PILOT STUDY CONDUCTED ON EXETER PMMA CEMENT REAMER

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Introduction

The intended application of the Exeter Cement Reamer is for modification of the distal femoral cement mantle in preparation for Cement-within-Cement (C-C) revision. In particular this applies to the use of the Revision (125mm length) Exeter stem. The required volume and location of the polymethylmethacrylate (PMMA) mantle for removal is dependent on the relative stem size and geometry between the primary and revision stems selected. When revising a standard length Exeter stem to the shorter 125mm length revision stem with a wingless centraliser attached, removal of only small volumes of cement are required to allow revision. For this application predominantly dilation and finishing of the existing cement canal by reaming is required. As the longitudinal length of the primary cement canal is only slightly shorter than that required to accommodate the tip of a 125mm implant with centralizer, minimal end cutting is required. Design of a tool for modifying the cement mantle in preparation for revision to a 125mm length stem revision must therefore allow efficient reaming, with end cutting being a secondary application. When revising a standard length Exeter stem to another stem of equal length, removal of significantly larger volumes of cement is required. Due to the tapered geometry of the primary cement mantle, as reaming is continued in a more distal direction greater amounts of end cutting are required. Design of a tool for modifying the cement mantle in preparation for revision with an equivalent length implant must therefore also allow efficient end cutting. Should the primary cement mantle be incomplete distally or the canal within it be eccentric (for example in situations of varus malposition of the original stem), then optimally the tool would also be designed to allow side cutting transverse to the long axis of the cement canal. This would allow the surgeon to more adequately centre the prepared canal within the femur despite malposition of the original prosthesis. To allow accurate control of transverse reaming at the intended stem tip, design of a tool for this procedure should include a stout shank and web to increase bending strength and a short body for precision.

The Exeter PMMA Cement Reamer is illustrated in Figures 1 and 2. At the time of testing the reamer remains an experimental device which has not been commercially released for use. The device is an 8.5mm diameter 4 fluted reamer with a negative rake angle at the tip. Notches have been ground into two opposing blades at the tip to establish centre cutting. The point angle measures 118 degrees, and the helix angle of the body measures 30 degrees relative to the centre axis. The reamer has a short body of 9.2mm length, with a flute length to diameter ratio of 1.08. A limited pilot study and critical appraisal of the Exeter PMMA Cement Reamer was conducted in order to determine potential applications and improvements to design.

Method

8 short glass fibre reinforced sawbones femurs were implanted with a cemented Exeter stem Size 1 +37.5 offset stem fitted with a winged centralizer in the standard manner. Surgical Simplex P cement was applied in a retrograde fashion and a distal Bucks cement restrictor was used. The specimens were aged for duration of 1 week at 37^{o}C and at least 4 weeks at 22^{o}C prior to reamer testing. The implanted stems were extracted and the Exeter PMMA Cement Reamer was reamed at 250 Hz with the Exeter Cement Reamer as performed during distal mantle modification during C-C femoral revision.

Specimens underwent the following experimental protocols:

- 1 specimen was used as a trial of reaming technique and equipment.
- 1 specimen was used as a control sample and was not reamed to enable comparative analysis of the cement mantle by light microscopy and electron microscopy.

- 3 specimens underwent reaming for cement-within-cement femoral revision according to manufacturers recommendations, with saline irrigation and regular swarf clearance. Depth of reaming was determined by graduations provided on the reamer, and progressed to a depth sufficient to allow revision with a same length implant and attached revision centraliser.
- 3 specimens underwent reaming without irrigation and inadequate swarf clearance. Reaming depth in this case also progressed to a depth sufficient to allow revision with a same length implant and attached revision centraliser.

After reaming the specimens were cut in the coronal plane and one half used for fluorescent dye penetrant analysis under LM to detect cement mantle cracking. The other half was further sectioned in the axial plane, providing suitable sized samples to conduct SEM.

Results

Handling and Ease of Use

The centre of the canal was easily obtained and maintained due to the 4 flute geometry. Reaming progressed with acceptable speed and minimal effort while dilating more proximal sections of the cement mantle. To ream to a depth required for 125mm stem revision with the Exeter PMMA Cement reamer, the tool was easy to use and a minimum of force was required to advance the reamer. More distal reaming became difficult. As progressively more end cutting was required, the point of the reamer would quickly and repeatedly clog with PMMA swarf, reducing efficiency (Figure 3). When reaming with irrigation, frequent swarf clearance was required by repeatedly removing the reamer and breaking the impacted PMMA from the cutting edge at the tip. When reaming without irrigation in the more distal sections of the mantle, melting of the PMMA became a significant problem.

Mantle Inspection, Fluorescent Dye Penetrance and Electron Microscopy

General inspection of the cement mantles after sectioning showed a relatively uniform and smooth surface in the specimen reamed with irrigation and regular swarf clearance. In the specimen reamed without irrigation, a very rough surface which resembled delamination was created (Figure 4). Fluorescent dye penetrant studies under light microscopy confirmed the general appearances of surface roughness. No mantle cracks could be detected regardless of reaming technique employed (Figures 5 & 6). Scanning electron microscopy of the specimen reamed without irrigation showed an irregular rough surface created by the smearing of melted PMMA. Clear evidence of unstable delamination of the PMMA was however not confirmed by the appearances under electron microscopy. The macroscopic appearance resembling delamination is most probably caused by the irregular smearing of melted cement while reaming without irrigation. No mantle cracks could be detected regardless of reaming technique employed (Figures 7 – 13).

Discussion

The Exeter PMMA Reamer is an effective tool for reaming to depths required for revision with the 125mm length stem. The tool centres within the canal easily and reams quickly to the depth required with a minimum of heat production or force. Front cutting is a problem due to poor swarf removal at the tip.

Irrigation and regular blade clearing is recommended, particularly when using the tool to end cut. When reaming without due regard to cooling and swarf removal, melting of the PMMA occurs easily and material is deposited as an irregular fine layer over the underlying cement mantle. This layer although significantly increasing the surface roughness for revision cement mantle adhesion may potentially weaken the base cement mantle due to changing the material properties of the cement and creation of an additional C-C interface, *vis.* between melted and non melted PMMA. If melting of PMMA during drilling procedures is encountered, the effect is difficult to control and poorly reproducible. Furthermore, the temperature required to achieve glass transition of PMMA cement is well in excess of the threshold for thermal bone necrosis. Optimal preparation of the PMMA mantle should therefore avoid excessive heat generation and restrict PMMA melting.

The surface of reamed PMMA regardless of technique is roughened significantly compared to unreamed. This may allow better interdigitation of new-on-old cement mantles. Mantle cracking has not been demonstrated with either fluorescent dye penetrant under light microscopy or scanning electron microscopy.

Recommendations & Conclusions

The Exeter PMMA Reamer is an effective tool for reaming primary mantles created by standard length Exeter implants to depths required for 125mm revision stem. For C-C revision to equivalent length stems, using the Exeter PMMA reamer demonstrates difficultly in performing the end cutting procedures required for this application. For this application a purpose designed end cutting drill of sufficient length could be used or alternatively the Exeter PMMA Reamer could be redesigned to allow more efficient end cutting. Considerations may include providing a positive rake angle at the tip, and increasing the volume capacity of individual flutes by reducing the number to 2 or 3 instead of 4. These modifications may however potentially reduce efficiency of the tool in reaming and transverse side-cutting applications.

Surgical technique for reamer use should emphasize the requirement for irrigation and regular swarf removal.

Further experimentation on the end cutting and side cutting applications of the Exeter Cement Reamer within PMMA cement are required.

Figure 1 Prototype Exeter PMMA Cement Reamer.

Figure 2 Reamer Tip. Note the difference between negative rake angle established at the centre cutting area of the drill compared to positive helix angle of the drill body.

Figure 3 Swarf repeatedly re-accumulates in front of leading edge of drill tip when performing end cutting procedures. Note the flutes running down the body of the bit are clear of debris due to favourable helix angle.

Figure 4 Macroscopic appearance of mantle reamed to depth to allow revision with standard length stem. Reaming was conducted without use of irrigation or regular clearing of swarf. Note the delaminated appearance of reamed surface.

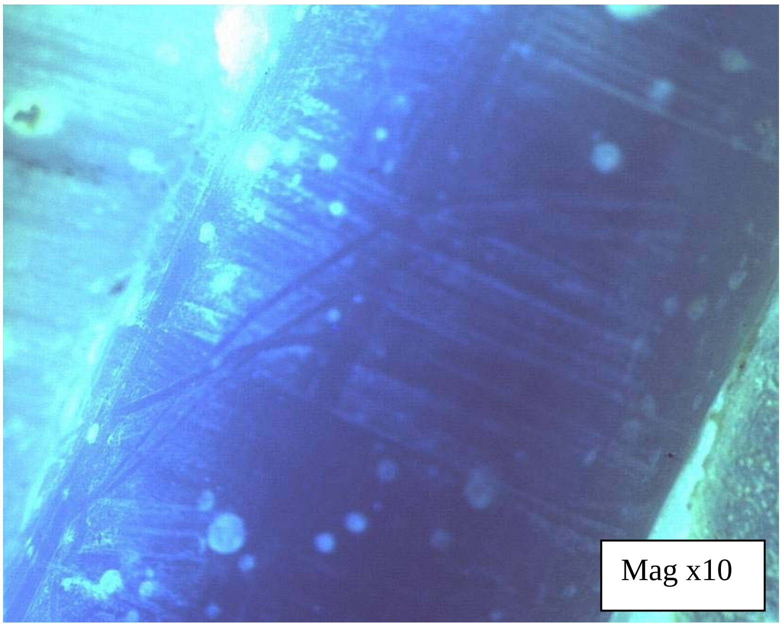


Figure 5 Fluorescent Dye Penetrant study on mantle reamed with irrigation and regular swarf clearance. Well finished surface with increased roughness compared to unreamed. Fine circumferential surface marks from the drilling tip are held by the material. No mantle cracks identified.

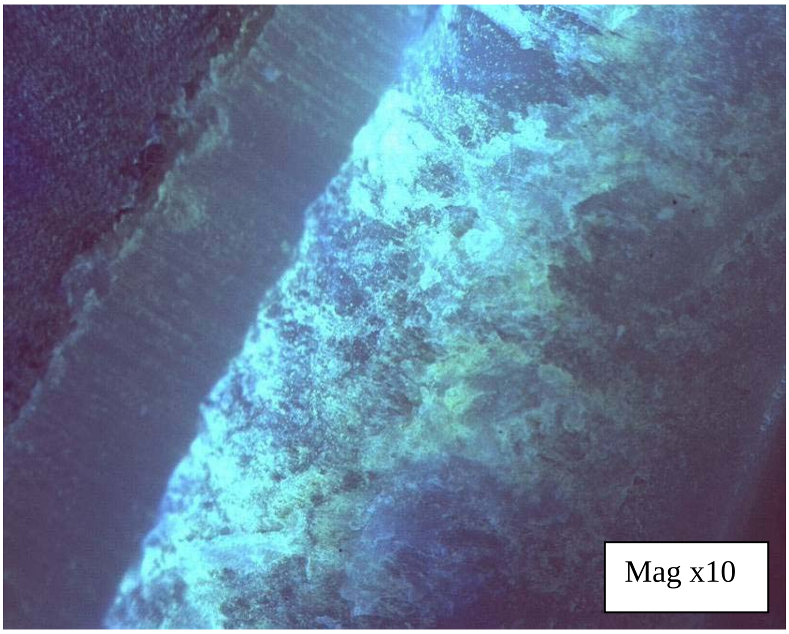


Figure 6 Fluorescent dye penetrant study on same mantle reamed without adequate irrigation or swarf clearance. Very rough surface with appearance of cement delamination. No mantle cracks identified.

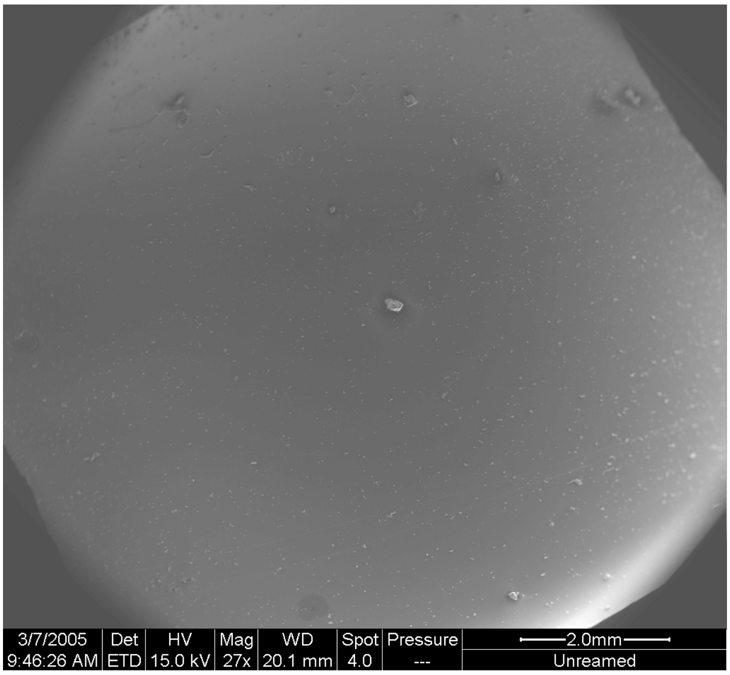
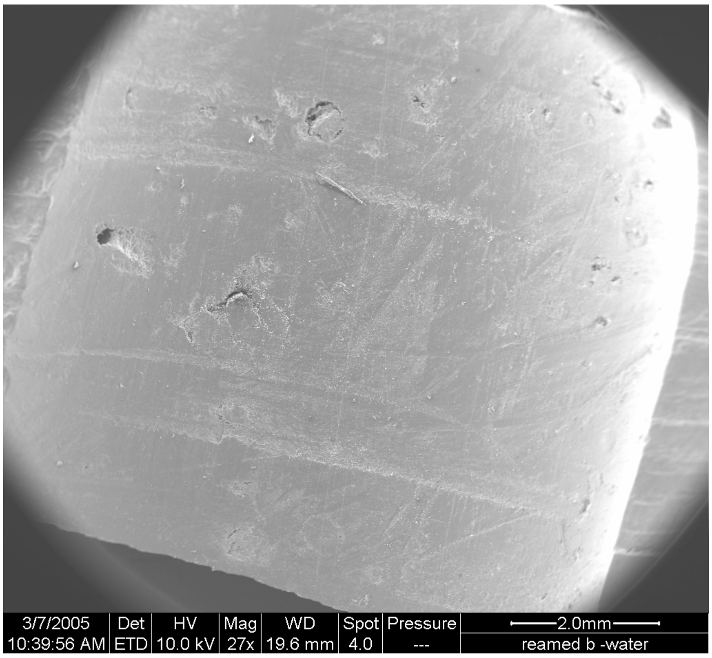
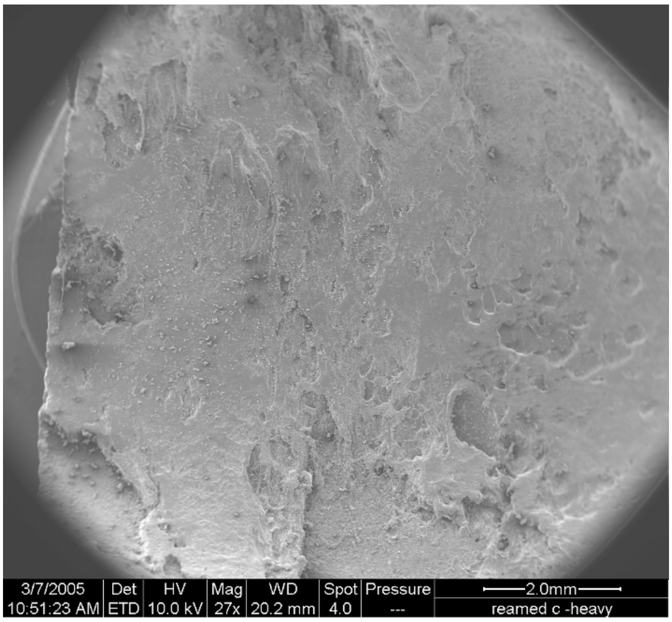


Figure 7 SEM (Magnification x27) PMMA Cement Mantle unreamed.



<u>Figure 8</u> SEM (Magnification x27) PMMA Cement mantle reamed according to manufacturer recommendations with use of irrigation and regular swarf clearance. Roughened surface but well finished.



<u>Figure 9</u> SEM (Magnification x27) PMMA Cement mantle reamed without irrigation or adequate swarf clearance. Very rough surface produced by smearing of melted PMMA produced during drilling procedure.

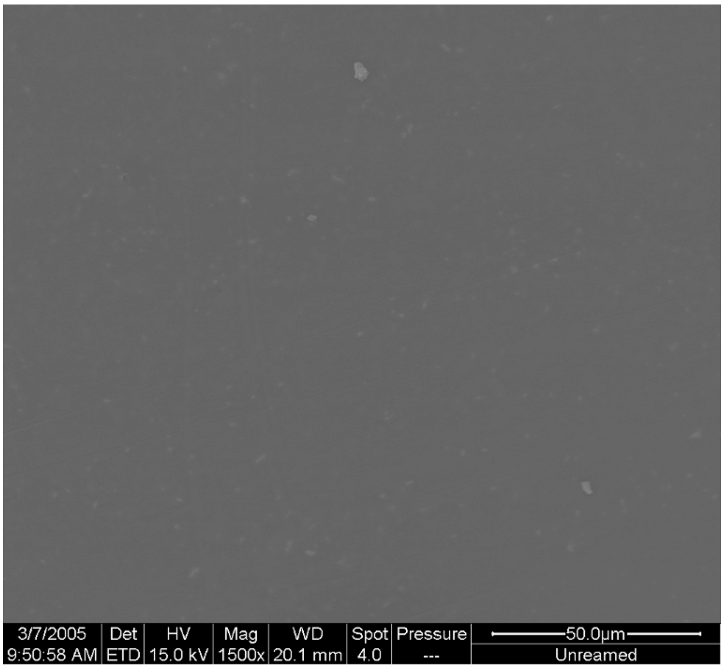


Figure 10 SEM (Magnification x1500) Unreamed PMMA cement mantle.

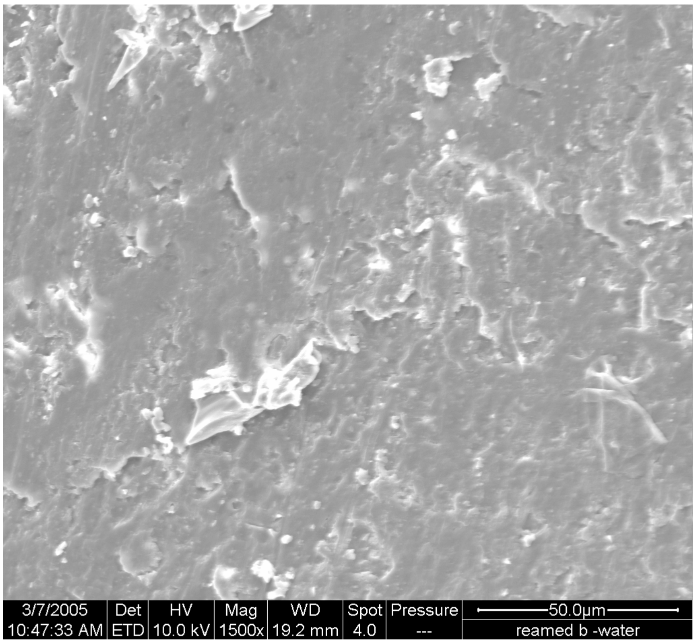


Figure 11 SEM (Magnification x 1500) Reamed mantle using irrigation and regular swarf clearance. Roughened surface with mantle integrity maintained.

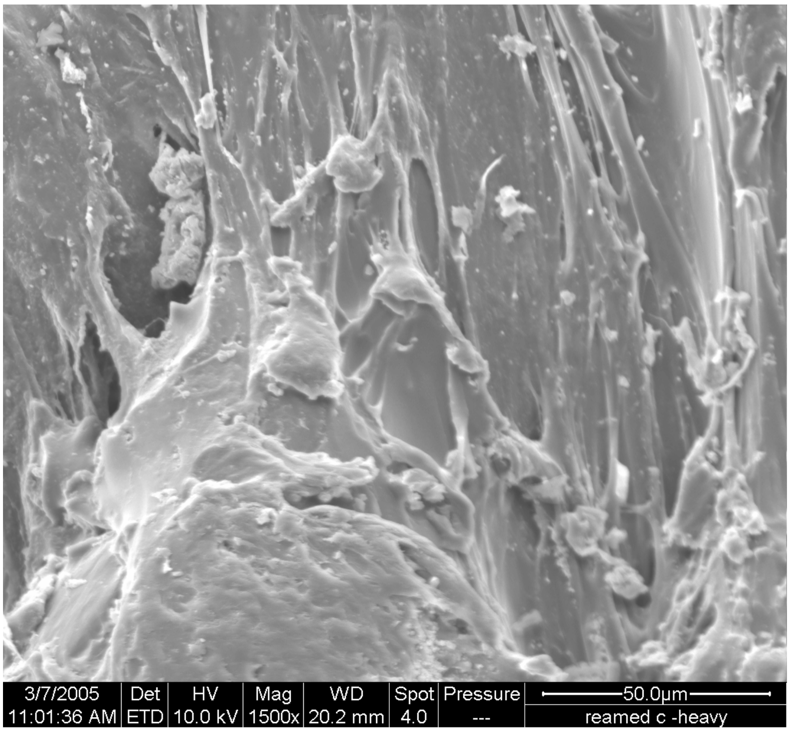


Figure 12 SEM (Magnification x1500) PMMA Cement mantle reamed without adequate irrigation or swarf clearance. Smearing of melted PMMA can be appreciated.

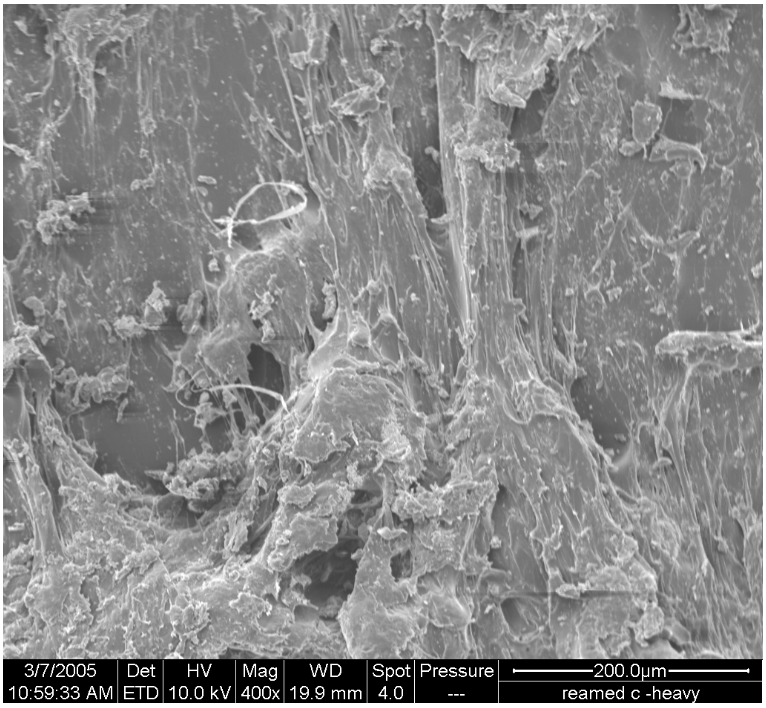


Figure 13 SEM (Magnification x400) of same mantle displayed in Figure 12.