Can the radiopaque marker in surgical swabs scratch orthopaedic implant surfaces?

J Anderson[1], A. A. Theodorides[2], R. Venkatesh[2] , T. D Stewart[1,2]

1. Institute of Medical and Biological Engineering, The University of Leeds
2. Leeds Musculoskeletal Biomedical Research Group, Chapel Allerton Hospital, Leeds.

Surgical swabs contain a radiopaque marker so that they can be easily identified on Xray should they be unaccounted for at the end of the operation. This study analysed the potential for the radiopaque marker to cause wear on a titanium surface when used during a typical wiping motion that might be expected for a swab. Results found that the radiopaque marker did not cause any measureable wear when rubbed against a polished medical grade titanium alloy surface. As titanium is the softest of the metallic implants, and thus the most likely to be worn, it is inferred that swabs containing a radiopaque marker are not likely to cause wear when used clinically against other harder implants such as stainless steel, cobalt chromium and ceramics. This is the first study of its kind in the literature.

Keywords (can put up to 10 keywords):

Swab; wear; radiopaque marker; Xray; metallic implant; titanium

Abstract

Aims: To determine whether the radiopaque marker strip, which is woven in surgical swabs, causes measureable wear on metal implants at pressures typically used to wipe off fluid from their surface.

Materials and Methods: Finger pressure used to wipe a surface was measured and used as a reference pressure for further testing. A tribological wear rig was then used to analyse the wear caused on polished titanium plates by a cobalt chromium pin (the control test), the pin covered by a surgical swab and the pin covered by a radiopaque marker strip.

Results: It was found that no significant wear was caused by the cotton part or the radiopaque marker of surgical swabs on polished medical grade titanium plates. In contrast severe scratching was observed from the cobalt chromium pin on its own.

Conclusion: To our knowledge this is the first study in the literature analysing the wear caused by the surgical swabs and radiopaque strip on metal implants. The results suggest that surgical swabs are safe to use on metallic implants at pressures typical of a wiping motion.

Introduction

Surgical swabs are used during surgery to absorb fluids and improve visibility of the operative field for the surgeon. The true incidence of retained swabs is unknown due to medicolegal implications but it is thought to be between 0.02% and 1% of all laparotomies and accounts for 50% of malpractice claims for retained foreign bodies (Sadeghifar 20123, Takigami 2008, Lauwers 2000). There have been reports of forgotten swabs in the peritoneal cavity, gynaecological and pelvic surgery as well as thoracic, breast and lower limb surgery. For this reason radiopaque markers have been woven within the swab to aid in identification on postoperative radiographs (Figure 1). This is particularly valuable should any be unaccounted for perioperatively.

Swabs are also used mechanically to help dislocate the hip during joint surgery where they may be wound around the neck of the femoral stem. From an implant perspective, arguably the most important application may be wiping of the polished bearing surfaces themselves. In the literature the presence of the barium sulphate radiopaque additive in bone cement has been attributed to a source of 3rd body wear and scratching of joint replacement surfaces (Bragdon 2003).

Figure 1. Surgical swab with radiopaque marker (black line in swab) woven into it.

The aim of the study was to investigate whether the action of wiping a surgical swab containing a radiopaque marker on the surface of a metallic implant may cause scratching and wear to the metallic implant surface.

Methodology

New unused cotton swabs (DetexTM, Xray detectable swabs, Synergy Health, Swindon, UK) incorporating a radiopaque marker were used. The radiopaque marker was subsequently removed from several swabs and analysed using a 3D non-contacting white light interferometer (Wyko, Veeko UK) to determine the surface roughness (Figure 2). The average surface roughness (Ra) along the length of the marker was ~50 µm.

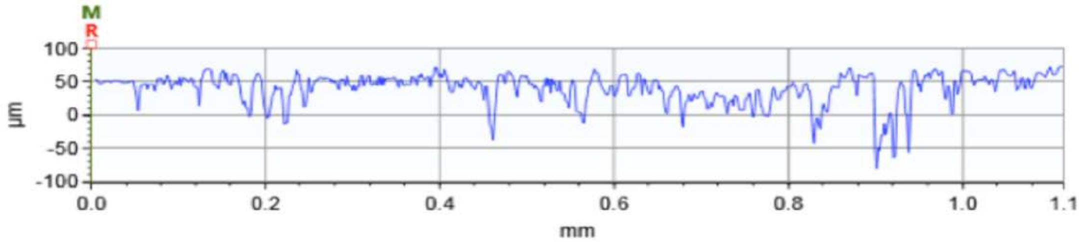

Figure 2. Typical radiopaque marker surface profile over a 1.1mm sample.

To simulate contact by rubbing/wiping, contact forces (force transducer) and areas (engineering blue dye) were estimated by analysing 3 volunteers using a single finger contact as a worst-case condition. The average contact pressure was then determined by dividing the average maximum force by the average contact area and found to be equal to 25 kPa (average force 2.7 Newtons, average area 107.5 mm^2). To replicate this condition in a tribological pin-on-plate test 12mm diameter pins were chosen with an applied load of 300g to create an estimated average stress of 26 kPa. Polished medical grade Titanium alloy (Ti6Al4V) plates, the softest medical grade metallic material, were used as shown in Figure 3. Swab materials were subsequently applied to the pin surfaces creating three test configurations as shown in Figure 4.

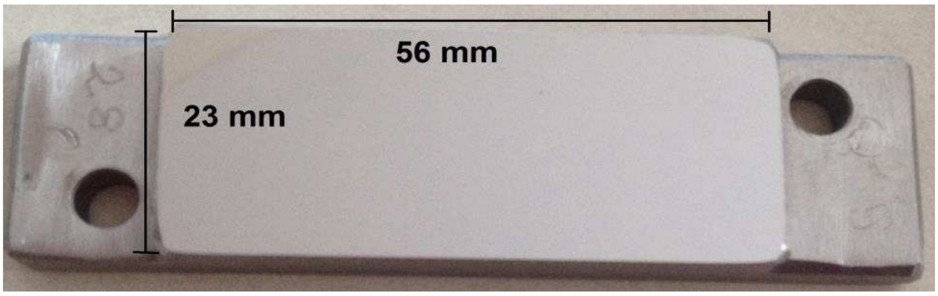

Figure 3. Typical titanium plate.

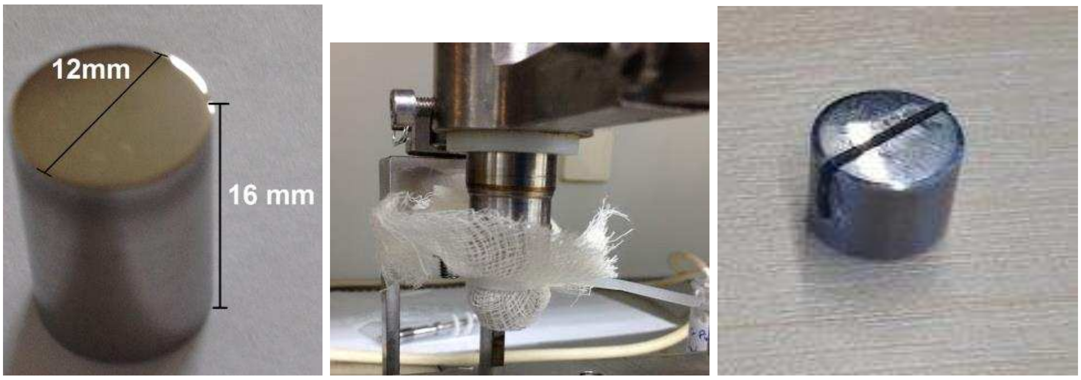

Figure 4. Tested pin configurations. a) Nude polished cobalt chromium pin with its dimensions; b) cotton part of swab secured on pin c) radiopaque marker glued at the sides of pin.

Wear testing was completed using an in-house single station tribological pin-on-plate testing machine (University of Leeds, Leeds UK, Besong 2001). Testing involved articulation of the pin against the plate over a sliding distance of 33mm at a rate of one cycle per second for 5 minutes over the same path for a total sliding distance of 9.9 m. Testing was performed with the pin and plate submerged in deionized water. The titanium plate and fluid were replaced after each test. Testing conditions are summarized in Table 1.

Table 1. Testing Conditions

Test	Plate	Pin Surface	Load	No of samples
1	Ti	Cotton	300g	3
2	Ti	Radiopaque Marker	300g	3
3	Ti	CoCr	300g	3

After each individual test, wear was assessed by analyzing the surface profile of the titanium alloy plate in 5 different locations using a Form Talysurf 5 surface profilometer (Model 120L, Taylor Hobson UK) which has a resolution of 3 nm. The magnitude of the average plate roughness was compared to new plates using a students T-Test to determine whether the results were statistically significant.

Results

Typical plate appearance following wear testing is shown in Figure 5. The cobalt chromium (CoCr) pin testing on titanium plate (used as a negative control) demonstrated a characteristic visible wear trace which was completely absent in both the cotton and radiopaque marker tests. No visible signs of wear on the titanium plates were present after the swab and radiopaque marker tests.

Figure 5. Typical post wear testing titanium plates following articulation against cotton part of surgical swab (a), radiopaquer marker (b) and cobalt chromium pin (c).

The mean surface roughness of new titanium plates was 0.0034 ± 0.0014 µm (standard deviation) and varied from 0.0019 to 0.0054 µm. The roughness of plates following testing with cotton covered pins and radiopaque marker covered pins is shown in Figure 6. Even though the average roughness of the titanium plates post wear testing with the cotton and radiopaque marker was greater than the average surface roughness of the new titanium plates the difference was not significant for either test (p values were 0.325 and 0.503 respectively). Additionally the accuracy of the testing machine is 3nm (0.003 µm), hence the differences between the test results, are within the experimental measurement error.

Plates that were contacted by articulating CoCr pins, increased in roughness significantly compared to new plates (p value 0.0004) by two orders of magnitude to 0.34 ± 0.07 µm (Figure 7). This was expected as it is a metal on metal contact with the harder cobalt chromium pin scratching the softer titanium plate.

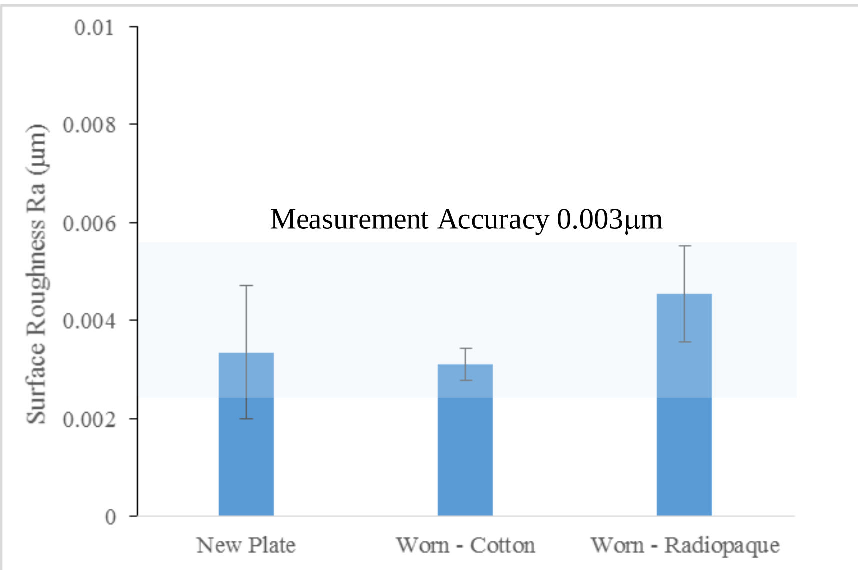

Figure 6. Mean roughness values (± Standard Deviation) for new and worn plates following articulation with both swab covered pins and radiopaque marker covered pins.

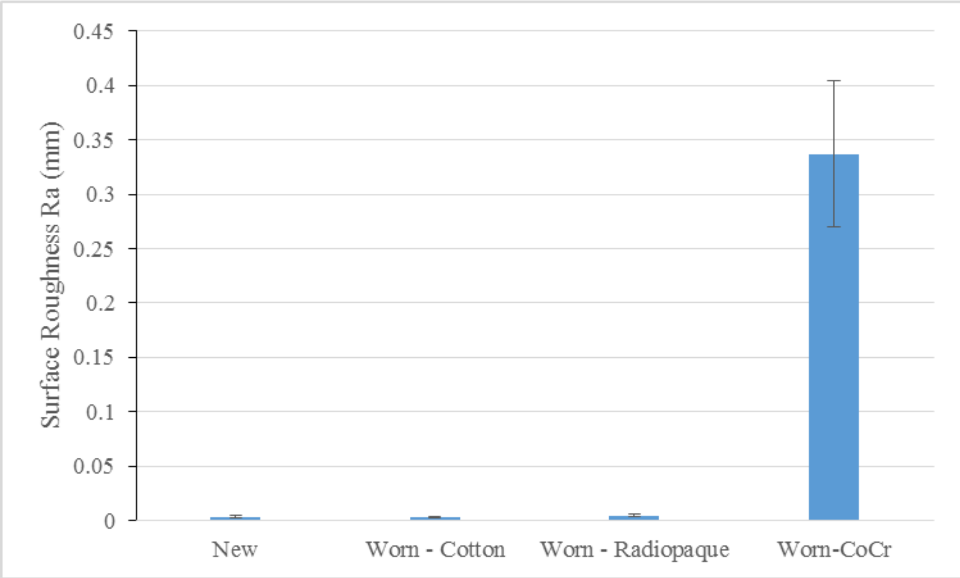

Figure 7. Mean Ra values (± Standard Deviation) of titanium plates for new and worn plates following articulation with cotton covered pins, radiopaque marker covered pins, and nude CoCr pins.

Discussion

Roughening of metallic articulating surfaces has been shown to accelerate wear on softer bearings such as ultra high molecular weight polyethylene (UHMWPE) due to the raised edges of the scratched metallic surface acting to increase abrasive wear of the other surface (Ingram 2004, Muratoglu 2004). The subsequent increased production of biologically active particles is critical concern in joint replacement surgery. Hence, the concern raised by the radiopaque marker is a very valid.

Bearing surfaces in joint replacement are more commonly cobalt chromium. However, medical grade Titanium alloy is a much softer material and is used in tibial trays and femoral stems. Thus the study utilised the softest clinical metallic alloy as a worst case scenario. The application of 300 cycles is also unlikely to occur clinically but allows for the analysis and comparison of wear under controlled conditions. The use of very highly polished plates with roughness at a nanometer level further offers the best chance of capturing the potential for a surface to be scratched. In the control test a single cycle of the nude polished cobalt chromium pins resulted in a visible scratch to the titanium plates, whereas the cotton and radiopaque marker covered pins produced no visible scratching after 300 repeated cycles. The results clearly show that the simulated wiping action of surgical swabs produced no significant wear caused by either the cotton component or the radiopaque marker component.

Theatre swabs have multiple uses in-vivo; in hip arthroplasty procedures they are wrapped around the femoral stem to investigate joint stability as well as to aid dislocations of the prosthetic joint. Thus the contact pressures applied in this study may not represent all clinical conditions. However, the contact using the metal pin produced significant scratching of the titanium plate, suggesting that the conditions were sufficiently severe to represent a condition where damage may occur.

Conclusion

300 repeated cycles of a radiopaque marker taken from a swab rubbing directly against a polished titanium plate, simulating the conditions of a clinical wiping action, produced no significant changes in the surface roughness of the plate and no visible scratching. The results thus suggest that the radiopaque marker component within a theatre swab is unlikely, to damage a metallic implant surface.

Acknowledgement

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