wear and particle generation in hip simulators: Conventional compared with cross-linked polyethylene', *J Bone Joint Surg*, Vol. 83 (A) Suppl 2 Part 2, 116 – 122.

Rimnac CM, Klein RW, Betts F, Wright TM 1994, 'Post irradiation aging of ultra high molecular weight polyethylene', *J Bone and Joint Surg*, Vol. 76A (7), 1052 – 1056.

Robinson CM, Adams CJ 2002, 'Implant related fractures of the femur following hip fracture surgery'*, J Bone Joint Surg* Vol. 84A, Number 7, 1116 – 1122.

Rybicki E, Purves M, 1996, 'SDS Polyacrylamide gel electrophoresis (SDS-Page', *Molecular biology techniques manual,* Dept of Microbiology, University of Cape Town.

Saikko V, Ahlroos T, Calonius O, Keränen J 2001, 'Wear simulation of total hip prostheses with polyethylene against CoCr, alumina and diamond like carbon'*, Biomaterials*, Vol. 22, 1507 – 1514.

Saum KA 1994, 'Oxidation vs depth and time for polyethylene-gamma sterilized in air*', Trans ORS*, 174 – 185.

Schaldach, M, Hohmann D. 1976. '*Advances in artificial hip and knee joint technology',* Engineering in Medicine 2, Springer Verlag.

Schmalzried TP, Campbell PA, Schmitt AK, Brown IC, Amstutz HC 1997, 'Shape and dimensional characteristics of polyethylene wear particles generated in vivo by total knee replacements compared to total hip replacements', *J Biomed Mater Res*, Vol. 38, 203 -210.

Schmalzried T P, Callaghan J J 1999, 'Wear in total hip and knee replacements', *J Bone and Joint Surg*., Vol. 81-A:115-136.

Schulte KR, Callaghan JJ, Kelly SS, Johnston RC 1993, 'The outcome of charnley hip arthroplasty with cement after a minimum twenty-year followup', *J Bone Joint Surg*, Vol. 75A, Number 7, 961 – 975.

Shigley JE, Mischke CR 2003, *Mechanical engineering design - sixth metric edition,* New York, McGraw-Hill.

Smith SL, Unsworth A 2000, 'A 5 station hip simulator', *J Bone Joint Surg*, Vol. 82(B) Suppl. 2, 137-142.

Sokoloff L, 1978, 'The joints and synovial fluid Vol. 1', *Academic Press Inc*, ISBN 0 12 655101 4.

Sulkowska A, 1997, 'Temperature effect on the stability of the complexes between purine derivates and serum albumien: proton NMR study', *Journal of Molecular Structure*, Vol. 4, 410 – 411.

Sun DC, Wang A 1996, 'Effect of radiation-Induced crosslinking on creep and wear performance of ultra-high molecular weight polyethylene, American Academy of Orthopaedic Surgeons*', 1996 Annual Orthopaedic Meeting, Scientific program.*

Sychterz CJ, Moon KH, Hashimoto Y, Terefenko KM, Engh CA Jr, Bauer TW 1996, 'Wear of polyethylene cups in total hip arthroplasty: A study of specimens retrieved post mortem', *J Bone Joint Surg*, Vol. 78 (A), 1193 – 1200.

The Norwegian arthroplasty register 2003, The department of Orthopaedic Surgery, Haukeland University Hospital.

Tipper JL, Firkins PJ, Besong AA, Barbour PSM, Nevelos J, Stone MH, Ingham E, Fischer J, 2001, 'Characterisation of wear debris from UHMWPE on zirconia ceramic, metal-on-metal and alumina ceramic-on-ceramic hip prostheses generated in a physiological anatomical hip joint simulator*', Wear*, Vol. 250, 120 -128.

Trieu HH, Paxson RD 1995, 'The oxidized surface layer in shelf aged UHMWPE'*, ORS*, Vol. 758,1995.

Wang A, Sun DC, Stark C, Dumbleton JC 1995, 'Wear mechanisms of UHMWPE in total joint replacements', *Wear* 181-183, 241-249.

Wang A, Essner A, Stark C, Dumbleton JH 1996, 'Comparison of the size and morphology of UHMWPE wear debris produced by a hip joint simulator under serum and water lubricated conditions'*, Biomaterials*, Vol. 17, 865-871.

Wang A, Essner A. Polineni VK, Stark C 1997, 'Wear mechanisms and wear testing of ultra high molecular weight polyethylene in total joint replacement, in polyethylene wear in orthopaedics implants workshop'*, Minneapolis, Society of Biomaterials*, 4 – 18.

Wang A, Sun DC 1997, 'Orientation softening in the deformation and wear of ultra high molecular weight polyethylene', *Wear* 203 -204, 230-241.

Wang A, Essner A, Polineni VK, Stark C, Dumbleton JC 1998, 'Lubrication and wear of ultra high molecular weight polyethylene in total joint replacements', *Tribology International*, Vol. 31 nr 1-3, 17-33.

Wang A, Polineni VK, Stark C, Dumbleton JH 1998, 'Role of proteins and hylauronic acid in the lubrication and wear of UHMWPE acetabular cups', *24th Annual Meeting of the Society for Biomaterials, April 22-26, 1998*, San Diego, California, USA.

Wang A, Essner A, Dumbleton JH 1999, 'A biaxial line contact wear machine for the evaluation of implant bearing materials for total knee joint replacements', *Wear*, 225 -229, 701-707.

Wilkinson JM, Hamer AJ, Rogers A, Stockley I, Eastell R 2003, 'Bone mineral density and biochemical markers of bone turnover in aseptic loosening after total hip arthroplasty', *J Orth Res*, Vol. 21.

Young-Hoo, K, Kim JS, 2001, 'A comparison of polyethylene wear in hips with cobalt-chrome or zironia heads: A Prospective, randomized Study', *J Bone Joint Sur*, Vol. 83(B), 742 – 750.

Zupanc O, Antolic V, 2001, 'The assessment of contact stress in the hip joint after operative treatment for severe slipped capital femoral epiphysis', *Int Orth*, Vol. 25, 9-12.

ANNEXURE A

Retrieval analysis of 20 acetabular cups

Patient 1

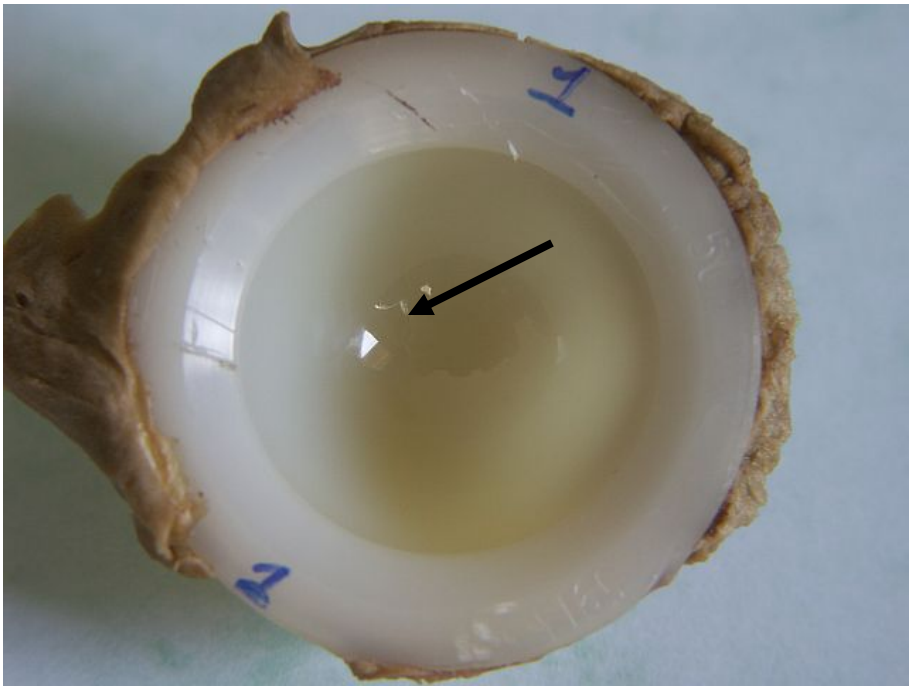


Figure A1

Figure A2

Cup analysis: Patient 1

1	Femoral head size	32 mm
2	Type of head	Alumina
3	Cup type	UHMWPE - Osteal
4	Crosslink	No
5	Amount of linear wear	± 1.1 mm
6	Duration in vivo	13 years and 7 months
7	Size of wear debris from pathologist	10 – 30 µm
8	Visible discoloration	Yes (Figure 1)
9	Metal backing	No
10	Thickness of poly	9 mm
11	Mechanical damage	No
12	Cracks in material	No
13	Plastic flow	No
14	Scratches	No (visually)
15	Adhesion wear	Yes
16	Wear particles embedded in base material	No
17	Flaking	No

Patient 2

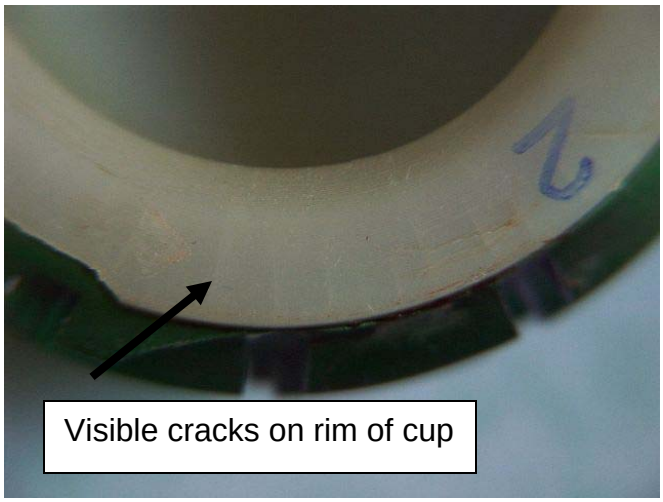


Figure A3

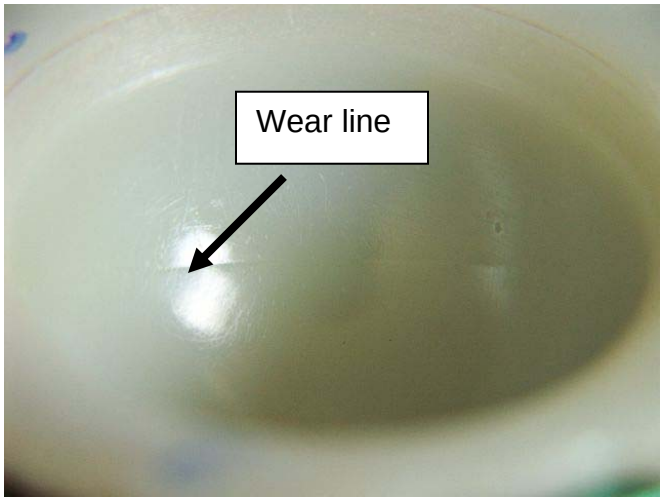


Figure A4

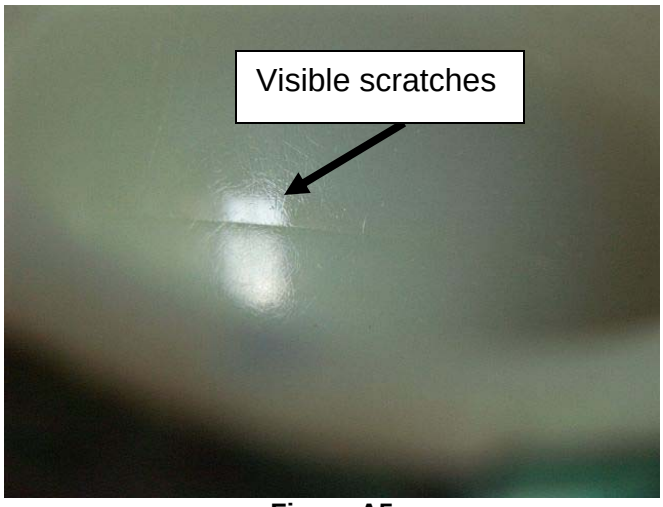


Figure A5

Cup analysis: Patient 2

1	Femoral head size	32 mm
2	Type of head	Alumina
3	Cup type	UHMWPE - Osteal
4	Crosslink	No
5	Amount of linear wear	± 0.8 mm
6	Duration in vivo	17 years
7	Size of wear debris from pathologist	20 – 110 µm, avg. 40 µm
8	Visible discoloration	Yes (Figure 1)
9	Metal backing	No
10	Thickness of poly	± 7 mm
11	Mechanical damage	Yes
12	Cracks in material	Yes
13	Plastic flow	No
14	Scratches	Yes
15	Adhesion wear	No
16	Wear particles embedded in base material	No
17	Flaking	No

Patient 3

Figure A6

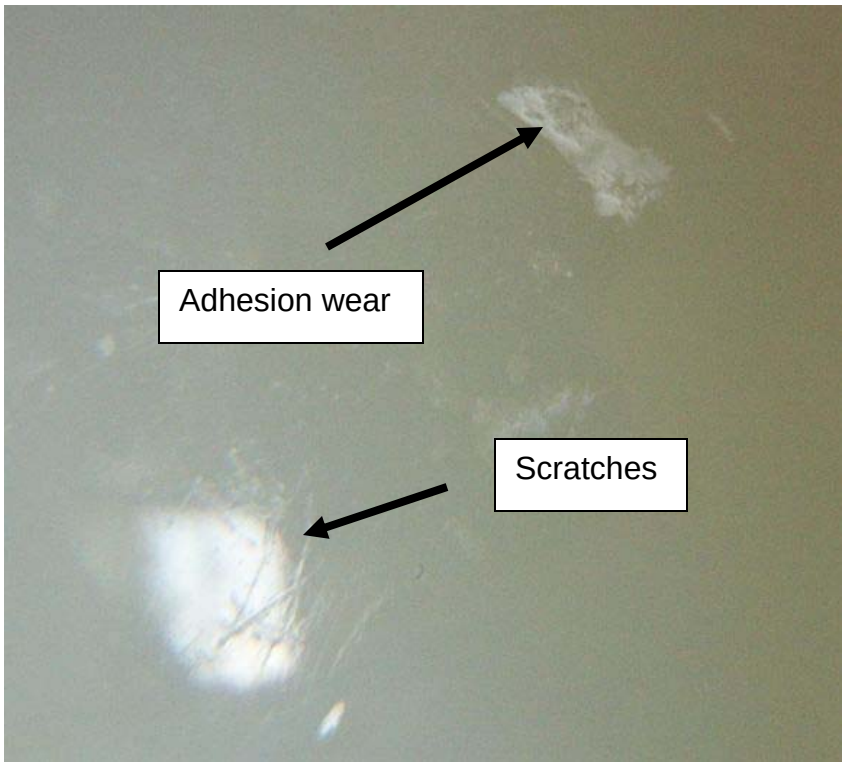


Figure A7

Cup analysis: Patient 3

1	Femoral head size	26 mm
2	Type of head	Alumina
3	Cup type	UHMWPE - Aesculab
4	Crosslink	No
5	Amount of linear wear	± 0.4 mm
6	Duration in vivo	6 years
7	Size of wear debris from pathologist	10 – 50 µm
8	Visible discoloration	Yes (Figure 6)
9	Metal backing	No
10	Thickness of poly	9 mm
11	Mechanical damage	No
12	Cracks in material	No
13	Plastic flow	No
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	Yes
17	Flaking	No

Patient 4

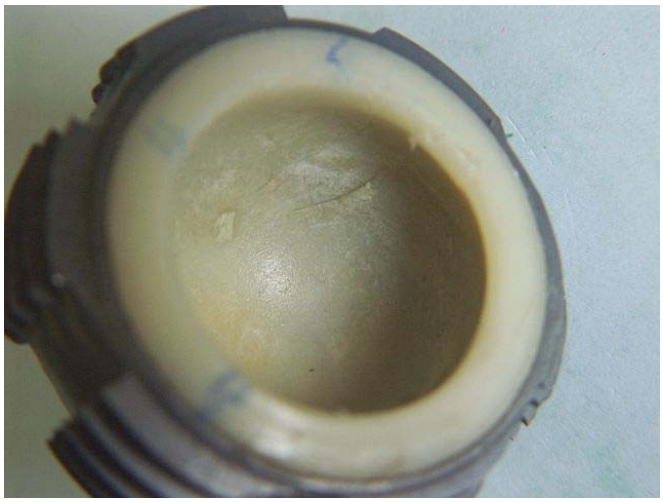


Figure A8

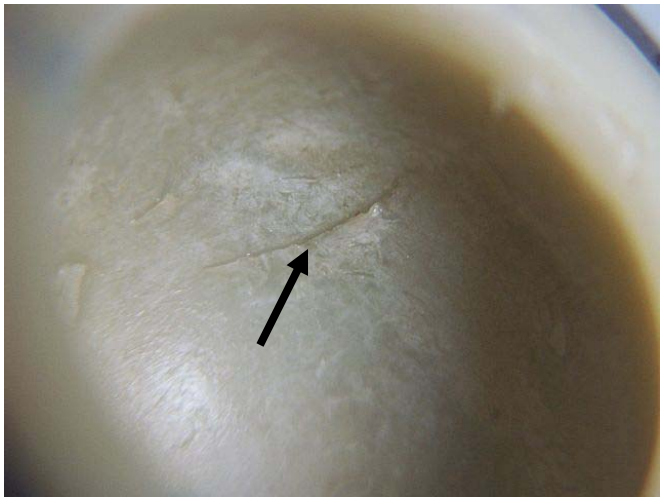


Figure A9

Figure A10

Cup analysis: Patient 4

1	Femoral head size	32 mm
2	Type of head	Alumina
3	Cup type	UHMWPE – ARD
4	Crosslink	No
5	Amount of linear wear	± 4.5 mm
6	Duration in vivo	12 years
7	Size of wear debris from pathologist	10 – 90 µm
8	Visible discoloration	No
9	Metal backing	Yes
10	Thickness of poly	± 5 mm
11	Mechanical damage	Yes
12	Cracks in material	Yes
13	Plastic flow	No
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	Yes
17	Flaking	No

Patient 5

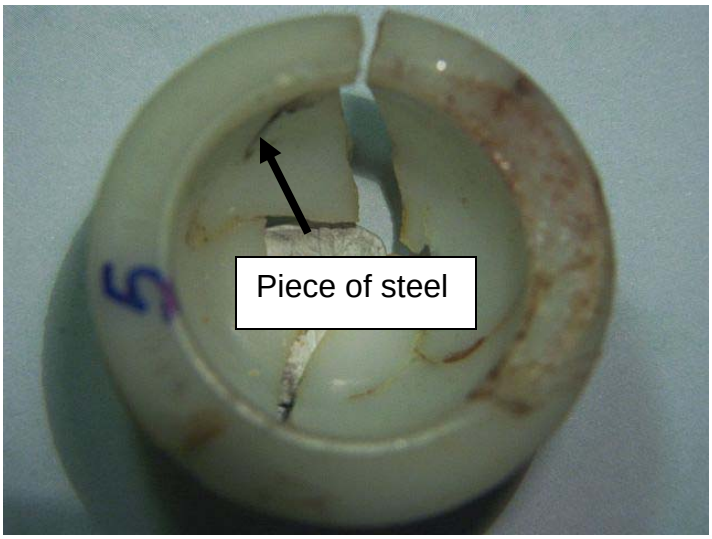


Figure A11

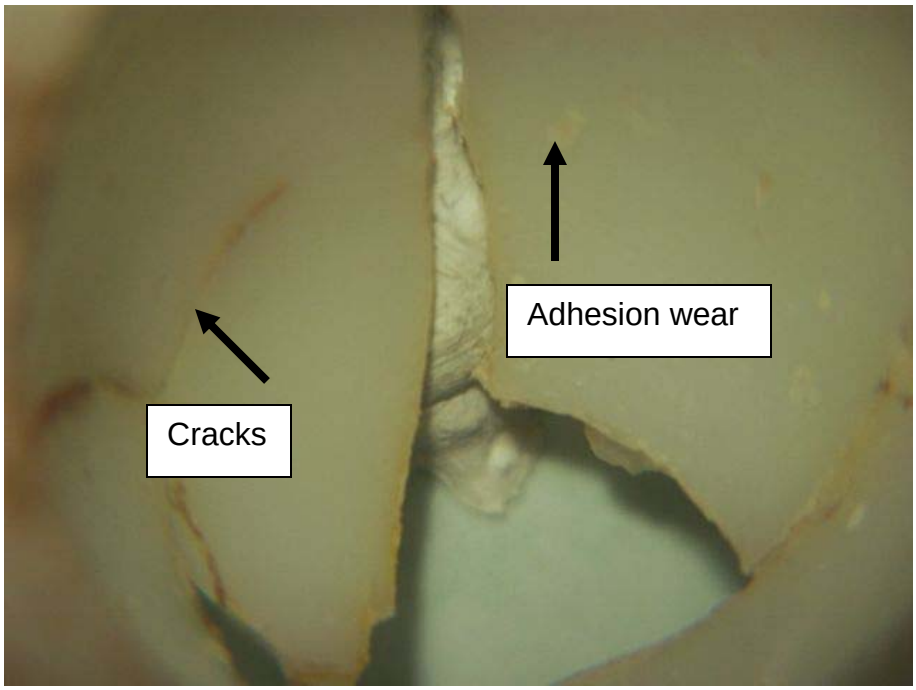


Figure A12

Cup analysis: Patient 5

1	Femoral head size	32 mm
2	Type of head	Stainless
3	Cup type	UHMWPE – ARD
4	Crosslink	No
5	Amount of linear wear	± 5 mm
6	Duration in vivo	9 years and 5 months
7	Size of wear debris from pathologist	100 – 800 µm, avg. 600 µm
8	Visible discoloration	No
9	Metal backing	No
10	Thickness of poly	7 mm
11	Mechanical damage	Yes
12	Cracks in material	Yes
13	Plastic flow	No
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	Yes
17	Flaking	No

Patient 6

Figure A13

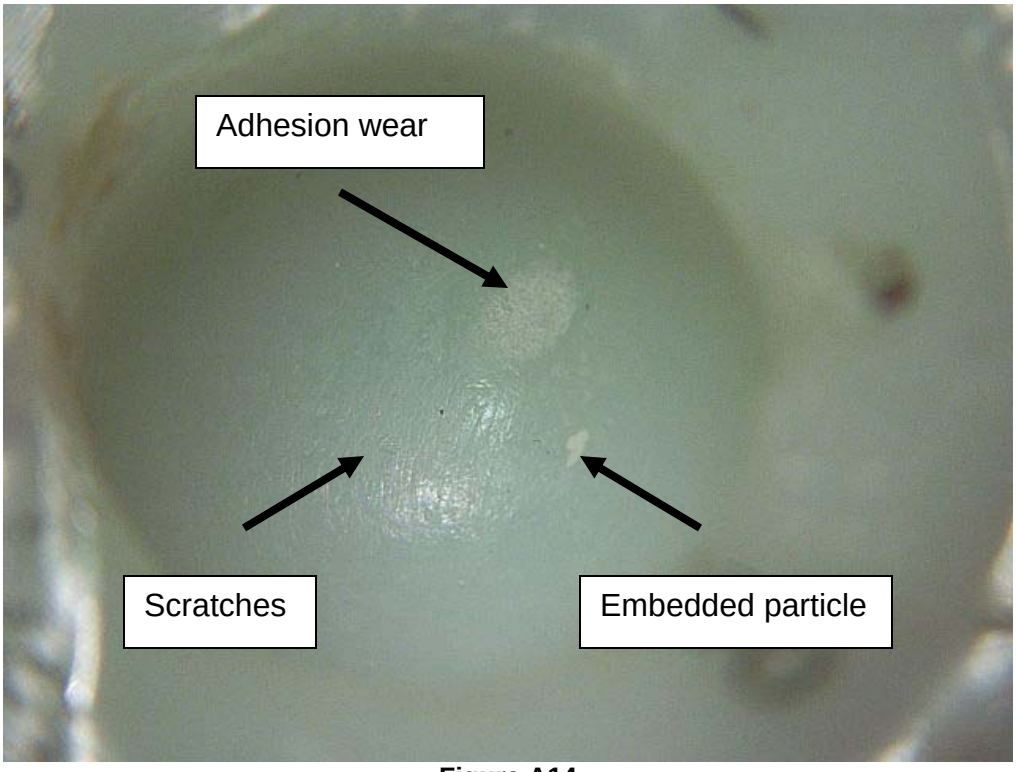


Figure A14

Cup analysis: Patent 6

1	Femoral head size	22 mm
2	Type of head	Stainless
3	Cup type	UHMWPE – Charnley
4	Crosslink	No
5	Amount of linear wear	± 3 mm
6	Duration in vivo	8 years
7	Size of wear debris from pathologist	60 – 140 µm
8	Visible discoloration	No
9	Metal backing	No
10	Thickness of poly	14 mm
11	Mechanical damage	No
12	Cracks in material	No
13	Plastic flow	No
14	Scratches	Yes (figure 14)
15	Adhesion wear	Yes (figure 14)
16	Wear particles embedded in base material	Yes (figure 14)
17	Flaking	No

Patient 7

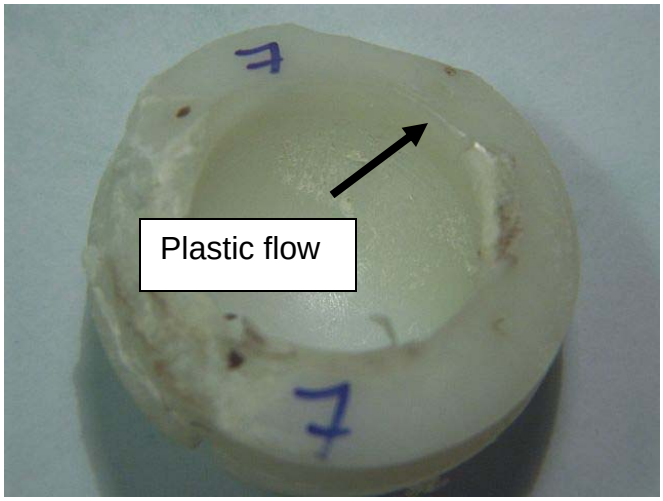


Figure A15

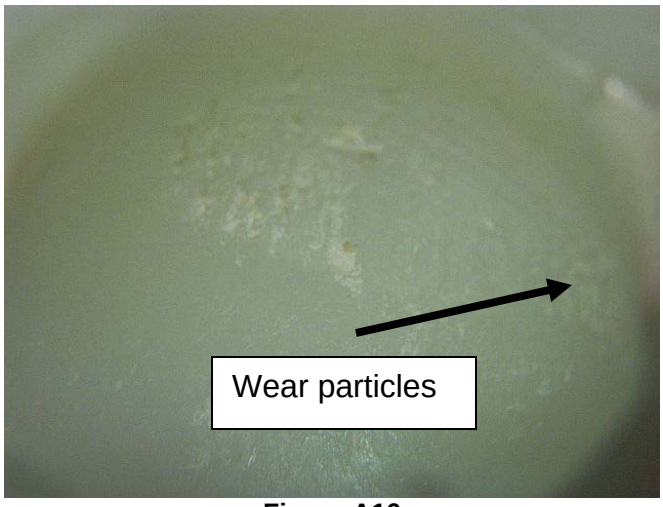


Figure A16

Figure A17

Cup analysis: Patient 7

1	Femoral head size	30 mm
2	Type of head	Stainless steel
3	Cup type	UHMWPE – ARD
4	Crosslink	No
5	Amount of linear wear	± 5 mm
6	Duration in vivo	23 years and 5 months
7	Size of wear debris from pathologist	20 – 180 µm
8	Visible discoloration	No
9	Metal backing	No
10	Thickness of poly	9 mm
11	Mechanical damage	Yes
12	Cracks in material	No
13	Plastic flow	Yes (figure 15)
14	Scratches	Yes (figure 16 & 17)
15	Adhesion wear	Yes (figure 16 & 17)
16	Wear particles embedded in base material	Yes (figure 16)
17	Flaking	No

Patient 8

Figure A18

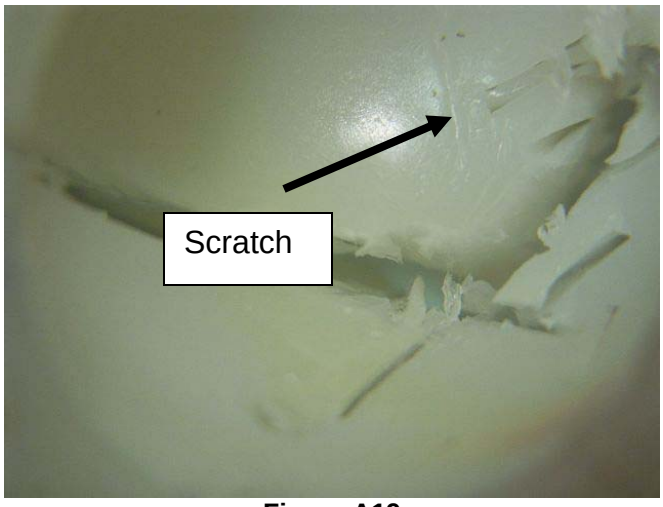


Figure A19

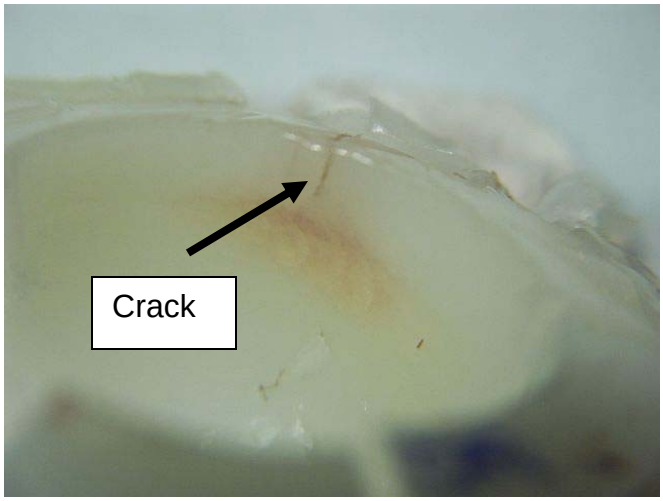


Figure A20

Cup analysis: Patient 8

1	Femoral head size	30 mm
2	Type of head	Stainless steel
3	Cup type	UHMWPE – ARD
4	Crosslink	No
5	Amount of linear wear	± 5 mm
6	Duration in vivo	16 years and 4 months
7	Size of wear debris from pathologist	Not known
8	Visible discoloration	Yes (Figure 18)
9	Metal backing	No
10	Thickness of poly	9 mm
11	Mechanical damage	Yes
12	Cracks in material	Yes
13	Plastic flow	Yes
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	Yes
17	Flaking	No

Patient 9

Figure A21

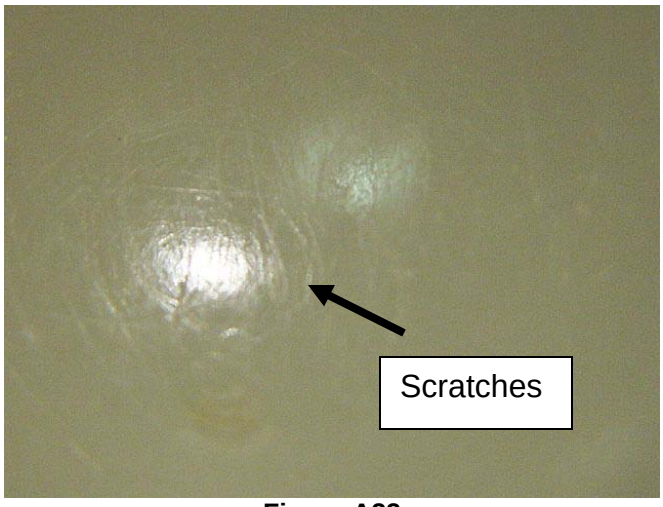


Figure A22

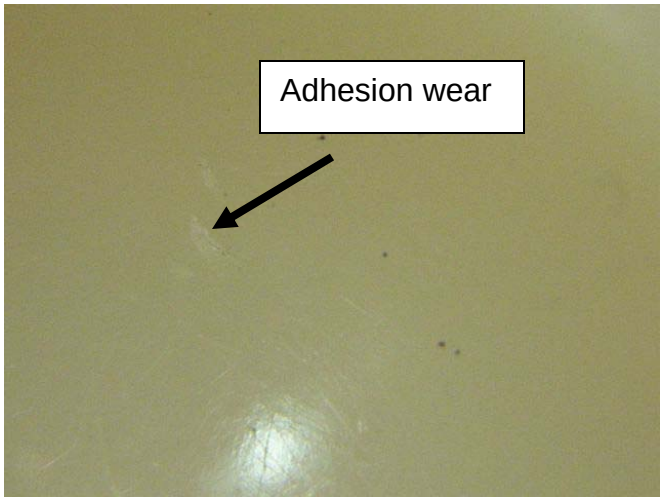


Figure A23

Cup analysis: Patient 9

1	Femoral head size	32 mm
2	Type of head	Zirconium
3	Cup type	UHMWPE – Aesculab
4	Crosslink	Yes
5	Amount of linear wear	± 0 mm
6	Duration in vivo	3 years and 9 months
7	Size of wear debris from pathologist	Not available
8	Visible discoloration	No
9	Metal backing	Yes
10	Thickness of poly	19 mm
11	Mechanical damage	No
12	Cracks in material	No
13	Plastic flow	No
14	Scratches	Yes (figure 22)
15	Adhesion wear	Yes
16	Wear particles embedded in base material	No
17	Flaking	No

Patient 10

Figure A24

Figure A25

Cup analysis: Patient 10

1	Femoral head size	28 mm
2	Type of head	Alumina
3	Cup type	UHMWPE – Aesculab
4	Crosslink	Yes
5	Amount of linear wear	± 0 mm
6	Duration in vivo	7 Months
7	Size of wear debris from pathologist	Not available
8	Visible discoloration	No
9	Metal backing	Yes
10	Thickness of poly	23 mm
11	Mechanical damage	No
12	Cracks in material	No
13	Plastic flow	No
14	Scratches	No
15	Adhesion wear	No
16	Wear particles embedded in base material	No
17	Flaking	No

Patient 11

Figure A26

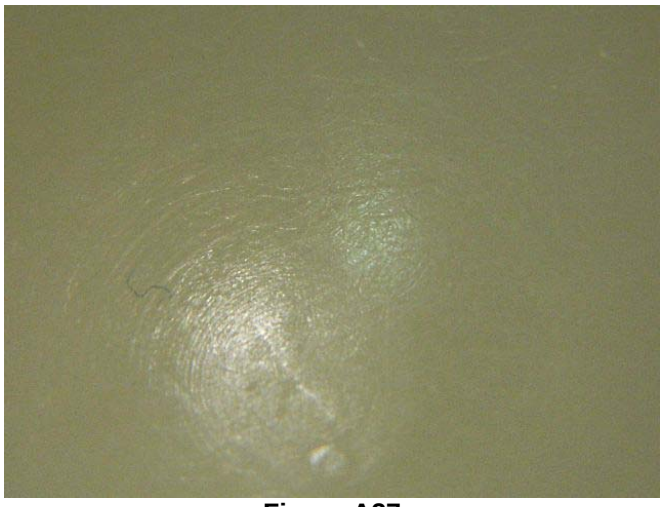


Figure A27

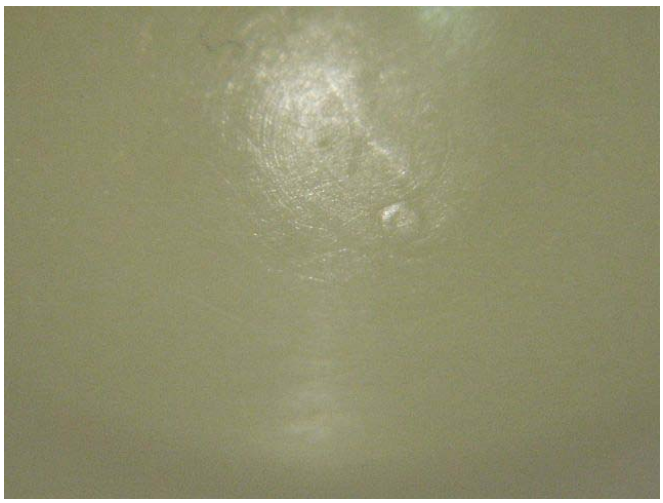


Figure A28

Cup analysis: Patient 11

1	Femoral head size	28 mm
2	Type of head	Zirconium
3	Cup type	UHMWPE – Aesculab
4	Crosslink	Yes
5	Amount of linear wear	± 0 mm
6	Duration in vivo	14 months
7	Size of wear debris from pathologist	10 – 40 µm
8	Visible discoloration	No
9	Metal backing	Yes
10	Thickness of poly	9 mm
11	Mechanical damage	No
12	Cracks in material	No
13	Plastic flow	No
14	Scratches	Yes
15	Adhesion wear	No
16	Wear particles embedded in base material	Yes
17	Flaking	No

Patient 12

Figure A29

Figure A30

Figure A31

Cup analysis: Patient 12

1	Femoral head size	28 mm
2	Type of head	Zirconium
3	Cup type	UHMWPE – de puy
4	Crosslink	No
5	Amount of linear wear	± 3.5 mm
6	Duration in vivo	10 years
7	Size of wear debris from pathologist	20 – 80 µm
8	Visible discoloration	Yes
9	Metal backing	No
10	Thickness of poly	9 mm
11	Mechanical damage	Yes
12	Cracks in material	Yes
13	Plastic flow	Yes
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	No
17	Flaking	No

Patient 13

Figure A32

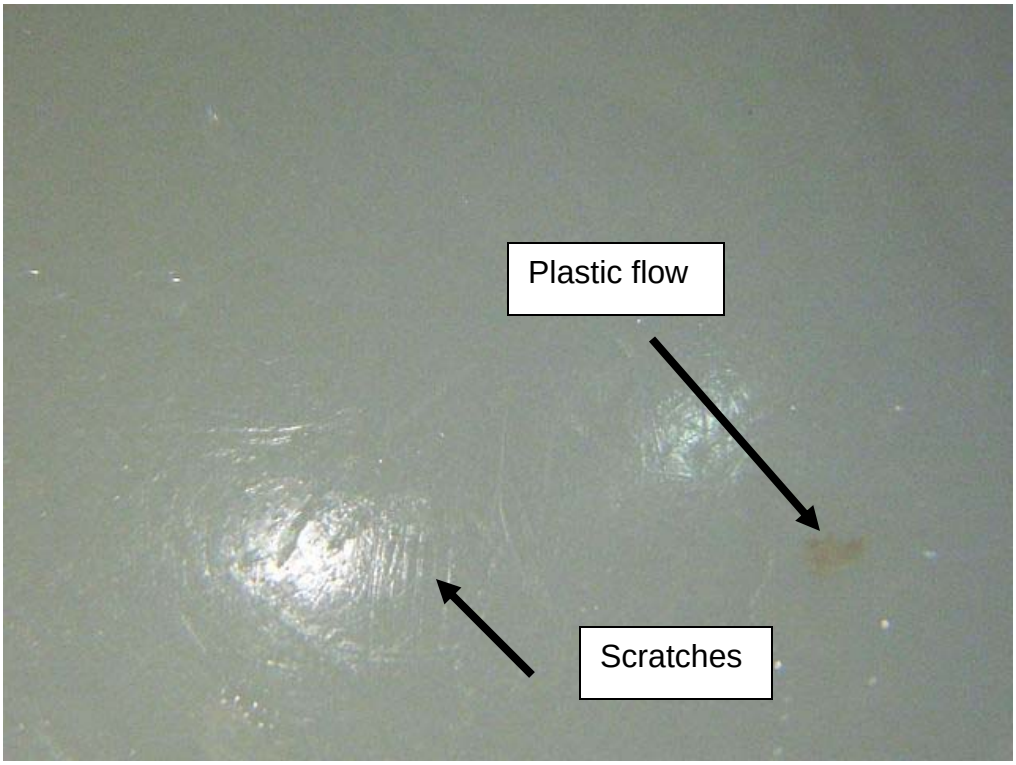


Figure A33

Cup analysis: Patient 13

1	Femoral head size	32 mm
2	Type of head	Zirconium
3	Cup type	UHMWPE – Aesculab
4	Crosslink	No
5	Amount of linear wear	± 3.5 mm
6	Duration in vivo	9 years and 3 months
7	Size of wear debris from pathologist	20 – 100 µm, avg. 60 µm
8	Visible discoloration	No
9	Metal backing	No
10	Thickness of poly	12 mm
11	Mechanical damage	No
12	Cracks in material	No
13	Plastic flow	Yes
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	Yes
17	Flaking	No

Patient 14

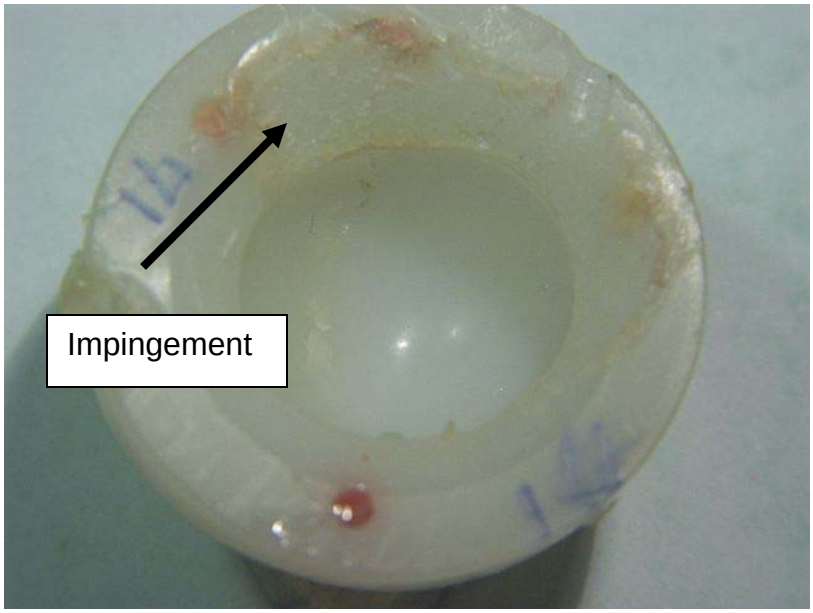


Figure A34

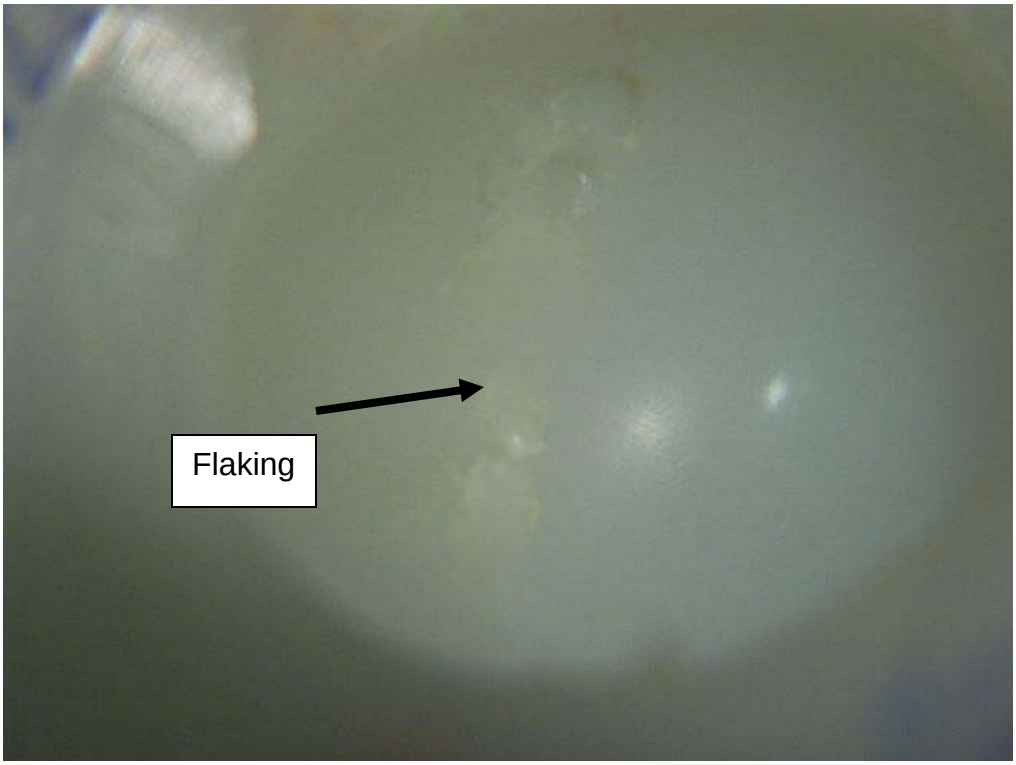


Figure A35

Cup analysis: Patient 14

1	Femoral head size	22 mm
2	Type of head	Zirconium
3	Cup type	UHMWPE – Aesculab
4	Crosslink	No
5	Amount of linear wear	± 5 mm
6	Duration in vivo	7 years
7	Size of wear debris from pathologist	Not available
8	Visible discoloration	Yes (Figure 34)
9	Metal backing	Yes
10	Thickness of poly	11 mm
11	Mechanical damage	Yes (serious impingement – see figure 34)
12	Cracks in material	Yes
13	Plastic flow	No
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	Yes
17	Flaking	Yes

Patient 15

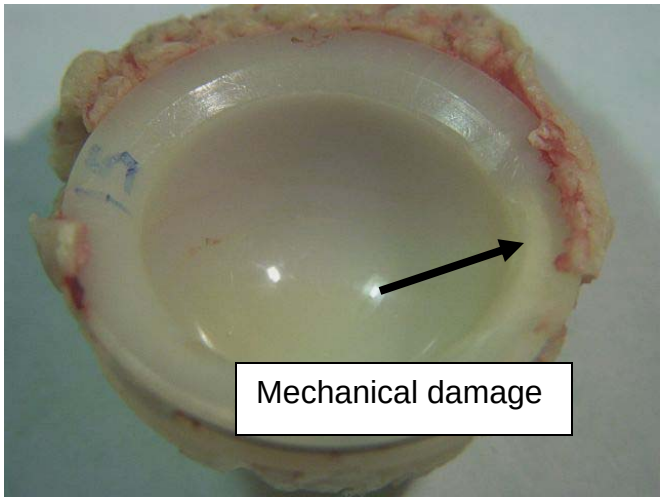


Figure A36

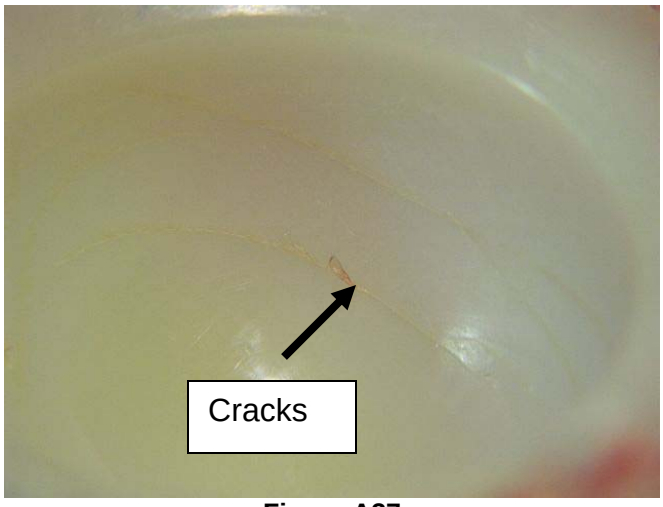


Figure A37

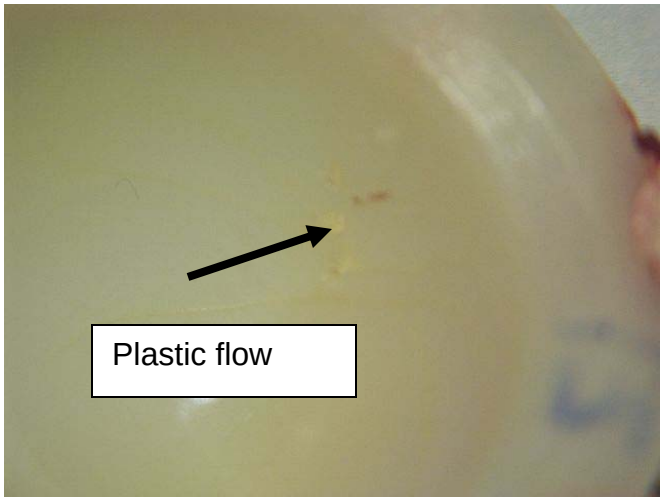


Figure A38

Cup analysis: Patient 15

1	Femoral head size	32 mm
2	Type of head	Alumina
3	Cup type	UHMWPE – Aesculab
4	Crosslink	No
5	Amount of linear wear	± 0.2 mm
6	Duration in vivo	15 years
7	Size of wear debris from pathologist	20 – 140 µm, avg. 80 µm
8	Visible discoloration	Yes (Figure 36)
9	Metal backing	No
10	Thickness of poly	7 mm
11	Mechanical damage	Yes (figure 36)
12	Cracks in material	Yes
13	Plastic flow	No
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	Yes
17	Flaking	No

Patient 16

Figure A39

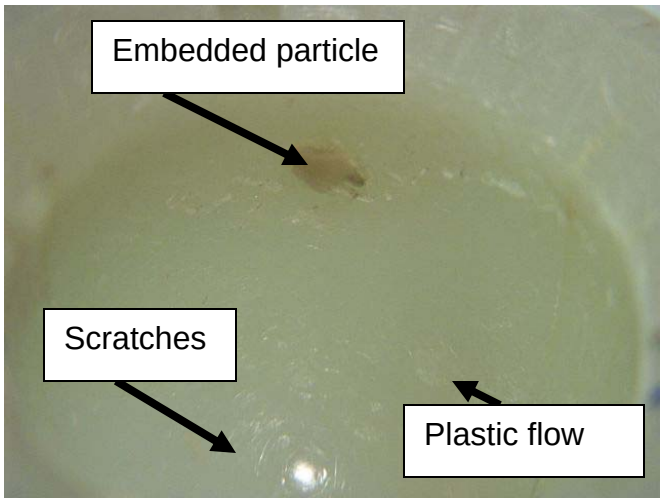


Figure A40

Figure A41

Cup analysis: Patient 16

1	Femoral head size	28 mm
2	Type of head	Zirconium
3	Cup type	UHMWPE – Aesculab
4	Crosslink	No
5	Amount of linear wear	± 3.5 mm
6	Duration in vivo	10 years
7	Size of wear debris from pathologist	20 – 350 µm
8	Visible discoloration	Yes (Figure 39)
9	Metal backing	No
10	Thickness of poly	11 mm
11	Mechanical damage	Yes (figure 39)
12	Cracks in material	No
13	Plastic flow	Yes
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	Yes
17	Flaking	No

Patient 17

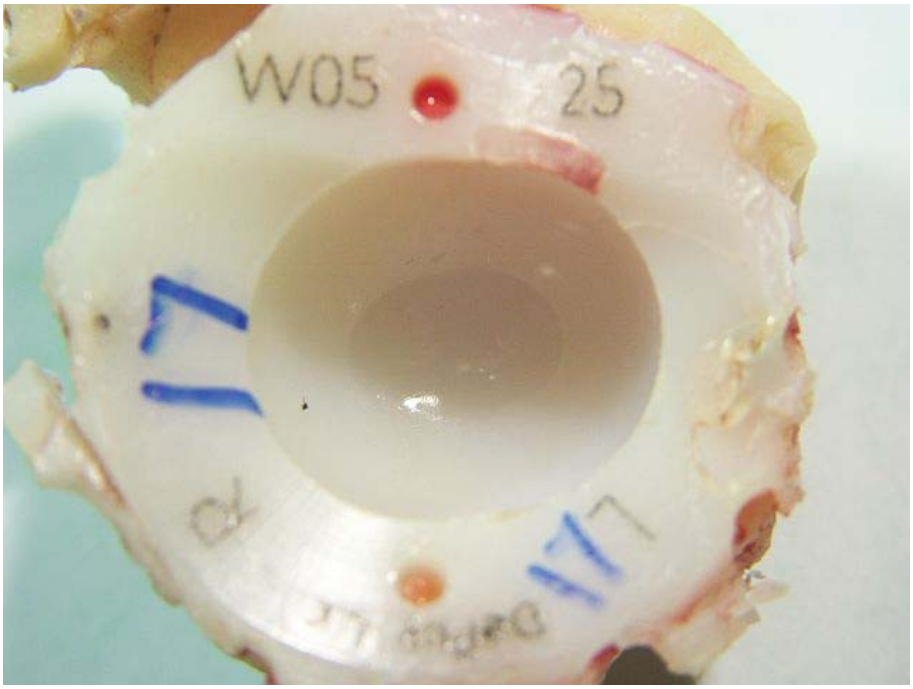


Figure A42

Figure A43

Cup analysis: Patient 17

1	Femoral head size	22 mm
2	Type of head	Stainless Steel
3	Cup type	UHMWPE – Charnley, de Puy
4	Crosslink	No
5	Amount of linear wear	± 6 mm
6	Duration in vivo	10 years and 6 months
7	Size of wear debris from pathologist	Not available
8	Visible discoloration	Yes (Figure 42)
9	Metal backing	No
10	Thickness of poly	13 mm
11	Mechanical damage	No
12	Cracks in material	No
13	Plastic flow	No
14	Scratches	Yes
15	Adhesion wear	No
16	Wear particles embedded in base material	No
17	Flaking	No

Patient 18

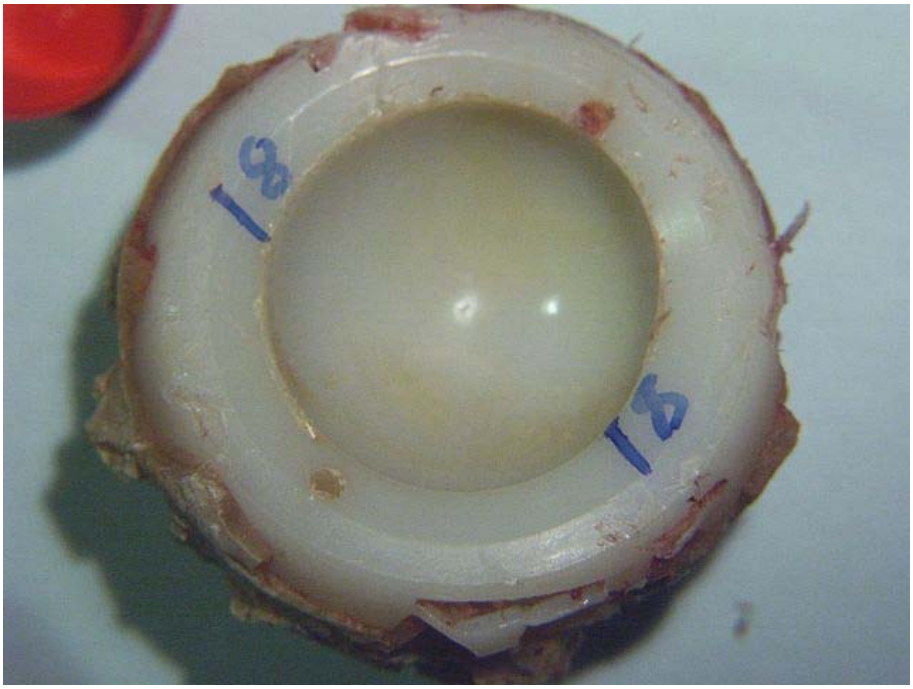


Figure A44

Figure A45

Cup analysis: Patient 18

1	Femoral head size	32 mm
2	Type of head	Alumina
3	Cup type	UHMWPE - Aesculab
4	Crosslink	No
5	Amount of linear wear	± 5 mm
6	Duration in vivo	6 years and 6 months
7	Size of wear debris from pathologist	Not available
8	Visible discoloration	Yes
9	Metal backing	No
10	Thickness of poly	12 mm
11	Mechanical damage	Yes
12	Cracks in material	No
13	Plastic flow	No
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	Yes
17	Flaking	No

Patient 19

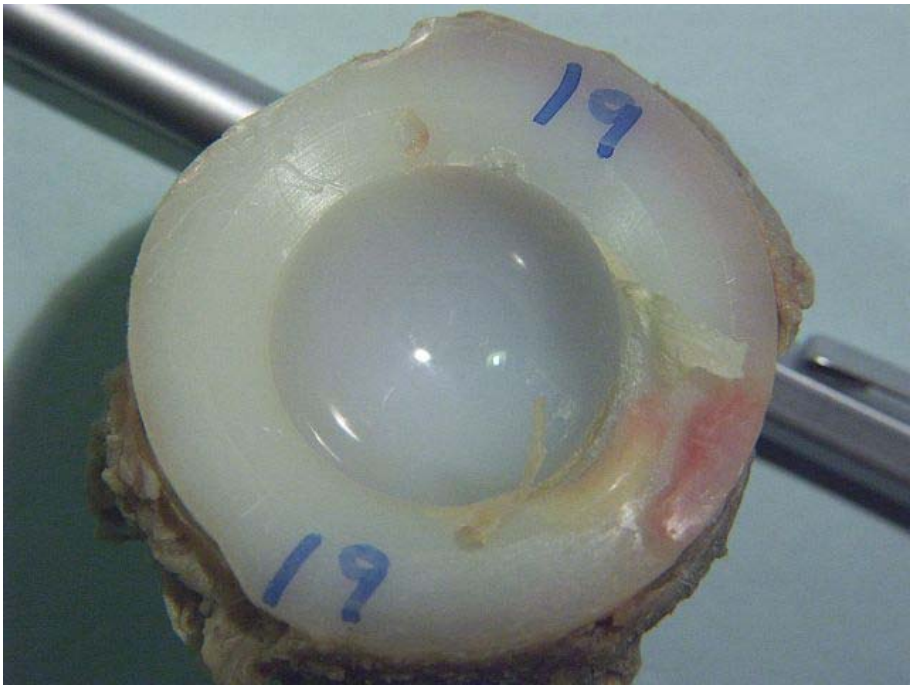


Figure A46

Figure A47

Cup analysis: Patient 19

1	Femoral head size	28 mm
2	Type of head	Alumina
3	Cup type	UHMWPE - BARC
4	Crosslink	No
5	Amount of linear wear	± 2 mm
6	Duration in vivo	15 years and 6 months
7	Size of wear debris from pathologist	Not available
8	Visible discoloration	Yes
9	Metal backing	No
10	Thickness of poly	10 mm
11	Mechanical damage	Yes
12	Cracks in material	Yes
13	Plastic flow	Yes
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	Yes
17	Flaking	Yes

Patient 20

Figure A48

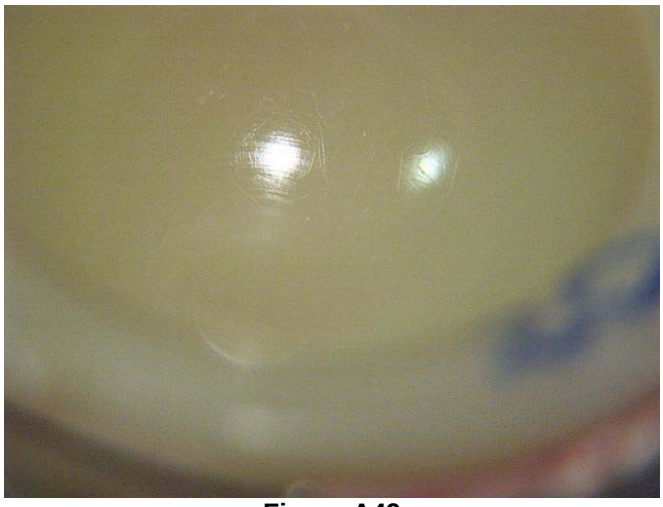


Figure A49

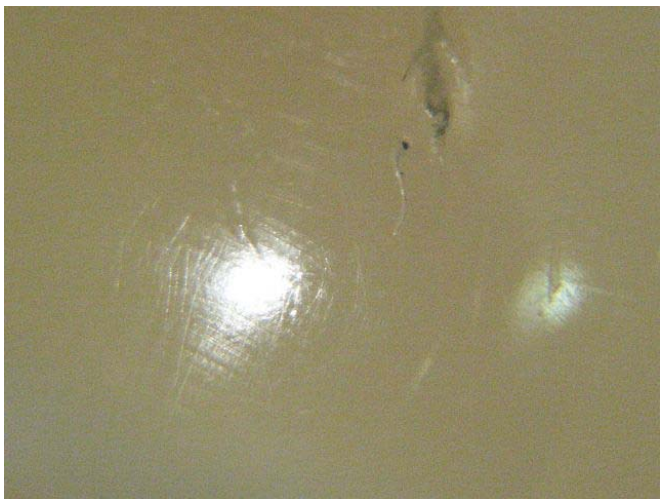


Figure A50

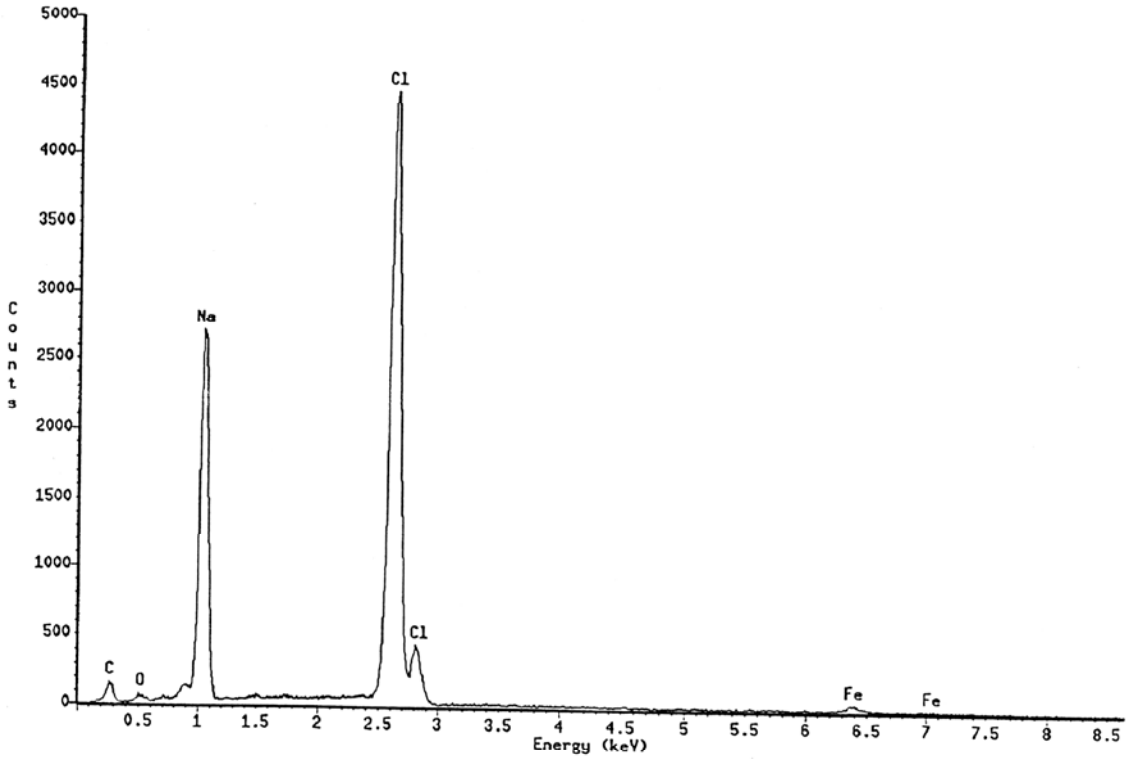
Cup analysis: Patient 20

1	Femoral head size	32 mm
2	Type of head	Zirconium
3	Cup type	UHMWPE - Aesculab
4	Crosslink	Yes
5	Amount of linear wear	± 0 mm
6	Duration in vivo	2 years and 4 months
7	Size of wear debris from pathologist	Not available
8	Visible discoloration	No
9	Metal backing	No
10	Thickness of poly	7 mm
11	Mechanical damage	No
12	Cracks in material	No
13	Plastic flow	No
14	Scratches	Yes
15	Adhesion wear	Yes
16	Wear particles embedded in base material	No
17	Flaking	No

ANNEXURE B

Electron microscope analysis of white deposits in acetabular cups

Annexure B



Column	: JEOL5800.Pioneer
Take-off angle	: 35
Acquisition type	: eds
Creation time	: 100/05/17 15:05
Livetime	: 100
Deadtime	: 28.089
Channels	: 2048
Channel width	: 10
Detector type	: Silicon/Lithium
Window type	: norvar
Window thickness	: 0.3
Coating material	: Al
Coating thickness	: 0.04
Contact material	: Au
Contact thickness	: 0.02
Crystal thickness	: 3

Accelerating voltage	: 20
Magnification	: 3500
Charge	: 100
Beam current	: 1
Beam spot size	: 0
Beam location	: 0,0
Working distance	: 10
Stage X	: 1.306
Stage Y	: -19.637
Stage Z	: 11.369
Stage tilt	: 0
Stage rotation	: 0
Contamination material	: none
Contamination thickness	: 0

File name :

Notes:

Wed May 17 15:04:01 2000

Livetime : 15.2 Sec.
Technique: Least Squares Fit

Elements Present:
C(6), Zn(30), Cl(17)

Energy (keV)	Intensity (counts)	Elements Present
0.273	127	C Ka
1.044	5019	Zn La1
2.626	8560	Cl Ka

ANNEXURE C

Electron microscope investigation into Brown discolouring in acetabular cups

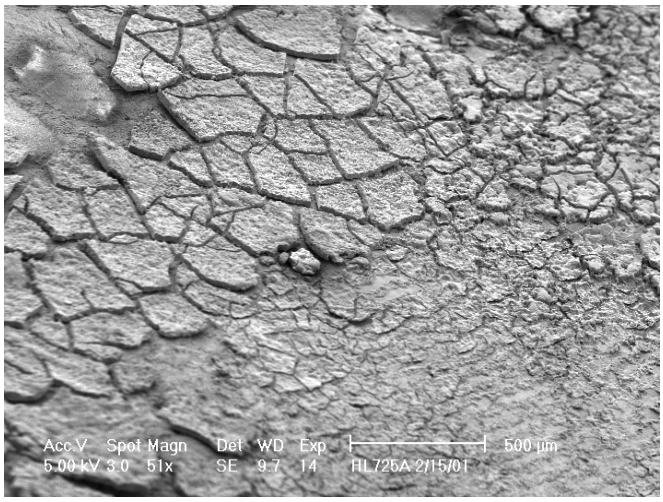


Figure C1

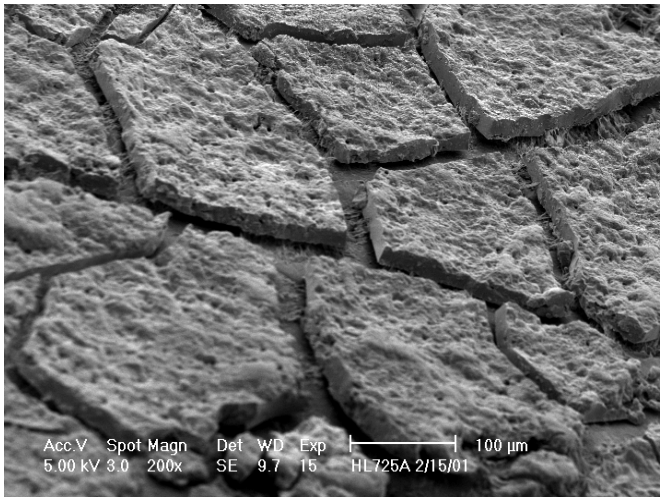


Figure C2

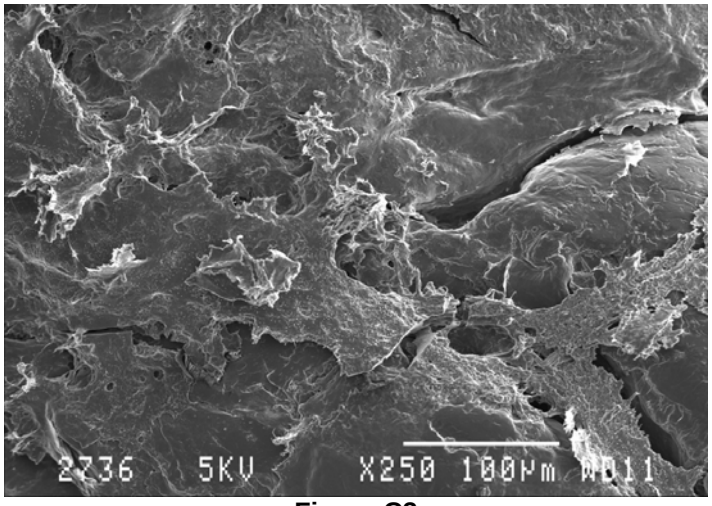


Figure C3

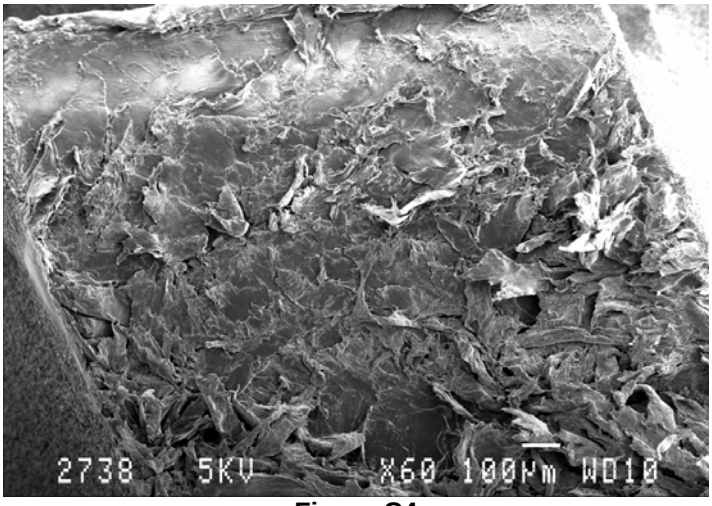


Figure C4

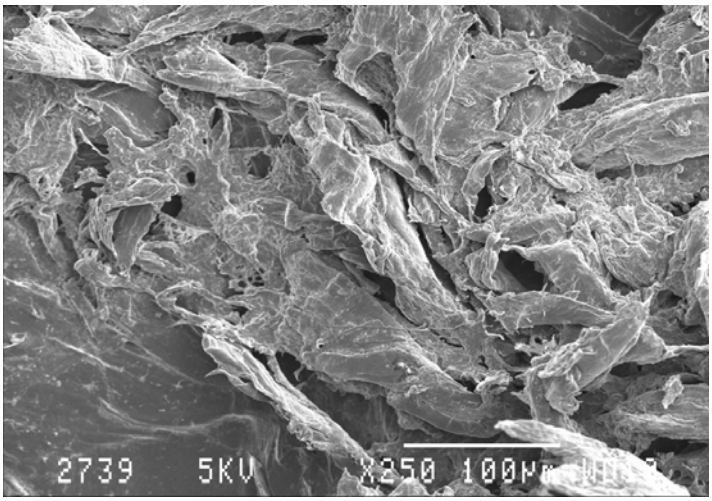


Figure C5

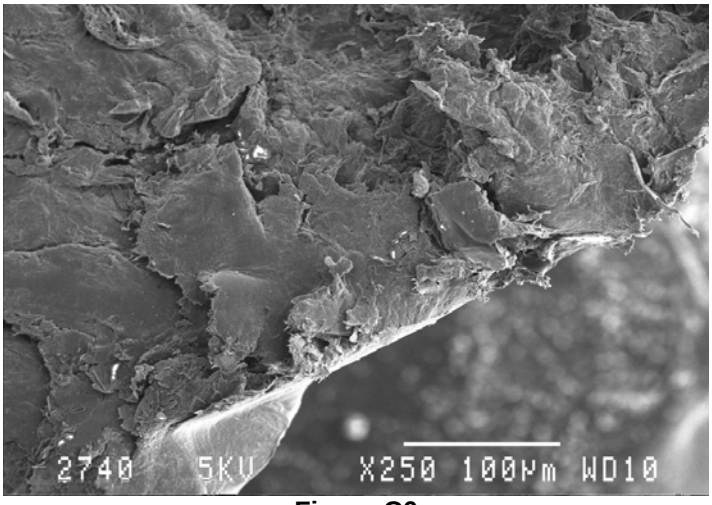


Figure C6

ANNEXURE D

Electron microscope investigation into structure of UHMWPE

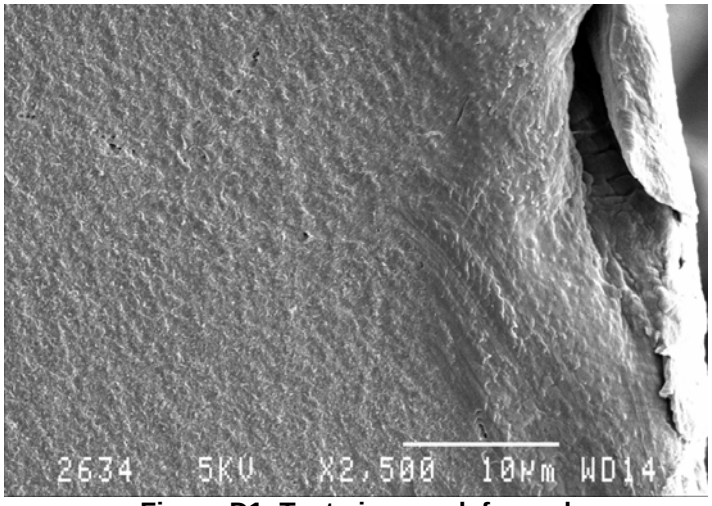


Figure D1: Test piece undeformed

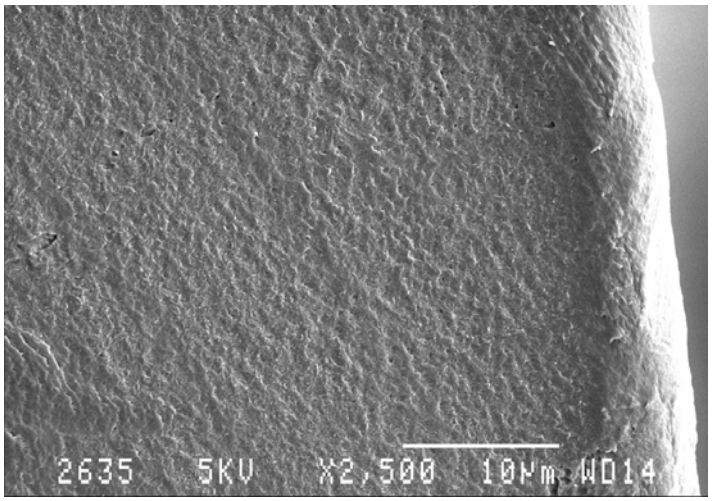


Figure D2: Test piece undeformed

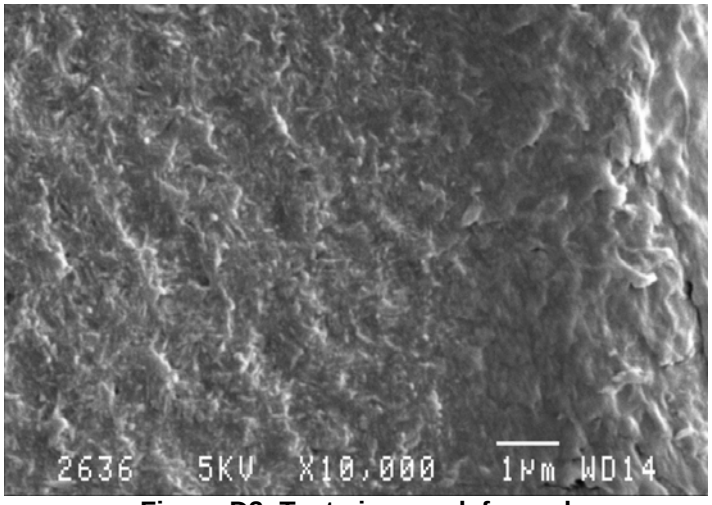


Figure D3: Test piece undeformed

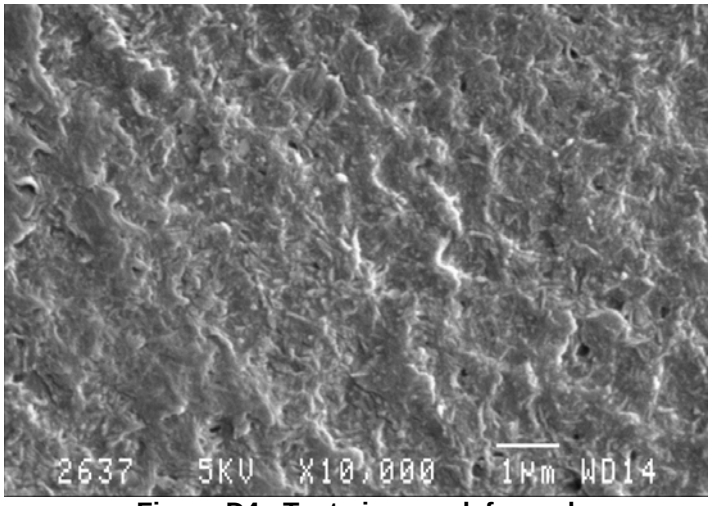


Figure D4: Test piece undeformed

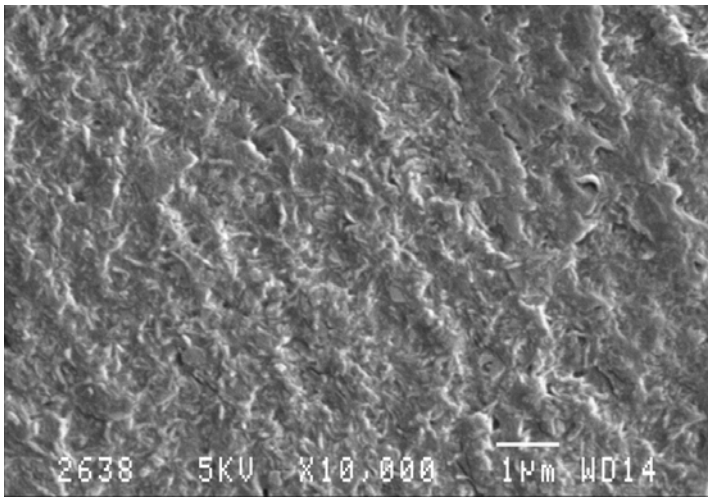


Figure D5: Test piece deformed

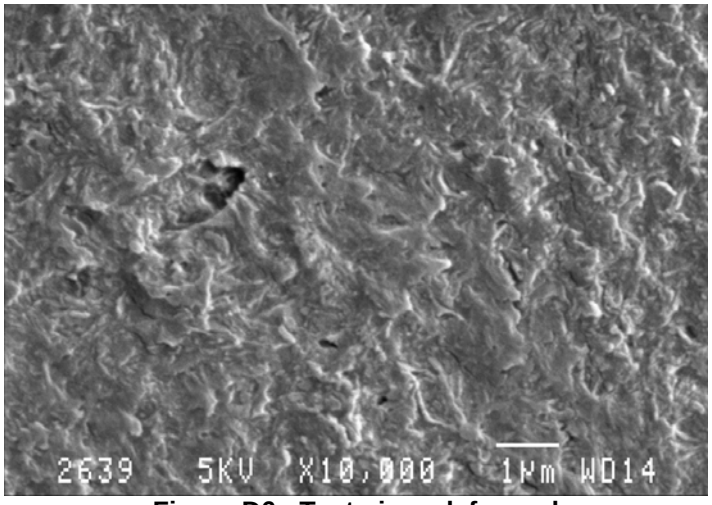


Figure D6: Test piece deformed

ANNEXURE E

Electron microscope investigation into micro wear

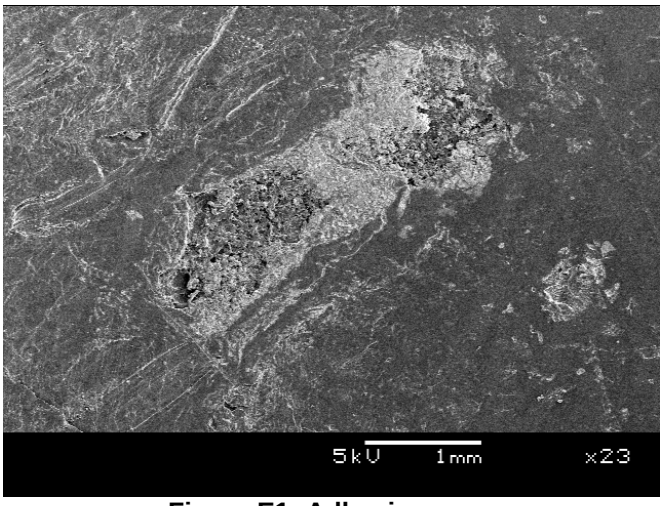


Figure E1: Adhesion wear

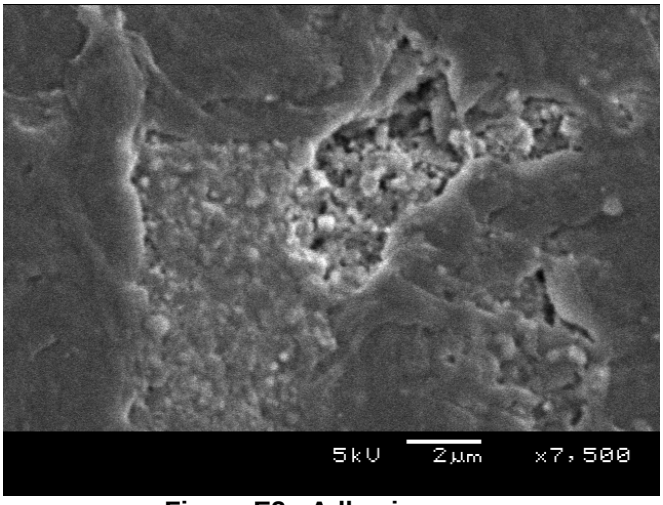


Figure E2: Adhesion wear

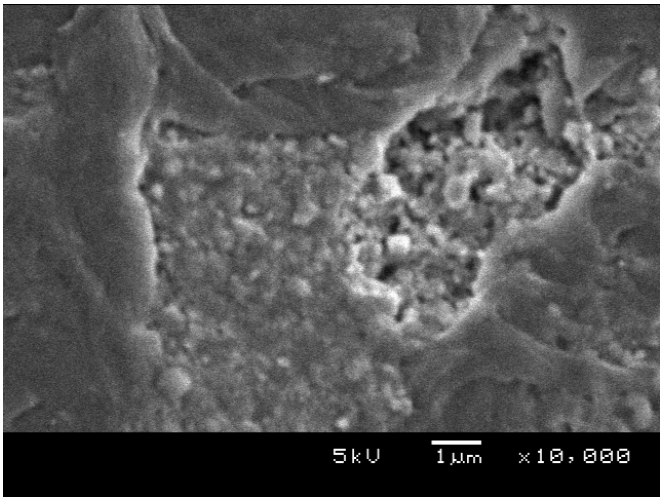


Figure E3: Adhesion wear

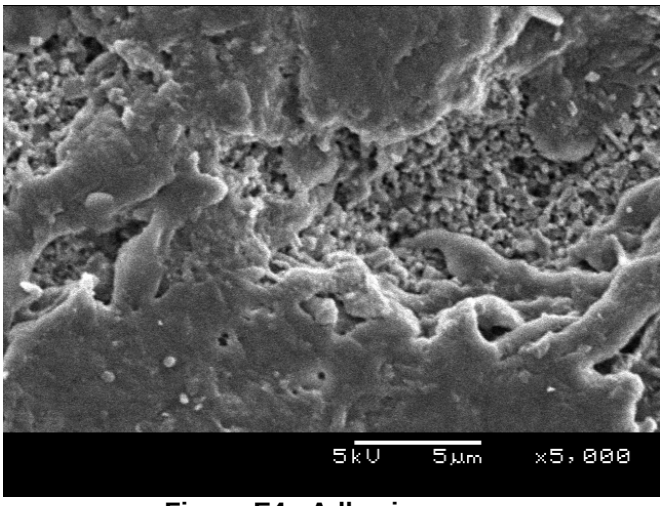


Figure E4: Adhesion wear

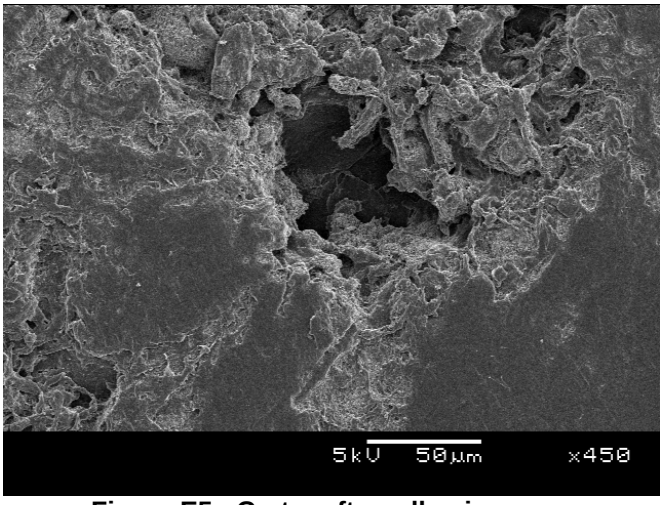


Figure E5: Crater after adhesion wear

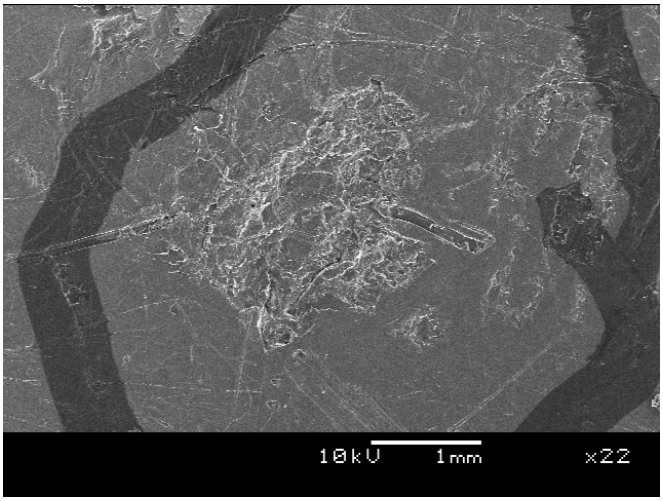


Figure E6: Patch with adhesion wear

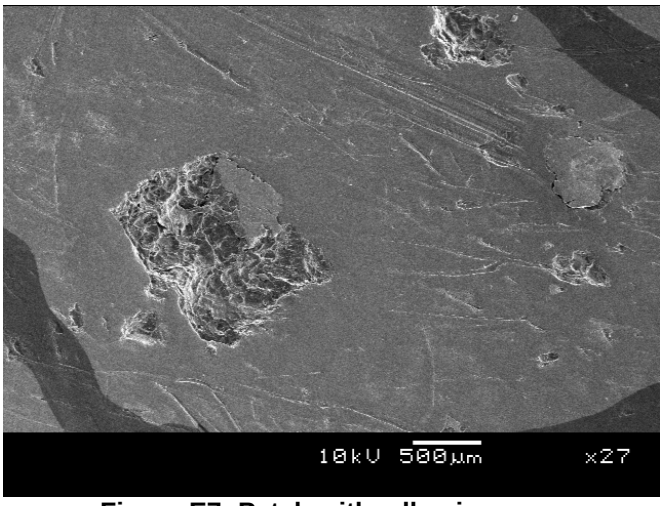


Figure E7: Patch with adhesion wear

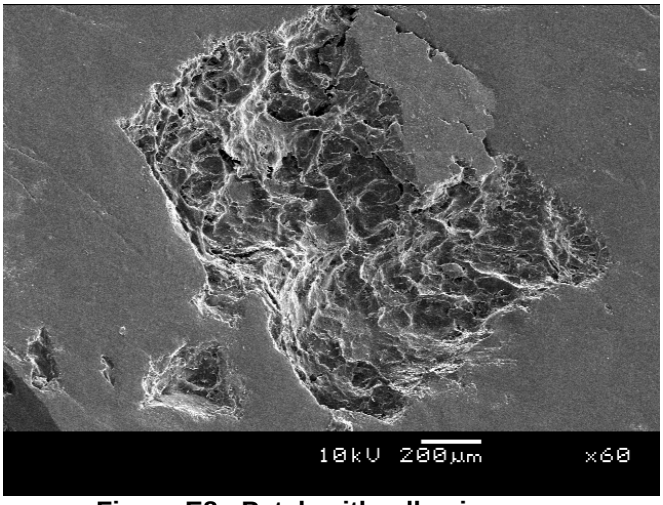


Figure E8: Patch with adhesion wear

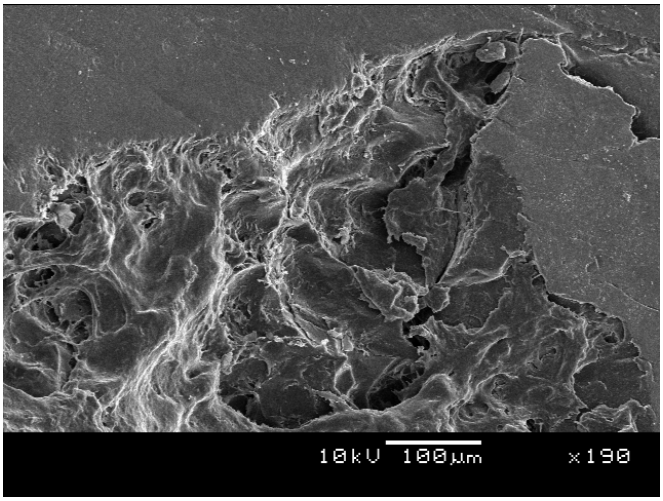


Figure E9: Patch with adhesion wear

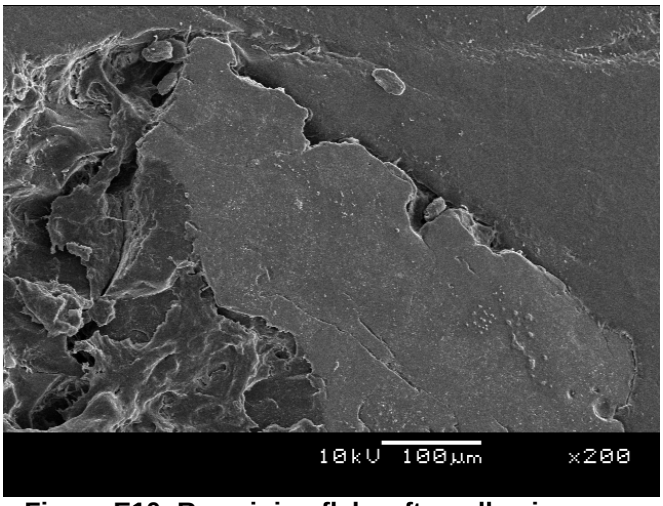


Figure E10: Remaining flake after adhesion wear

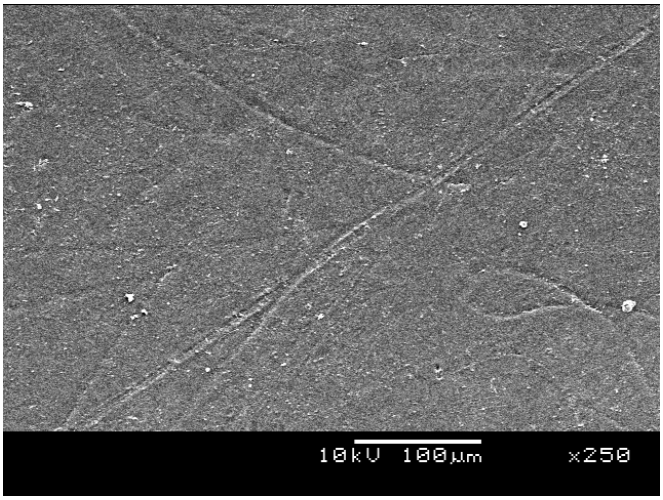


Figure E11: Scratches on bearing surfaces

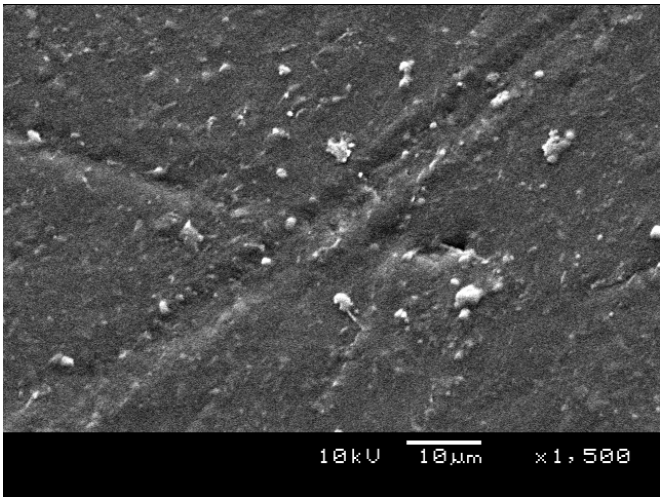


Figure E12: Scratches on bearing surfaces

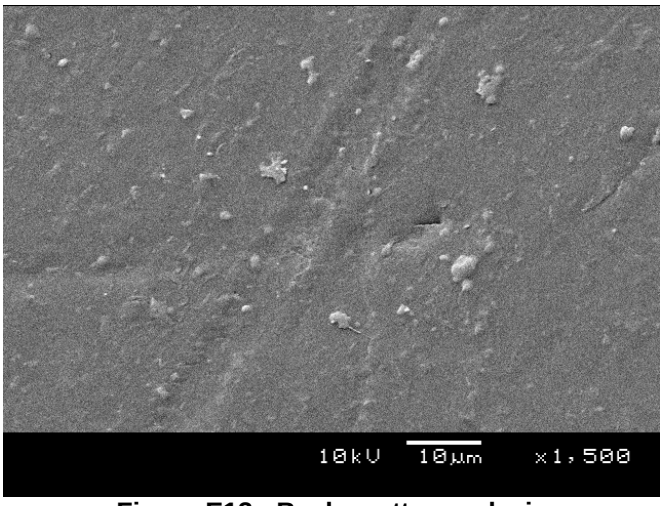


Figure E13: Back scatter analysis

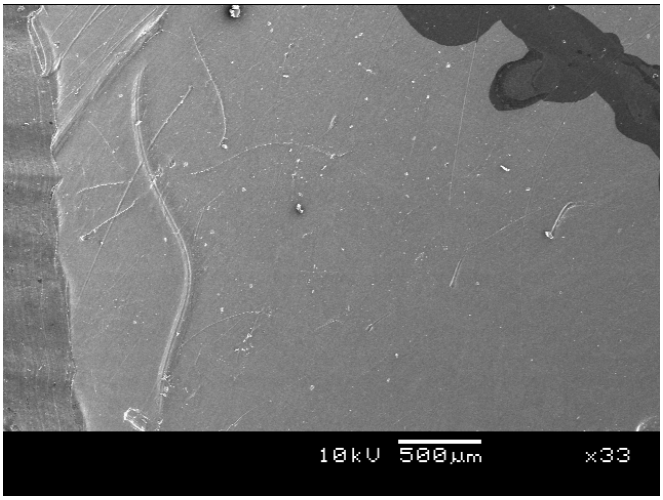


Figure E14: Scratches on bearing surfaces

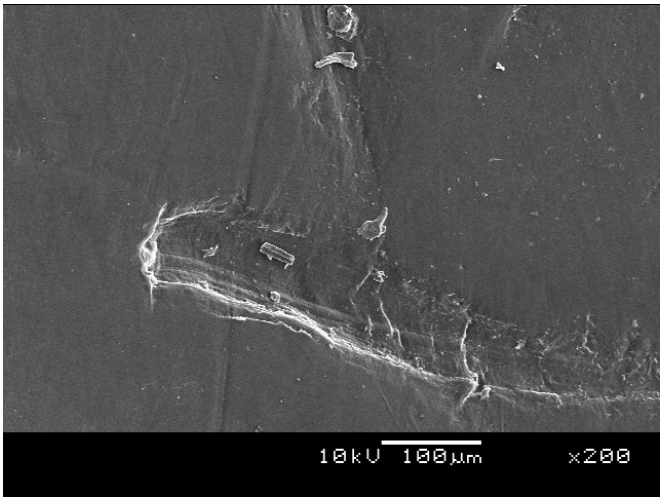


Figure E15: Scratches on bearing surfaces

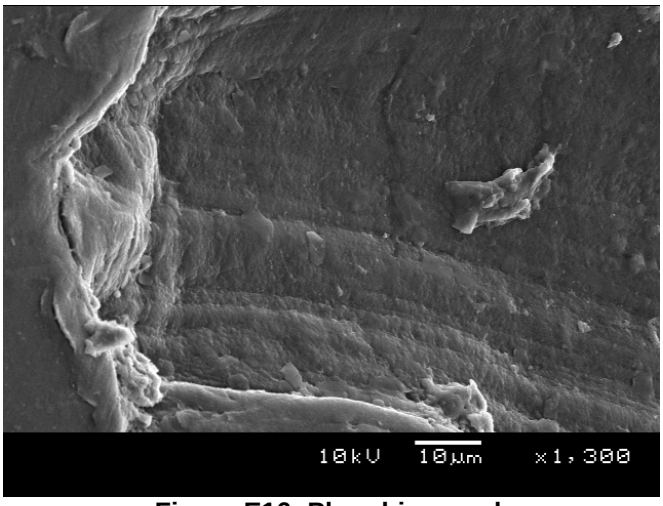


Figure E16: Ploughing mark

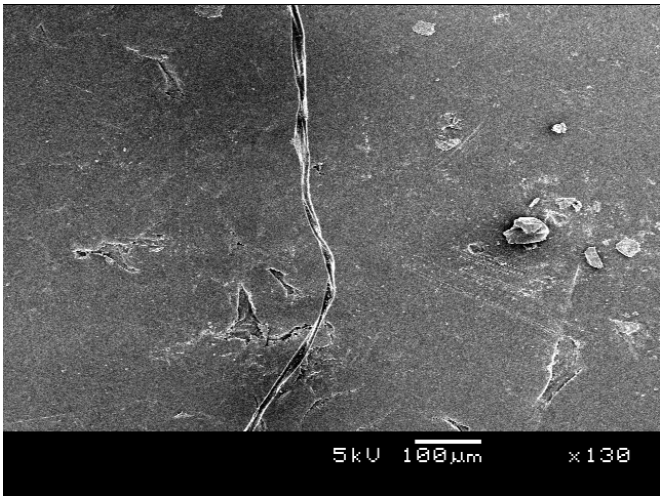


Figure E17: Scratch on bearing surface

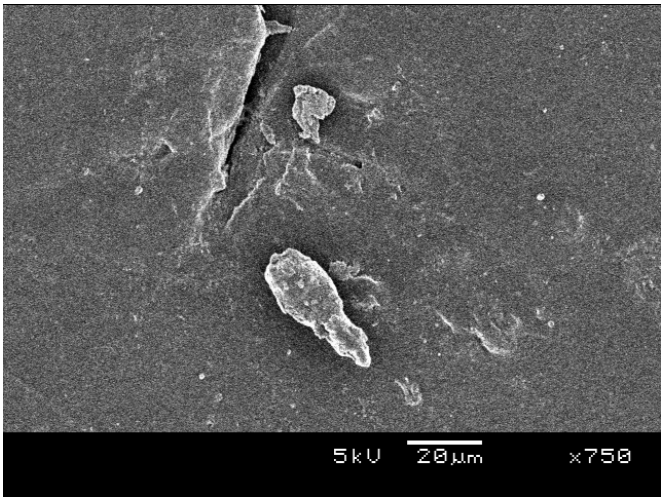


Figure E18: Wear particle

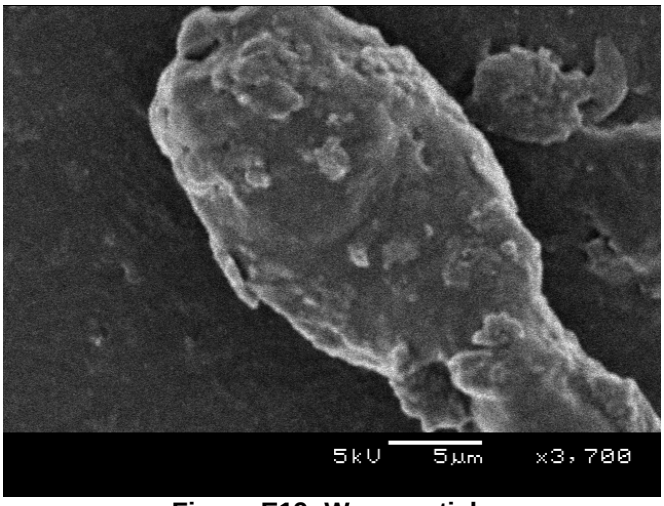


Figure E19: Wear particle

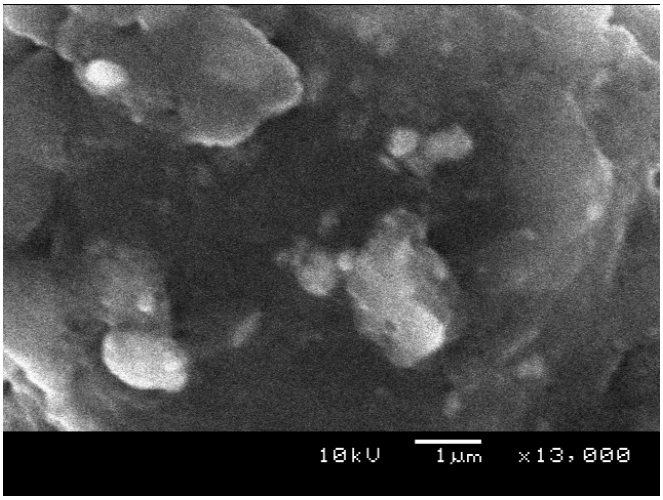


Figure E20: Wear particle

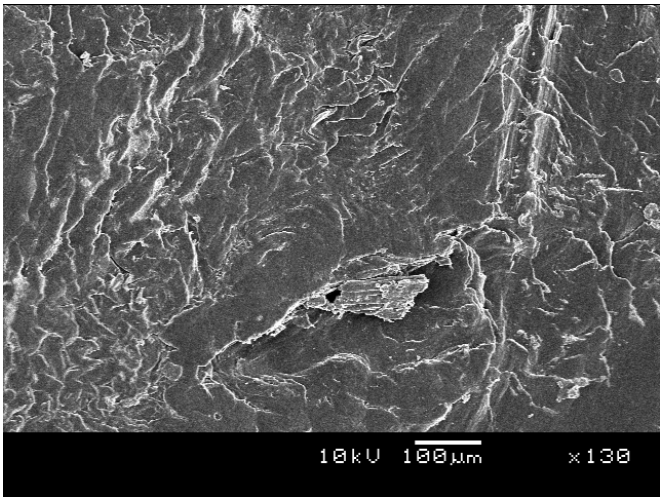


Figure E21: Plastic flow

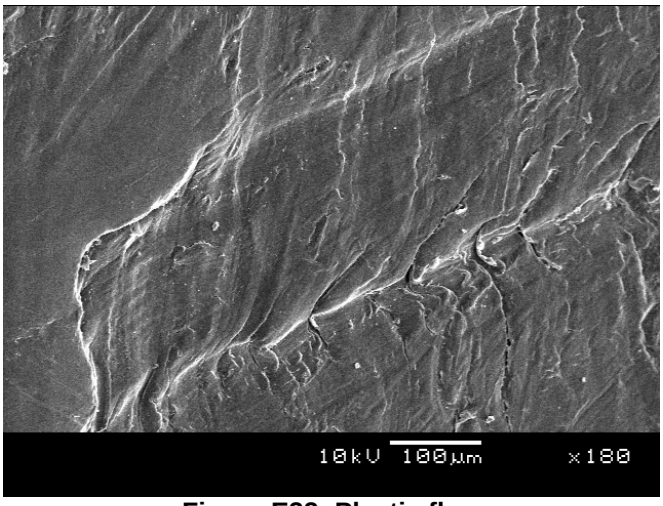


Figure E22: Plastic flow

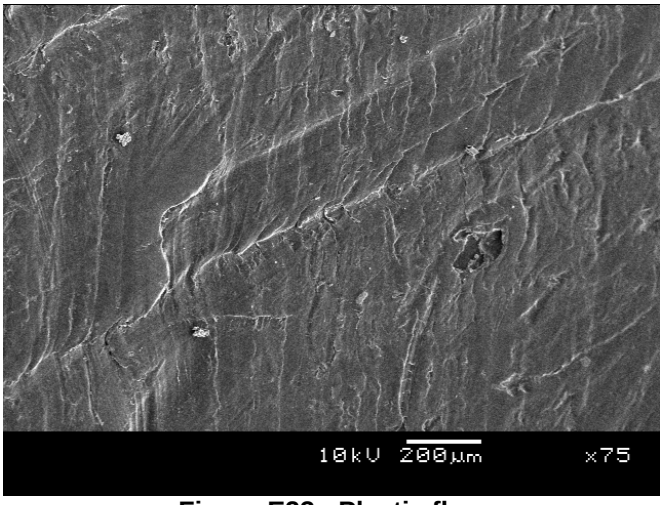


Figure E23: Plastic flow

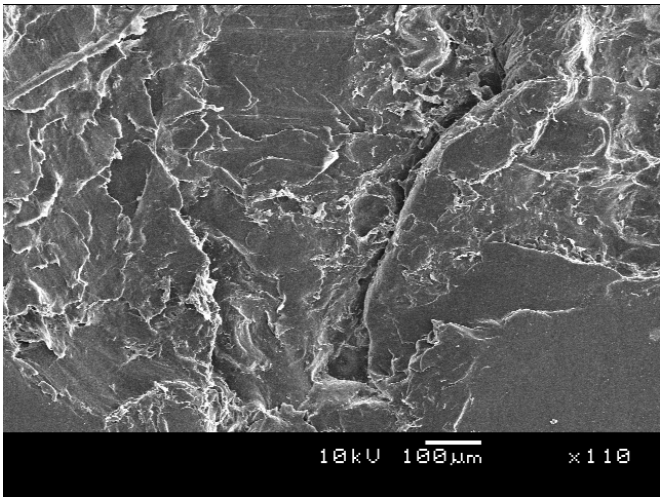


Figure E24: Crack after adhesion wear

ANNEXURE F

Electrophoresis analysis of particles retrieved from brown deposit in acetabular cups and synovial fluid

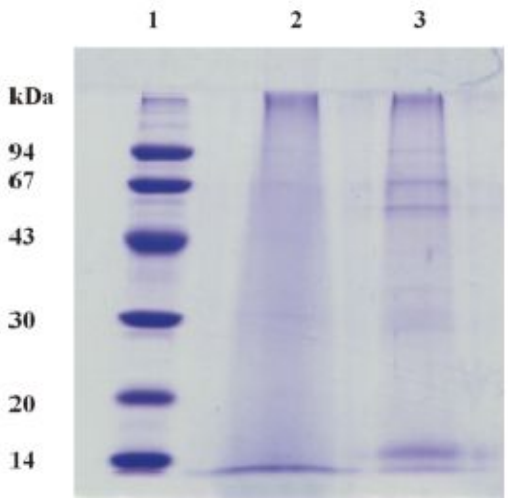


Figure F1: SDS-PAGE analysis of samples as trial study. Lane 1 is the molecular mass markers with mass indicated in kDa, on left hand side, line 2 and 3 is two different samples from different retrievals

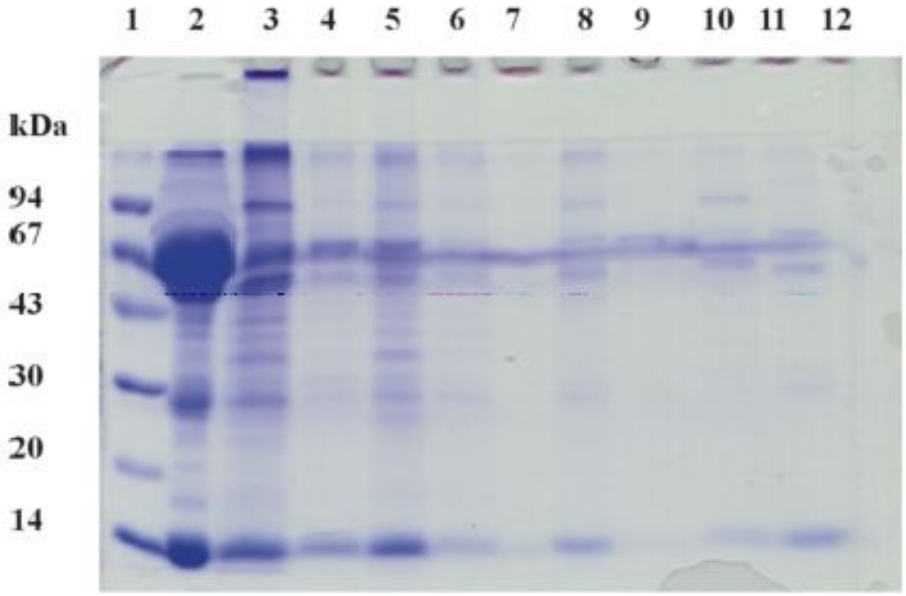


Figure F2: SDS-PAGE analysis of fresh retrievals. Lane 1 is the molecular mass indicated in kDa on left hand side. Lane 2 to 6 is a sample from a patient after 8 years in-vivo with lane 2 the synovial fluid. Lane 8 to 12 is a sample from patient after 4 years in-vivo

ANNEXURE G

Mass spectrometric analysis of particles retrieved from brown deposit in acetabular cups and synovial fluid

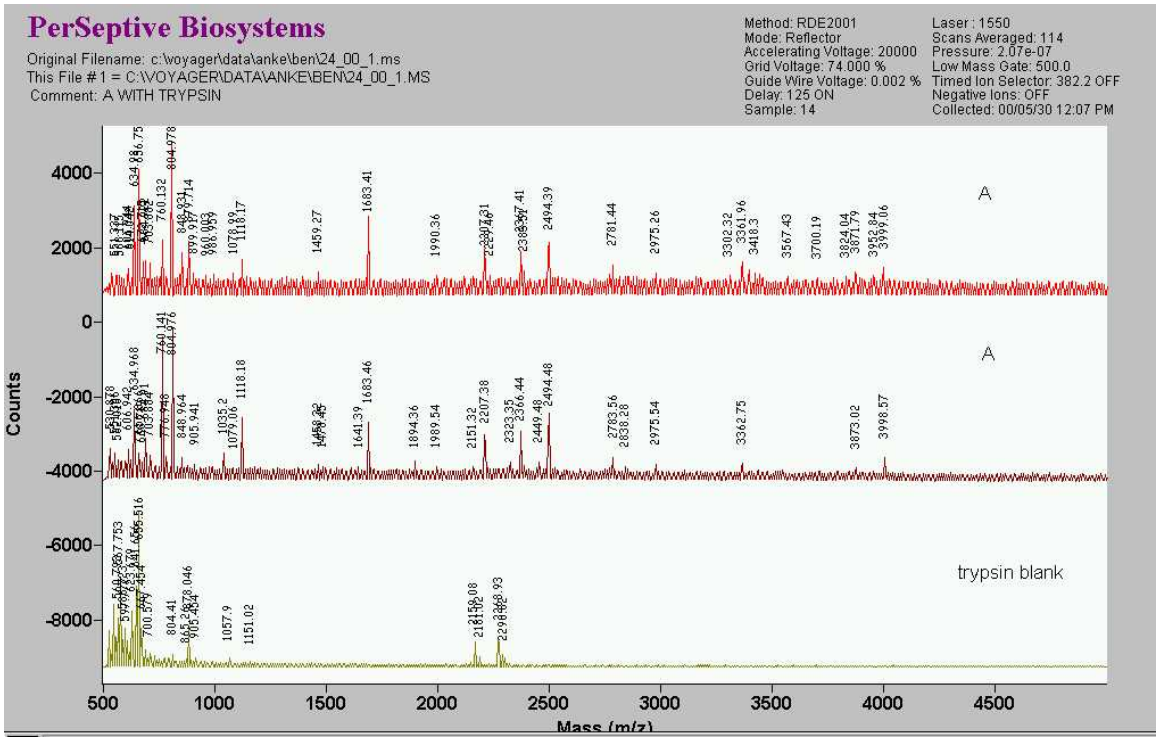


Figure G1

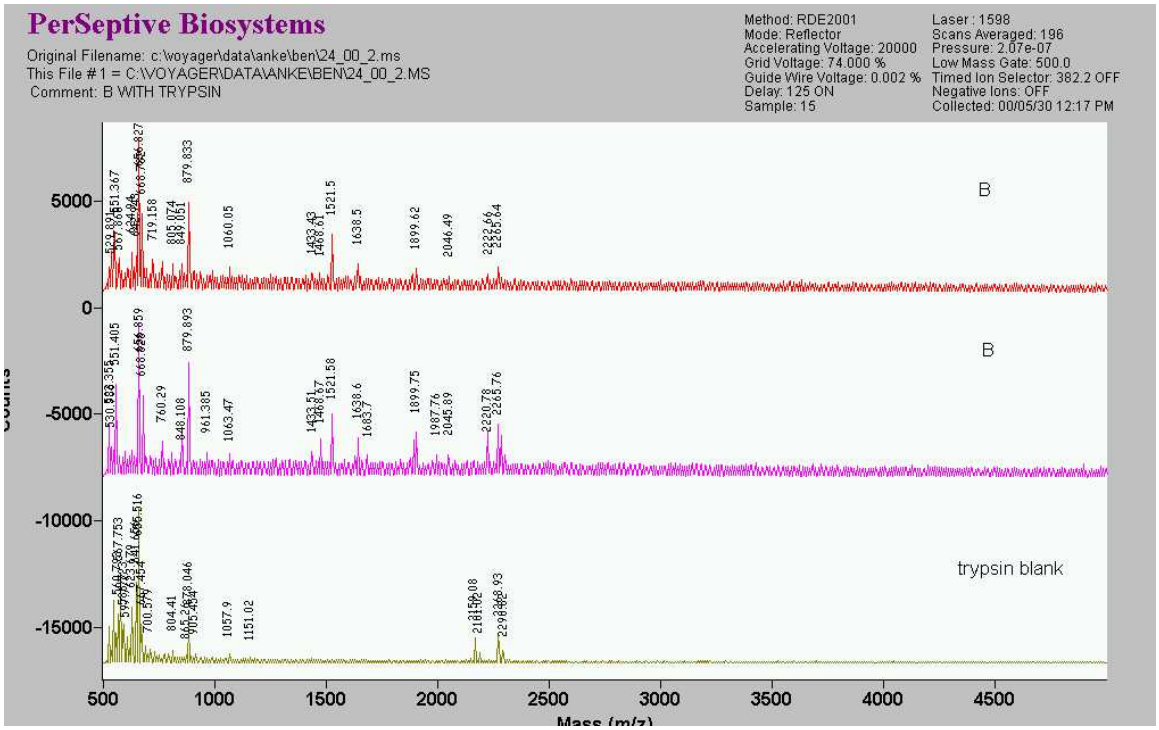


Figure G2

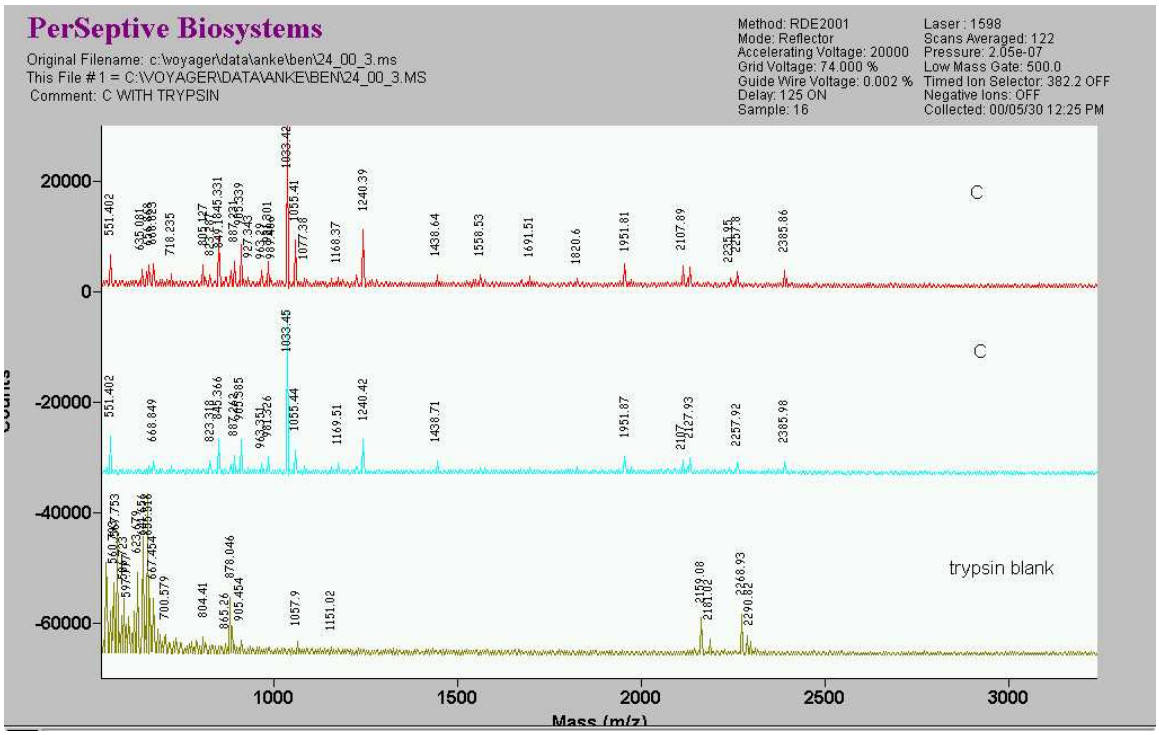


Figure G3

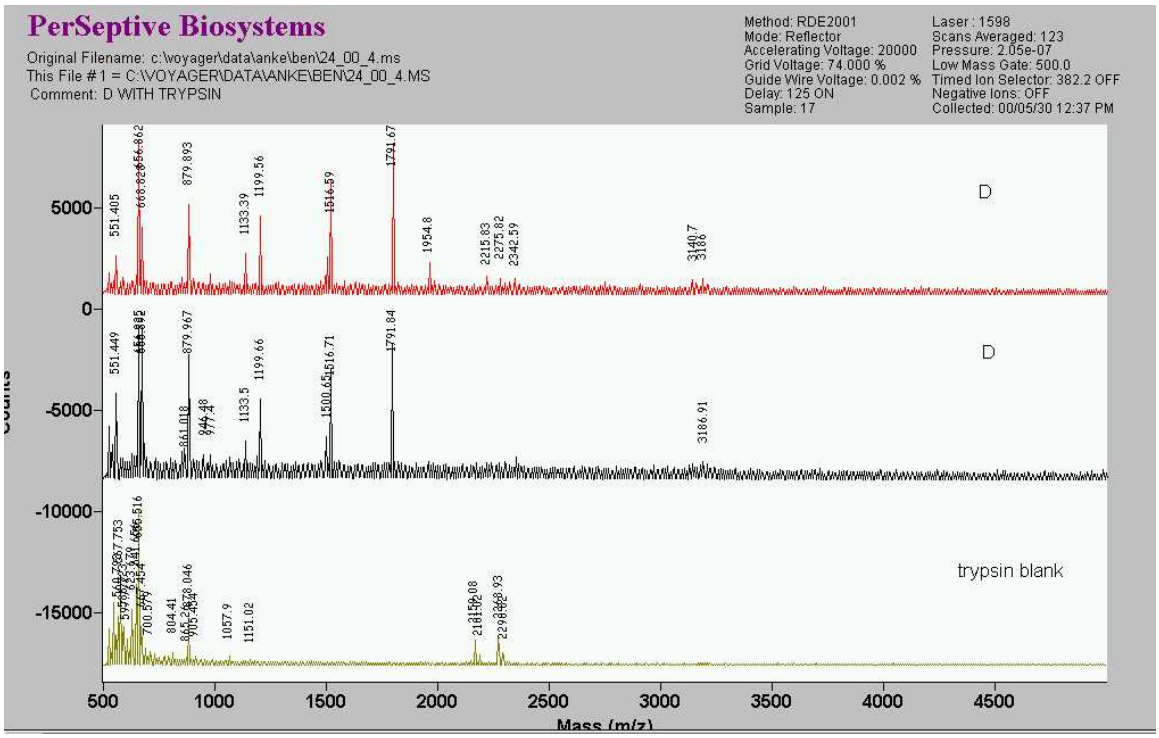


Figure G4

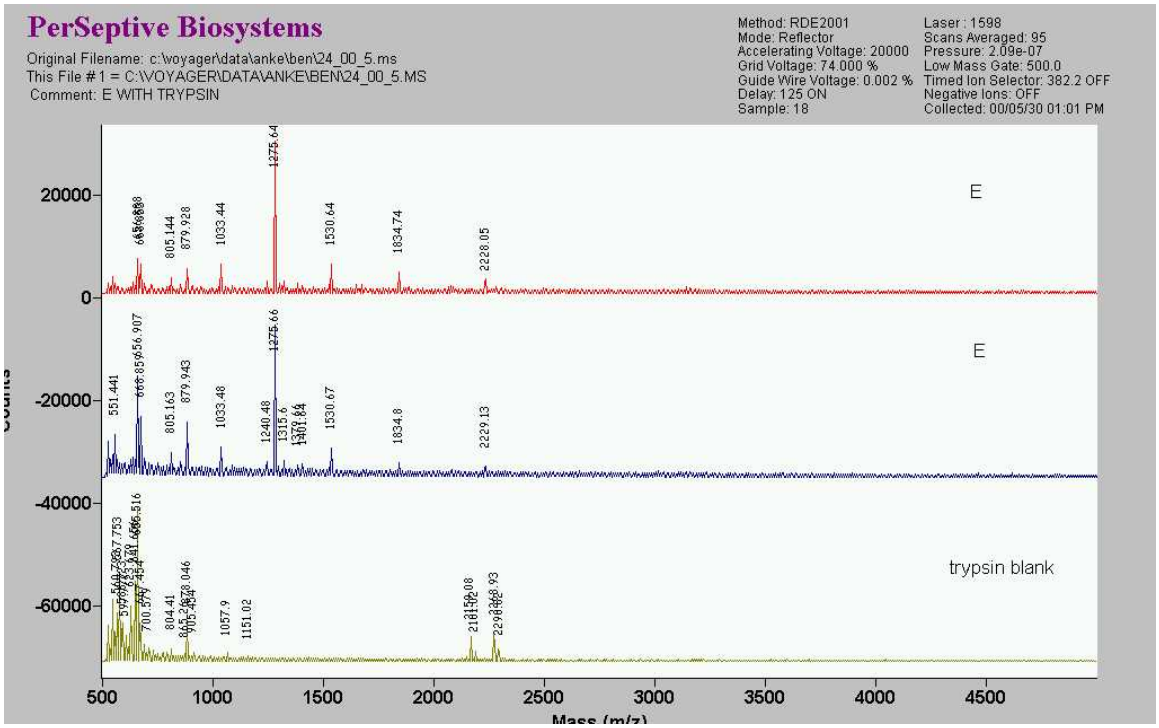

PerSeptive Biosystems
Original Filename: c:\voyager\data\anke\ben\24_00_5.ms
This File #1 = C:\VOYAGER\DATA\ANKE\BEN\24_00_5.MS
Comment: E WITH TRYPSIN
Method: RDE2001
Mode: Reflector
Accelerating Voltage: 20000
Grid Voltage: 74.000 %
Guide Wire Voltage: 0.002 %
Delay: 125 ON
Sample: 18
Laser: 1598
Scans Averaged: 95
Pressure: 2.09e-07
Low Mass Gate: 500.0
Timed Ion Selector: 382.2 OFF
Negative Ions: OFF
Collected: 00/05/30 01:01 PM
E
E
trypsin blank
20000
0
-20000
-40000
-60000
500
1000
1500
2000
2500
3000
3500
4000
4500

Figure G5

ANNEXURE H

Lubricity analysis of retrieved synovial fluid

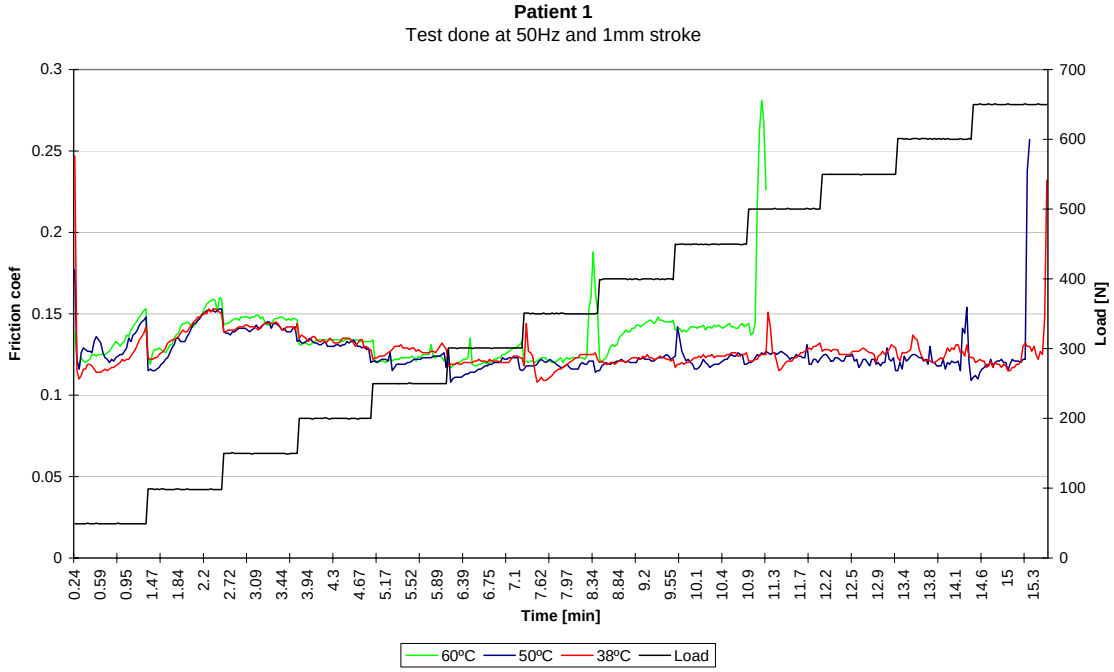


Figure H1

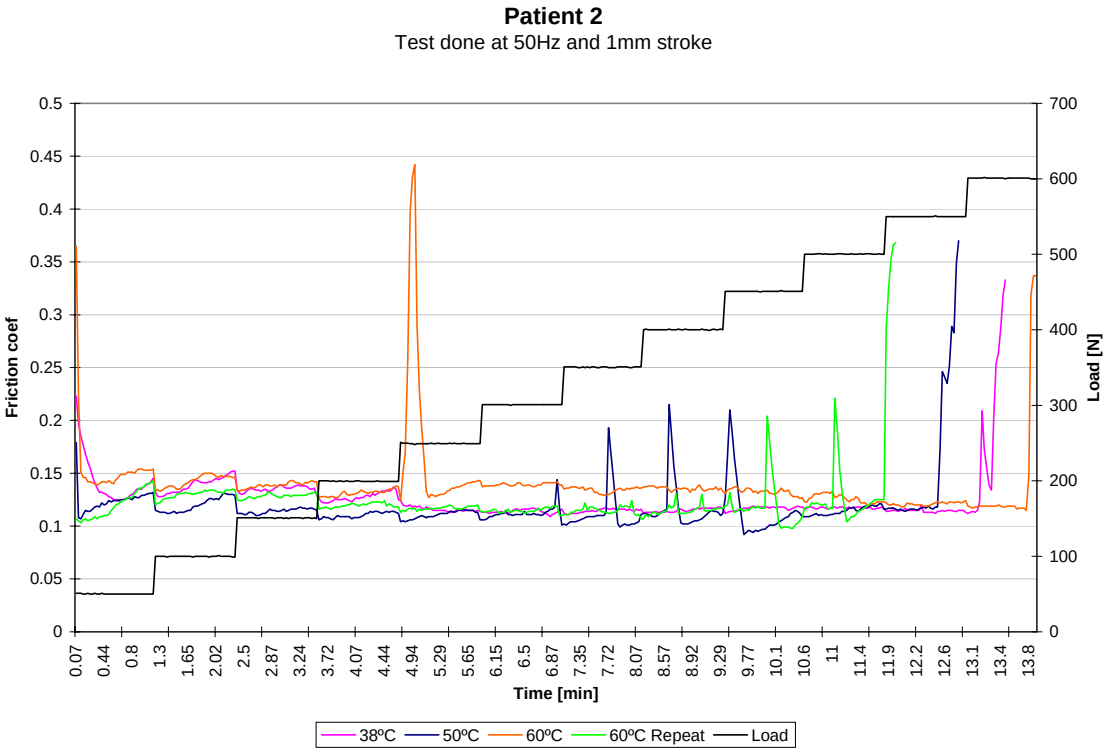


Figure H2

Patient 3
Test done at 50Hz and 1mm stroke

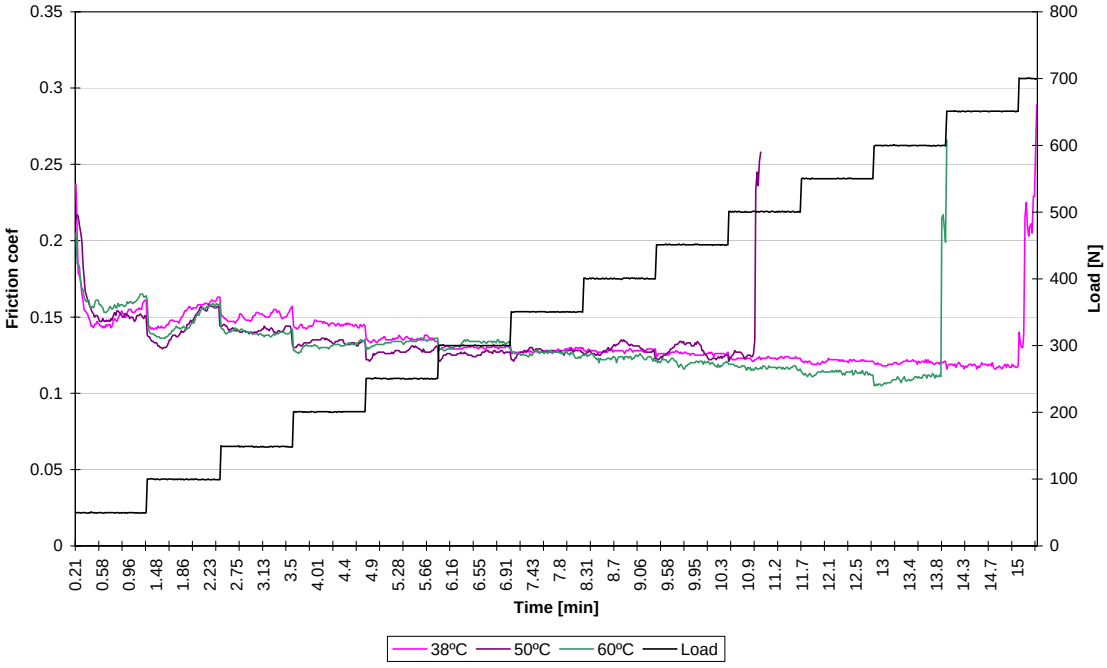


Figure H3

Patient 4
Test done at 50Hz and 1mm stroke

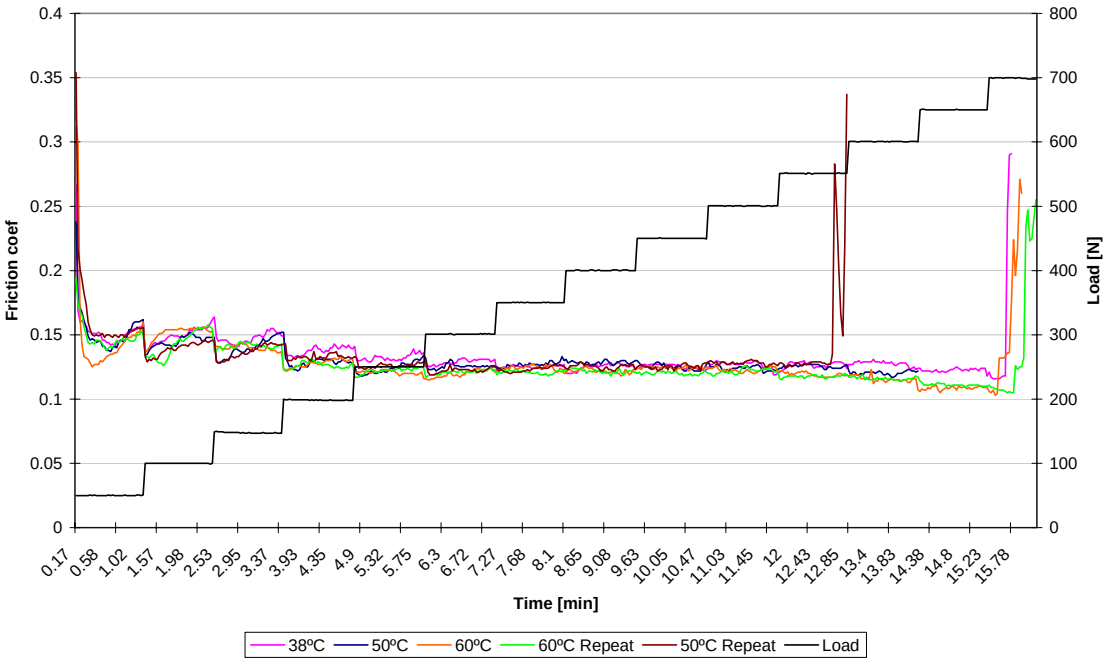


Figure H4

Patient 5
Test done at 50Hz and 1mm stroke

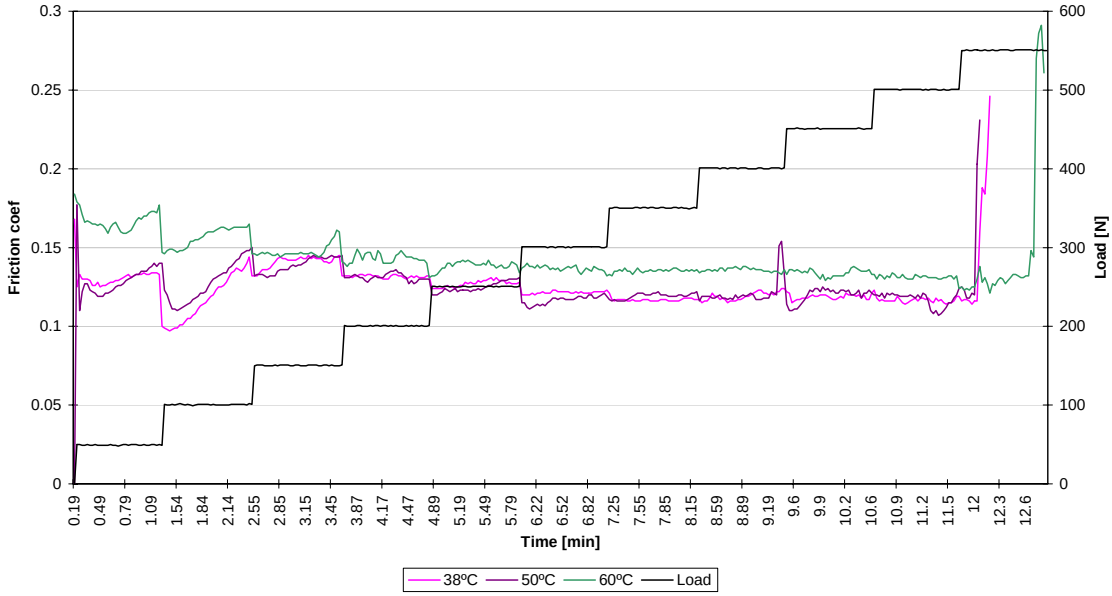


Figure H5

Patient 6
Test done at 50Hz and 1mm stroke

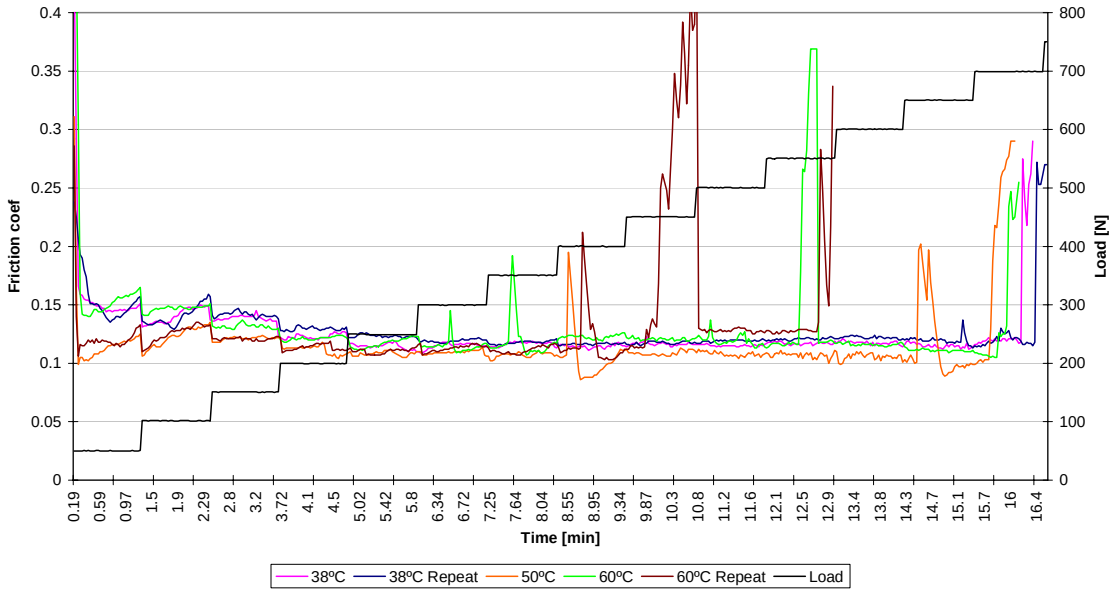


Figure H6

Patient 7
Test done at 50Hz and 1mm stroke

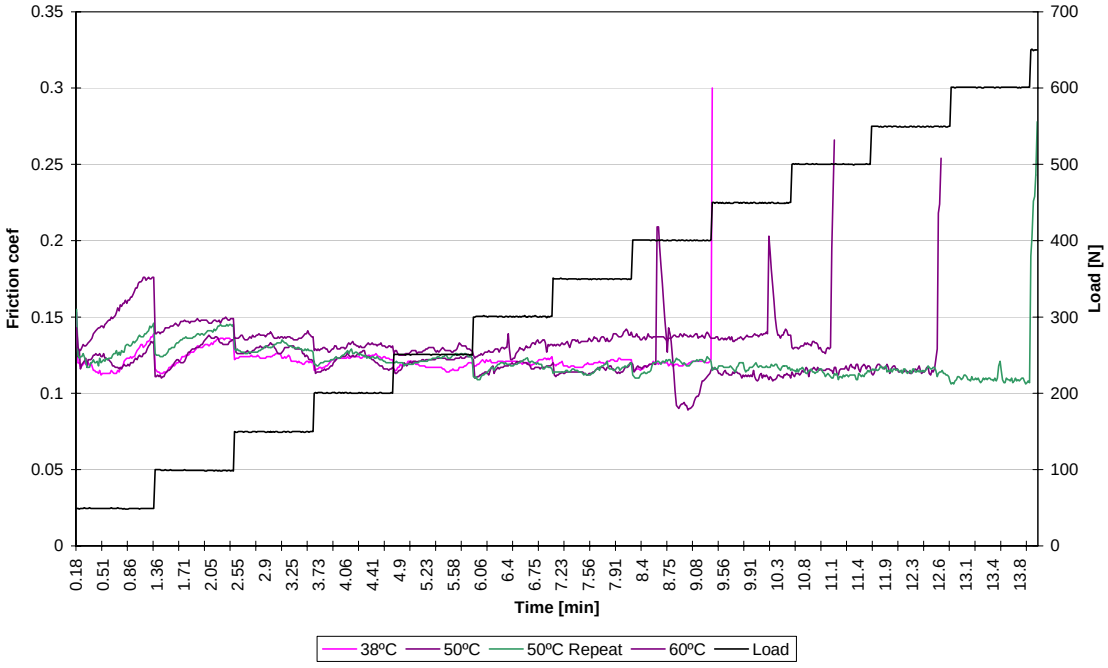


Figure H7

Patient 8
Test done at 50Hz and 1mm stroke

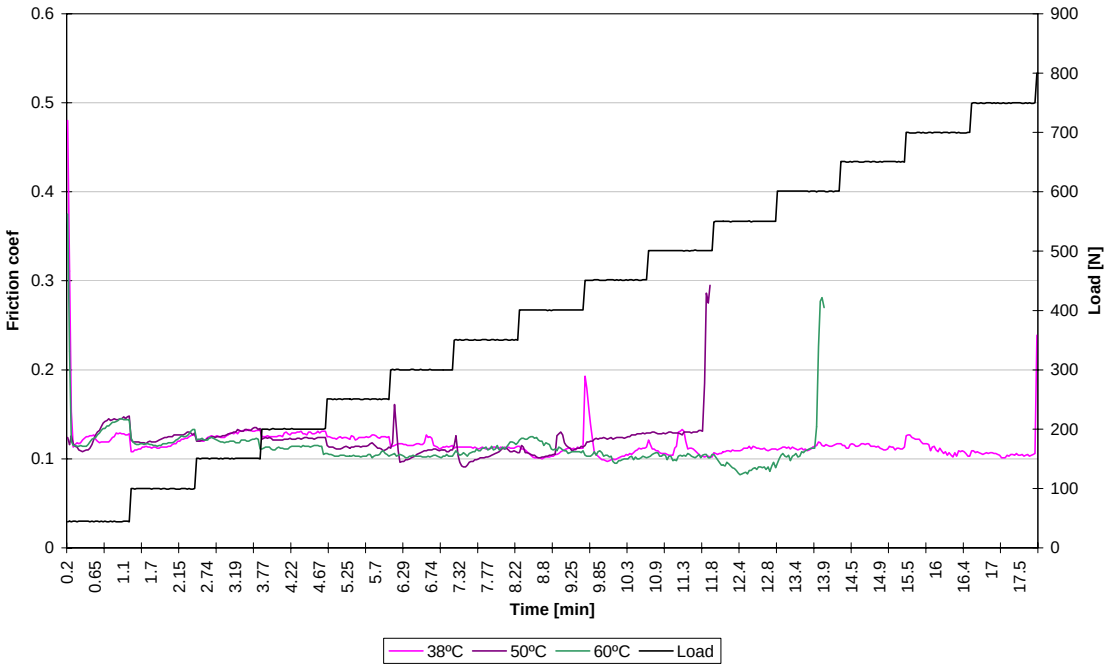


Figure H8

Patient 9
Test done at 50Hz and 1mm stroke

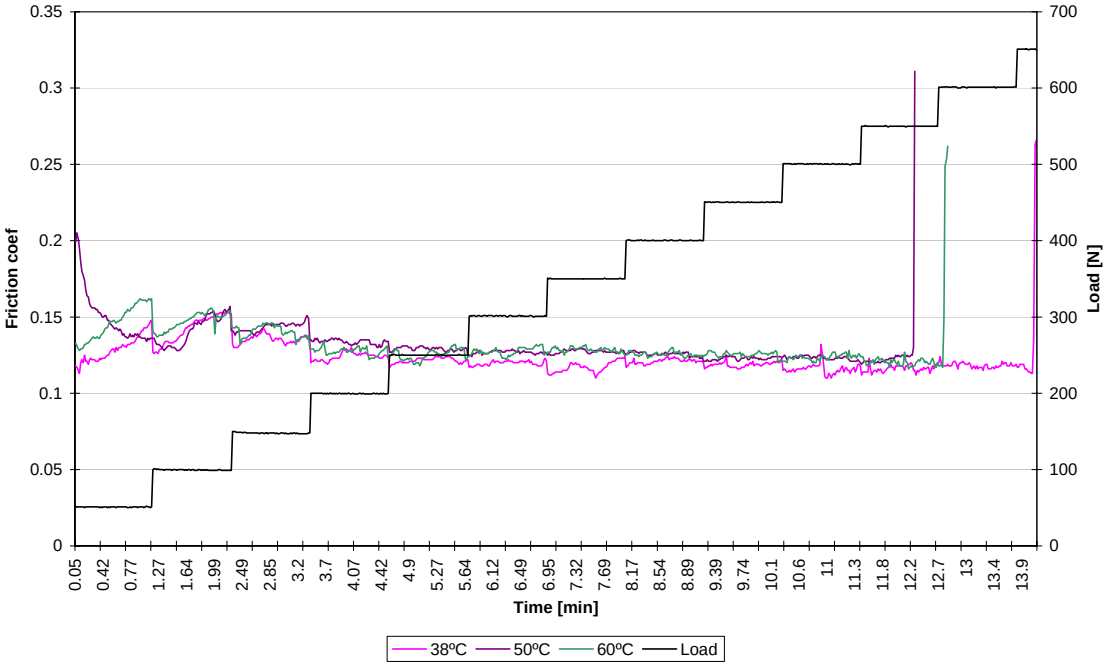


Figure H9

Patient 10
Test done at 50Hz and 1mm stroke

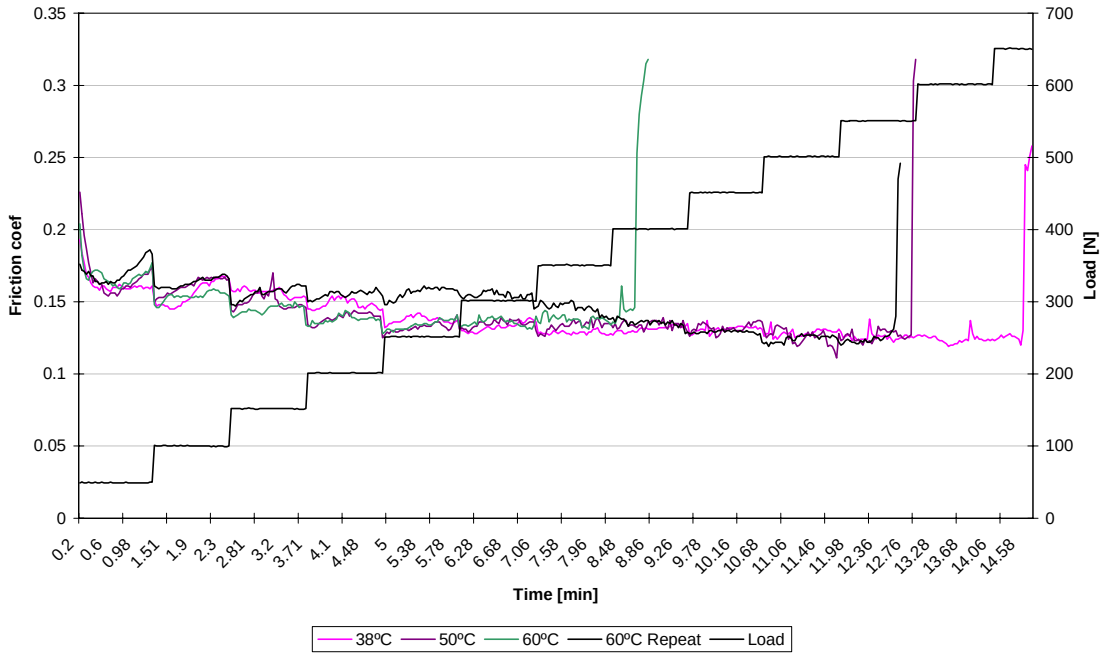


Figure H10

Patient 11
Test done at 50Hz and 1mm stroke

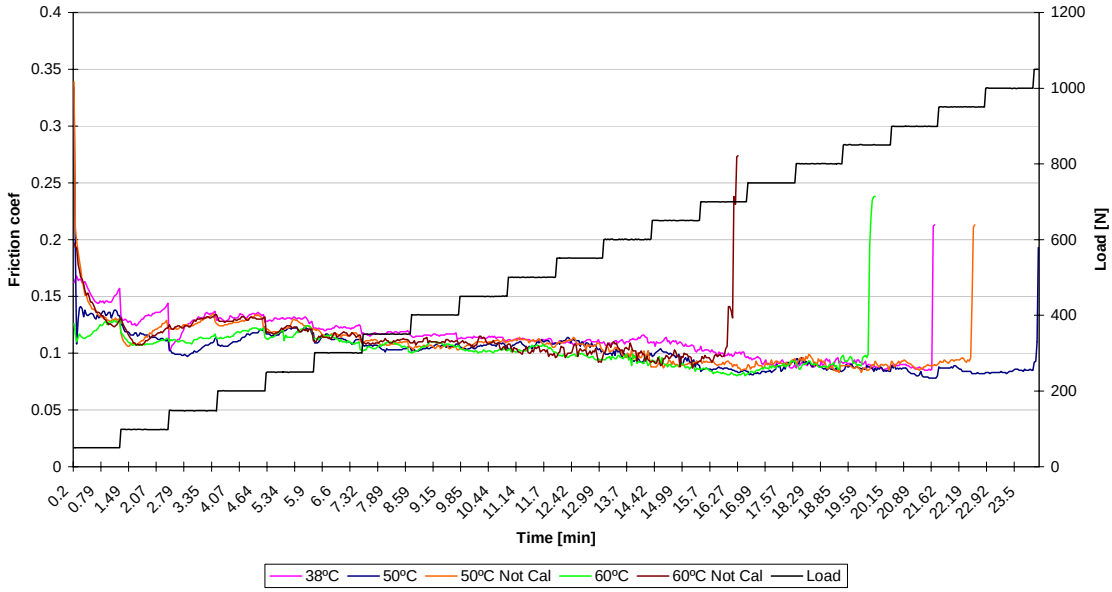


Figure H11

Patient 12
Test done at 50Hz and 1mm stroke

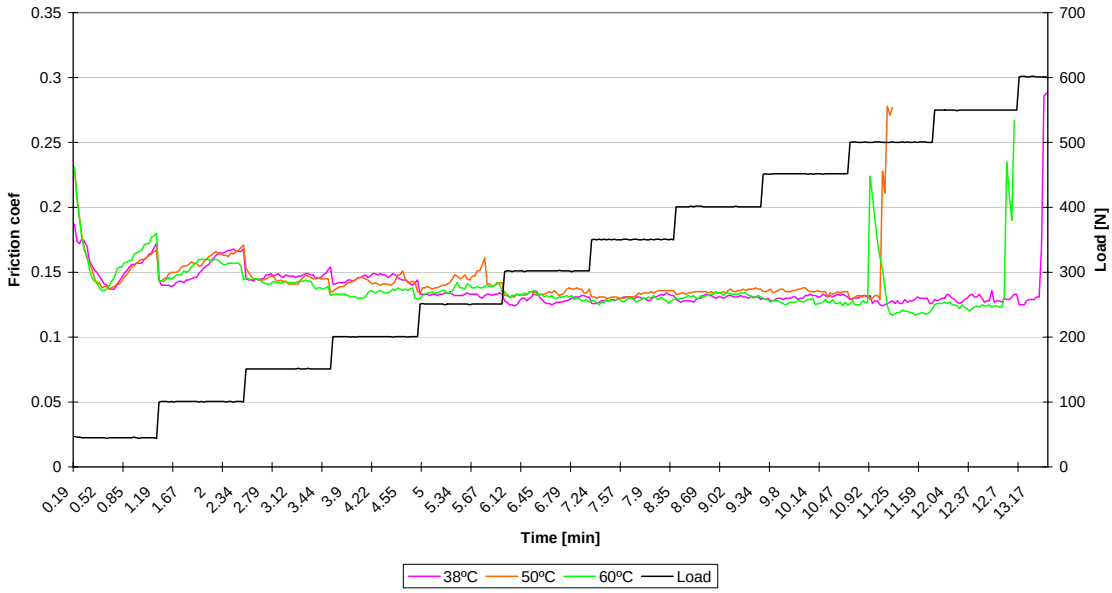


Figure H12