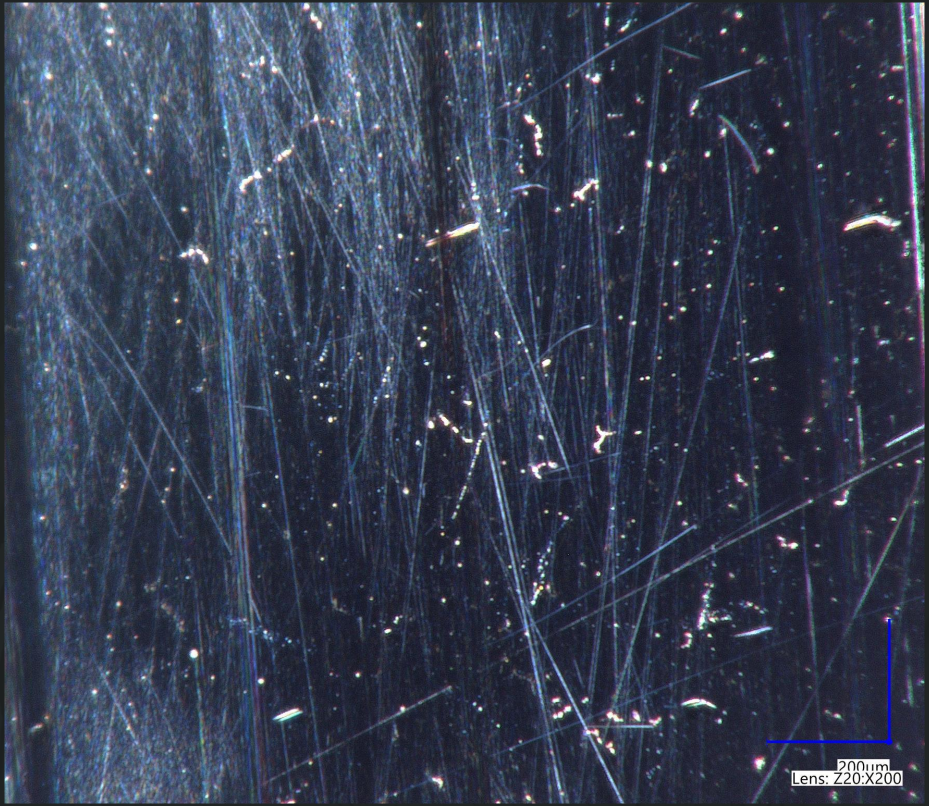

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Quantification of Wear of Total Knee Arthroplasty Femoral Components using Contact and Non-Contact Profilometry

Taber Ball, B.S.
JVL Orthopaedic Research Center

Background: TKA Wear

- Total knee arthroplasty (TKA) is well established and widely used to treat various knee issues including injury and arthritis [1]
- The number of TKAs performed each year is projected to continue increasing significantly over the next decade, and they are becoming increasingly common for younger patients [2]
- With the increase in demand, durability is essential
- Durability is primarily associated with the wear of the polyethylene (PE) tibial component, but third body abrasion can impact the metal femoral component and accelerate this process [3-5]

Background: Metal Sensitivity

- Metal sensitivity occurs when a patient has an allergy to the metal used in orthopaedic implants
- It is estimated that 10-15% of the population and 25-60% of patients with well functioning hip and knee replacements are sensitive to metal [6]
- There are currently no objective measures to diagnose or predict outcomes for patients with metal sensitivity [7]
- Better understanding the wear patterns and metal loss of TKAs is necessary to inform clinical decisions about durability and metal sensitivity

Background: Profilometry Methods

- Contact profilometry uses a stylus and diamond pin to trace the contours of a surface
- This is the most commonly used method for orthopaedic studies [8]
- Contact profilometry measurements are affected by the radius of the stylus, applied pressure, and material hardness [9]
- In contrast, non-contact profilometers use light in place of a stylus and are therefore able to measure smaller surface fluctuations [10]
- Few orthopaedic studies have utilized non-contact profilometry via high-resolution microscopes for surface roughness characterization [9,11,12]
- Study results suggest that non-contact profilometry is a promising new method for orthopaedic research, but there has yet to be a direct comparison between contact and non-contact values

Study Aims

01 Directly compare and validate contact vs non-contact profilometry methods.

02 Quantitatively characterize the surface roughness of retrieved TKA femoral components.

Methods: Damage Assessment

- n = 20 retrieved femoral components were selected for the study
- Component divided into six sections based on degrees of flexion (Figure 1)
- Each zone was assessed and scored for grooving, indentations, gouging, and retrieval damage on a scale from 0-1
- Area scores were then evaluated for each form of damage across each zone

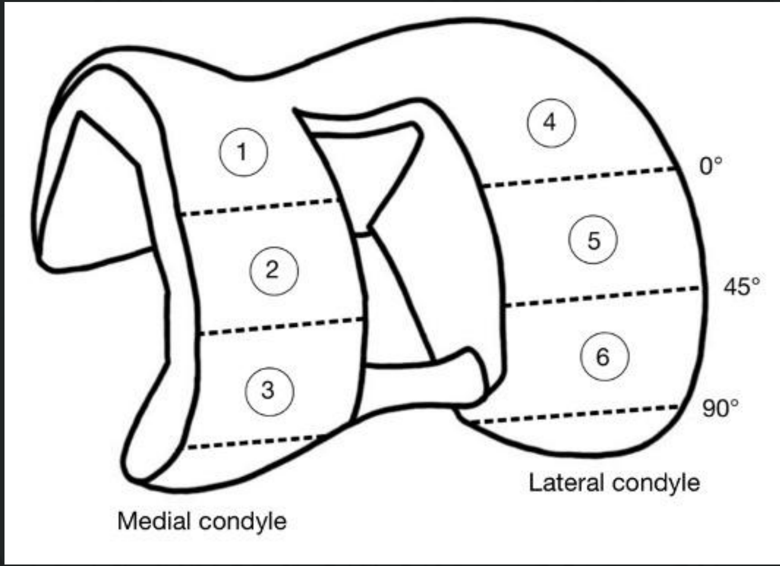

Figure 1. Zonation of Femoral Component based on degrees of flexion.

Methods: Contact Profilometry

- Three 1.0 mm traces were made at each flexion zone (0º, 45º, 90º)
- Measurements were taken in areas without extraction damage
- Total of n=18 traces per component
- Surface roughness parameters (Ra, Rz, Rp) were recorded for each trace
  - Ra = mean roughness
  - Rz = roughness depth
  - Rp = leveling depth
- Parameters were averaged per zone, per side, and per component

Figure 2. Contact profilometer used for surface roughness measurements..

Methods: Non-Contact Profilometry

- Three measurements were taken at each flexion zone (0º, 45º, 90º)
- Measurements were taken in areas without extraction damage
- Total of n=18 measurements per component
- Surface roughness parameters (Ra, Rz, Rp) were recorded for each trace
- Each parameter was averaged per zone, per side, and per component

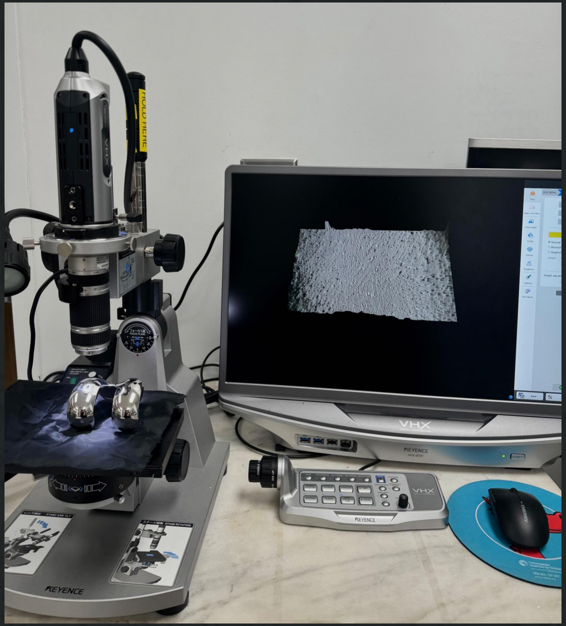

Figure 3. High resolution digital microscope used for non-contact surface roughness measurements..

Results

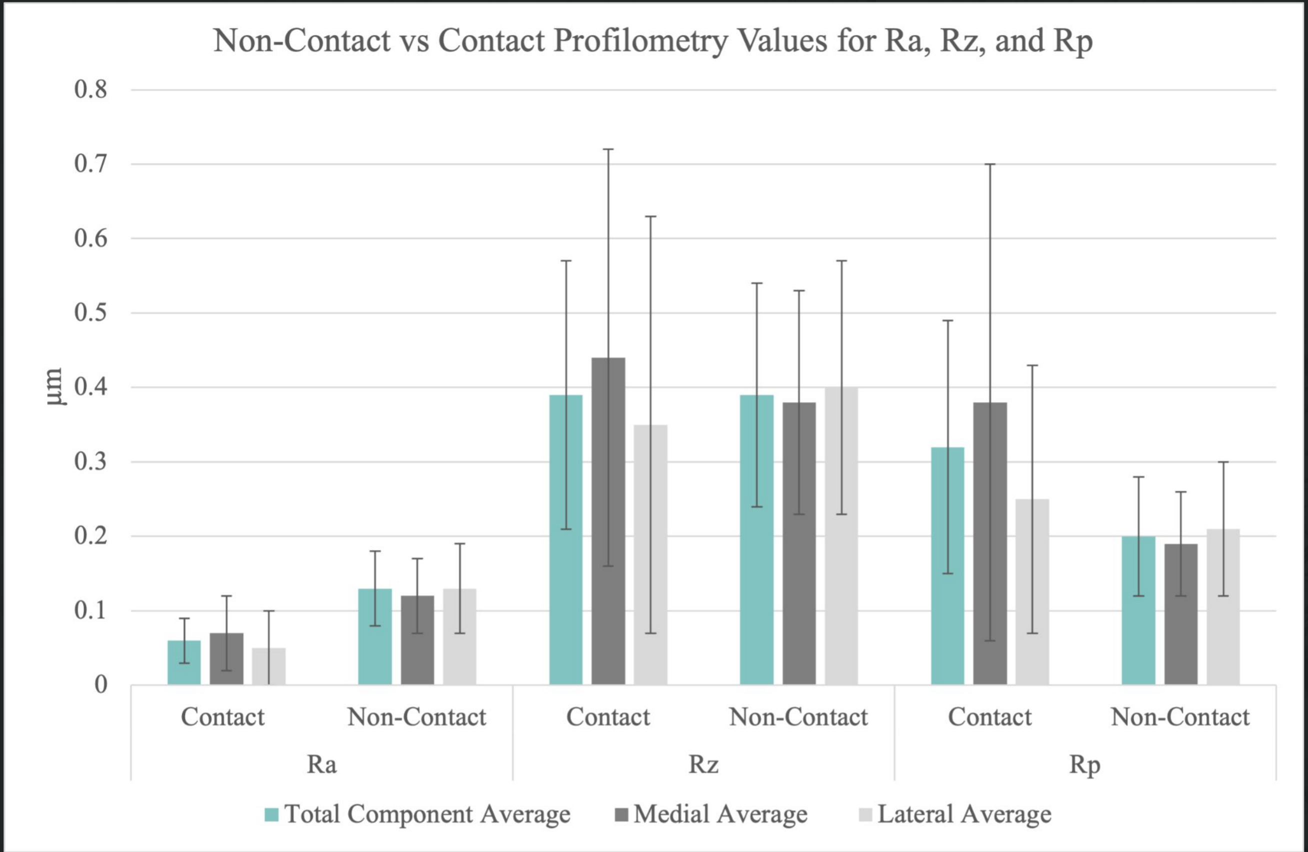

Figure 4.

Contact and non-contact profilometry values for Ra, Rz, and Rp measurements across total component averages, medial averages, and lateral averages.

Results

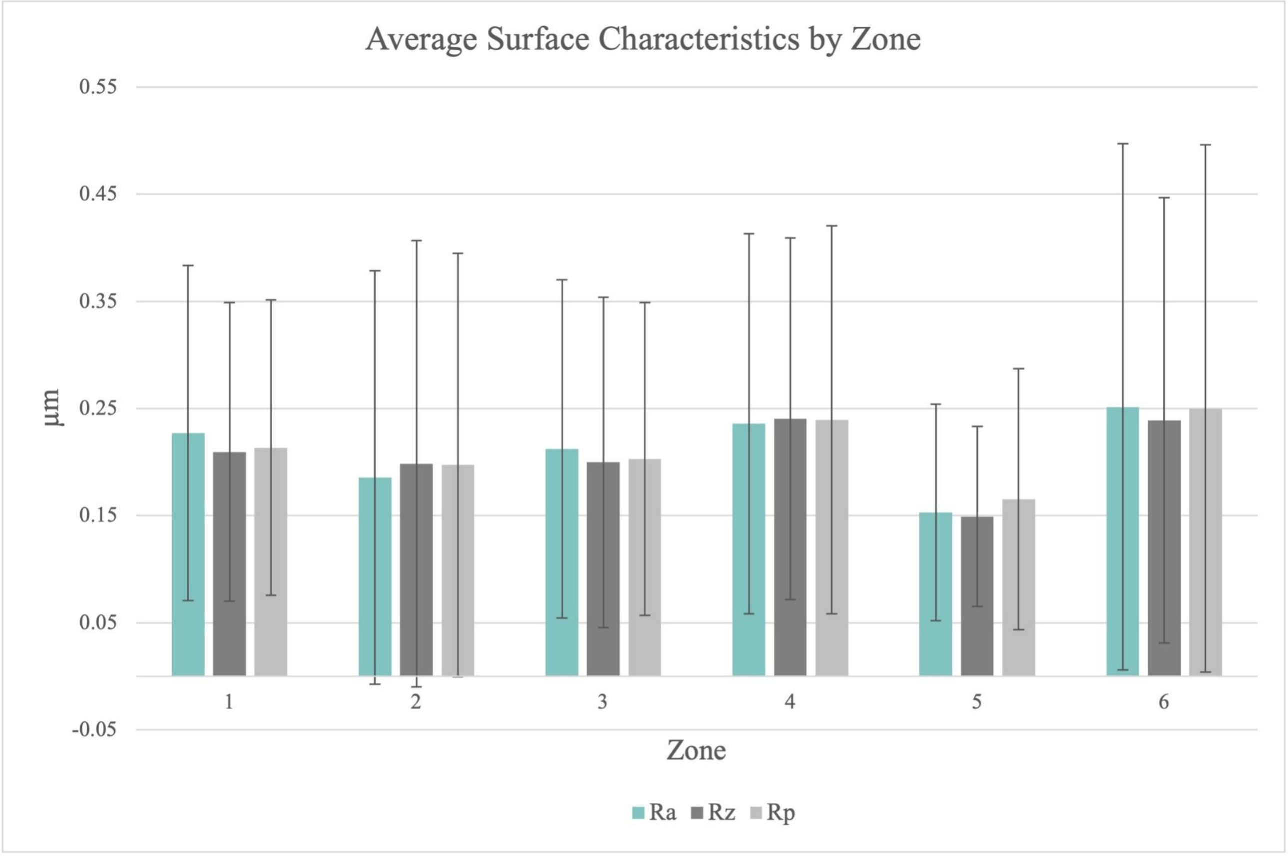

Figure 5.

Average Ra, Rz, and Rp for each wear zone. Values measured using non-contact profilometry.

Results

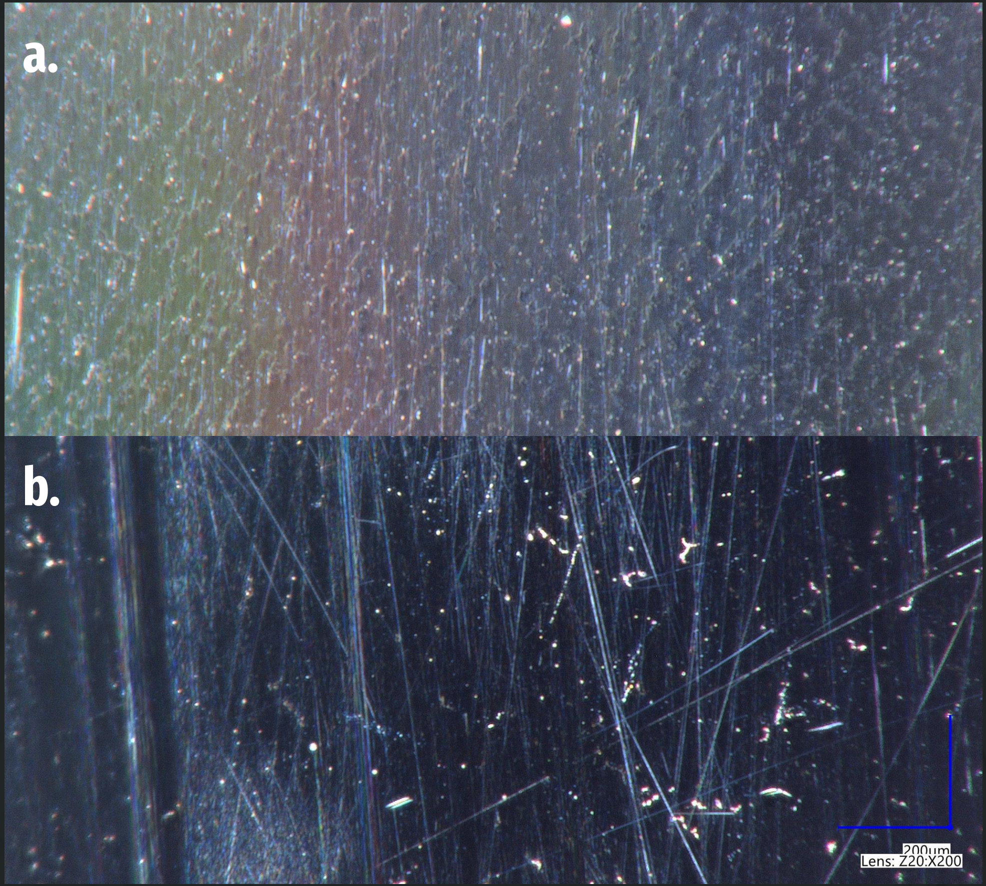

Figure 6.

a) High resolution microscopy image of a new, never implanted femoral component

b) High resolution microscopy image of a retrieved femoral component

Results

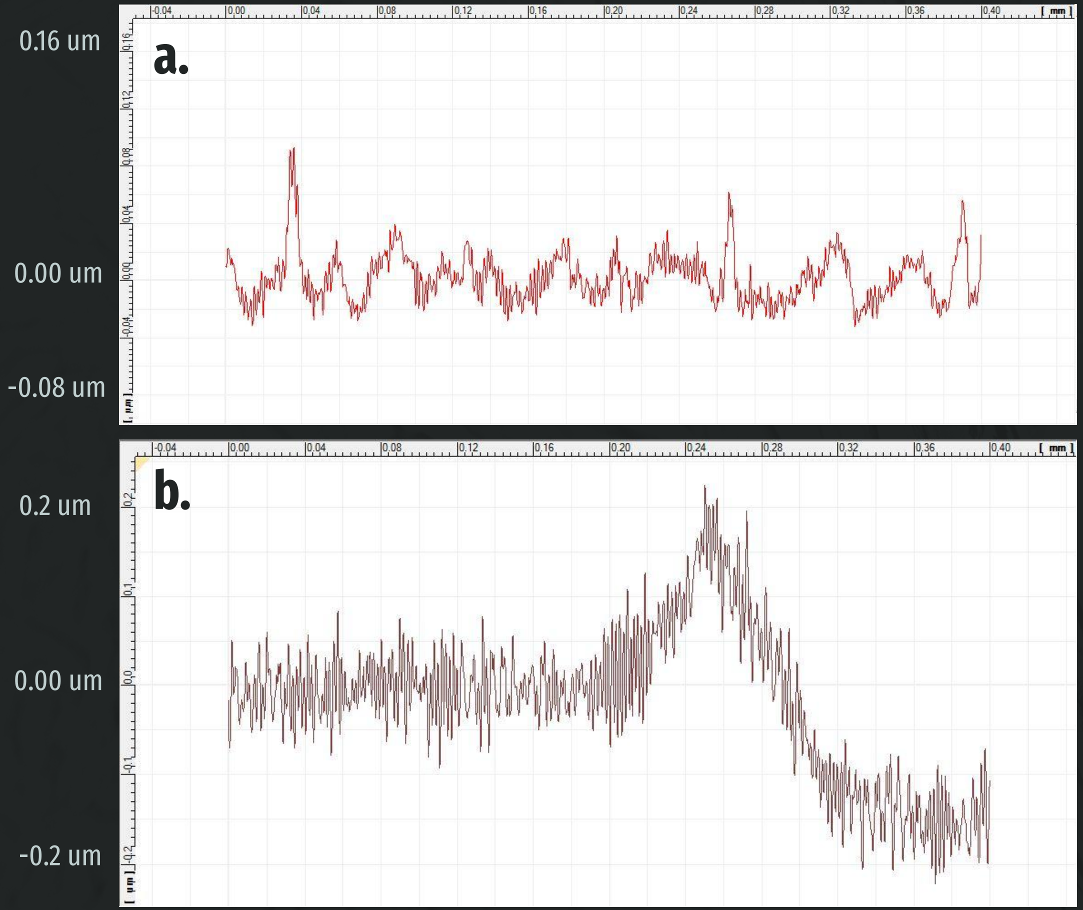

Figure 7.

a) Contact profilometry trace of new, never implanted femoral component (Ra = 0.0137)

b) Contact profilometry trace of retrieved femoral component (Ra = 0.0642)

Results

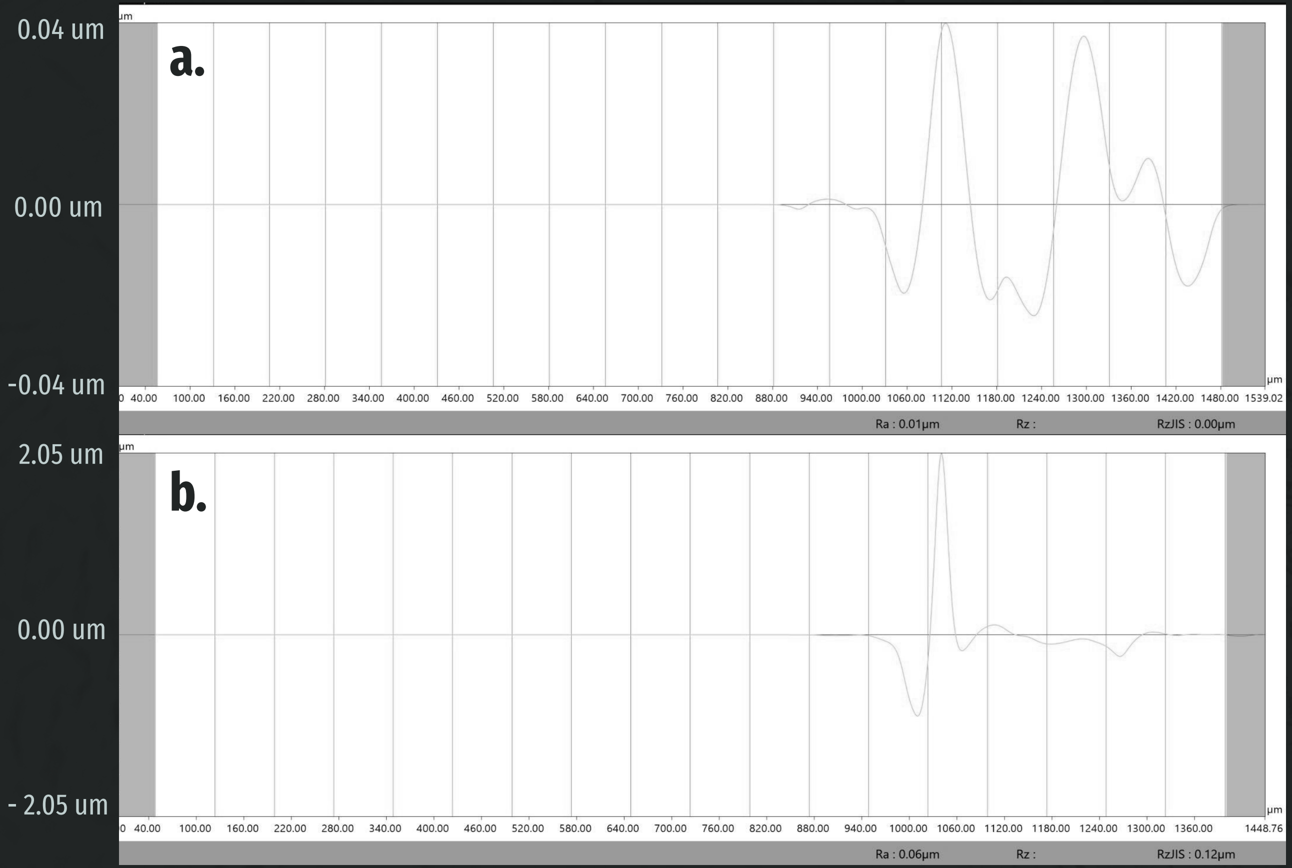

Figure 8.

a) Non-contact profilometry roughness profile of new, never implanted femoral component (Ra = 0.01)

b) Non-contact profilometry roughness profile of retrieved femoral component (Ra = 0.06)

Results

01

There was a significant difference ($p < 0.05$) between average Ra values measured by contact and non-contact profilometry. Ra measured by non-contact methods was slightly larger. There were no other significant relationships between methods of measurement.

02

There was no significant difference in wear across zones.

Discussion

- Comparison between new and retrieved implants showed significant changes in the surface characteristics due to in vivo wear
- Due to similar contact and loading patterns throughout flexion of the knee, all wear zones showed relatively similar wear characteristics.
- This is the first study to directly compare contact and non-contact profilometry methods in the context of orthopaedic research.
- While there was a significant difference in the Ra values, the difference was slight and lack of other significant relationships means that this difference likely has limited clinical significance.
- However, it is possible that the non-contact profilometer was more sensitive to sub-micron damage resulting in a slightly larger roughness measurement.
- Sub-micron particles are generally considered to be the source of metal sensitivity and the subsequent lymphocytic response [13]
- If this is the case, non-contact profilometry will be an important tool in understanding metal sensitivity moving forward.

THANK YOU.

References

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