Tips & Techniques

Methods of Removing Excess Bone Cement

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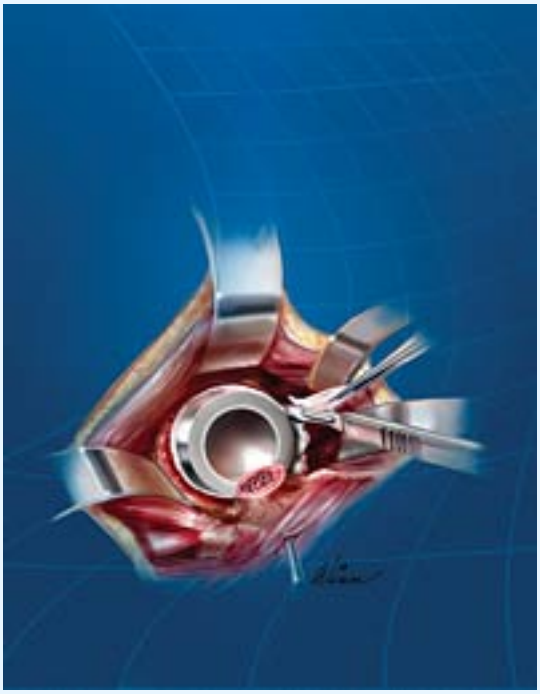
This article investigates the effect of different bone cement removal techniques and their influence on cement mantle integrity.

A septic loosening of total joint replacements represents a major clinical problem.[1] Endosteal bone lysis characteristically occurs either due to foreign body reactions to polymethylmethacrylate (PMMA),[2] metal,[3] and polyethylene [4] particles, or intermittent high fluid pressures.[5] The pathway by which particles and pressure waves reach the site of granuloma formation and lysis, often remote from the joint cavity, is via the implant-cement interface with a cement mantle defect at the lytic site, allowing exposure of the endosteal surface.[6] The particles and joint fluid are transported along this pathway due to cyclic intra-articular pressure changes,[7] and can achieve upper limits of 700 mm Hg.[8,9] Recent studies indicated that the process begins with implant debonding from the cement mantle,[8,10] with subsequent prosthetic micromotion causing cement cracks, particularly at weak areas of thin or incomplete cement mantle.[10] The cement mantle, as the "sea" concept, has been hypothesized to act as a retardant to particulate debris transport from the joint cavity to the site of osteolysis.[11]



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During cemented prosthetic replacement surgery, excess bone cement is invariably extruded from exposed margins following implant insertion. No standard method of removing excess cement has been described; thus, various techniques are practiced including cutting, scraping, "thumbing," and cementotomy of the overflow. Different techniques of removal produce variable cement mantle margins as a function of the method and timing.

Materials and Methods

A pilot study was initially undertaken with hand mixed Hygenic orthodontic polymethylmethacrylate resin (Coltene/Waldent, Mahwah, NJ). All tests were conducted at room temperature, due to the reported increased porosity of refrigerated cement.[12] Each test was conducted on a base plate of 7.5-mm-thick polyvinyl chloride with a polysiloxane protectant (George Mann and Co, Providence, RI). The cement was mixed for 1 minute and immediately poured onto the baseplate surface, in four oblong masses (6×4×2 cm). A standard glass microscope slide, with two equidistant centralized stainless steel spaces (5×2×2 mm)

attached to its undersurface, was placed onto each cement mass. The slide then was pressurized to create a cement mantle underneath the viewable slide surface of 2 mm, as maintained by the spacers. Of the four slides in each test, each was designated for excess cement removal by one of four techniques. Three involved soft cement, and are referred to as "soft removal" methods: cutting with a sharp scalpel, scraping with a blunt retractor, and guillotining with the palmer surface of the surgeon's thumb (thumbing). The latter technique involves direct pressurization with the palmer surface of the thumb over the edge, thereby causing the excess cement to be guillotined by the adjacent interface surfaces. The fourth removal technique, cementotomy with an osteotome, was performed after the cement had fully hardened. The timing of removal varied from 1 to 12 minutes, after mixing commenced, at 1 minute intervals. The same sequence of experiments were repeated with a glass base plate, 1-mm cement mantle, and vacuum mixing of the cement.

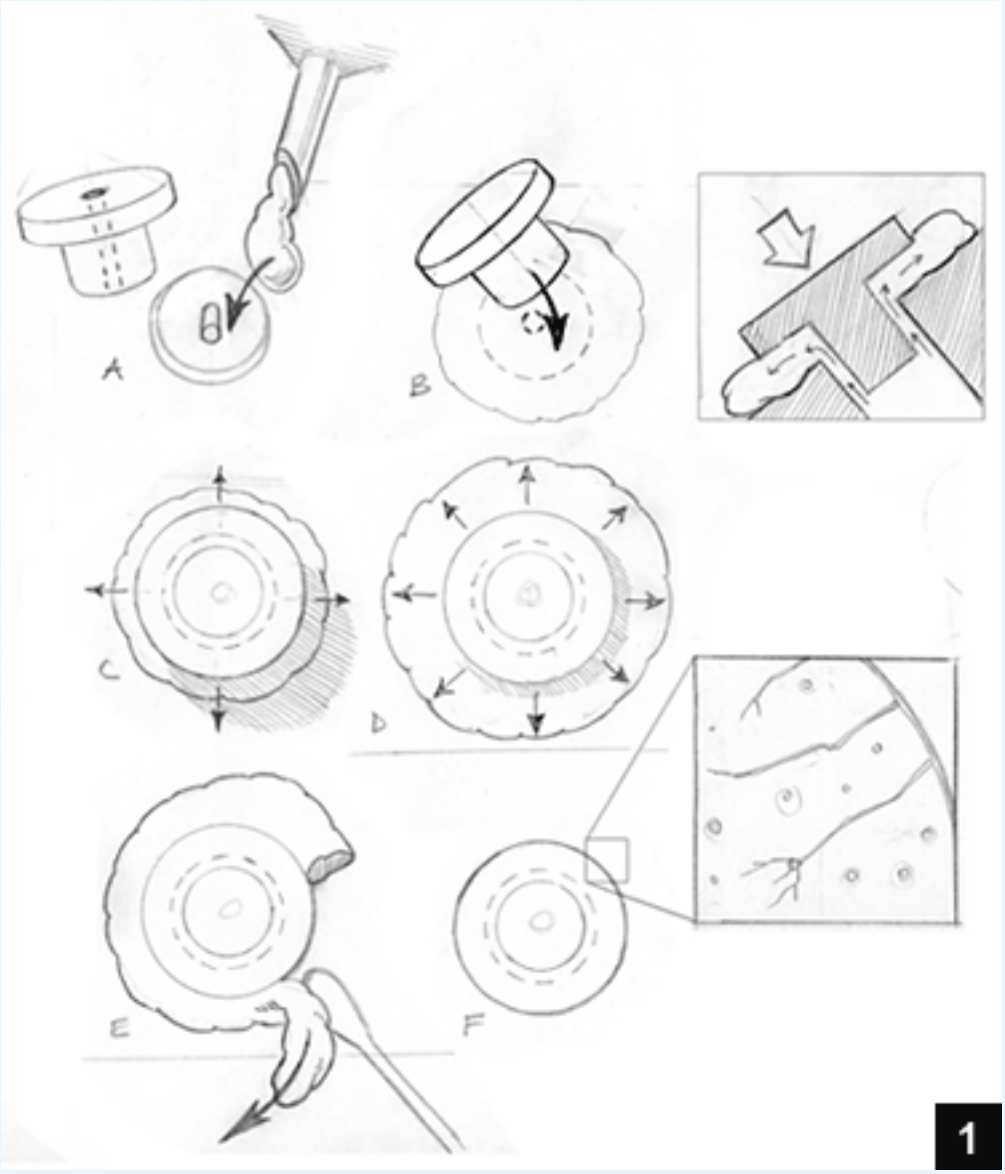
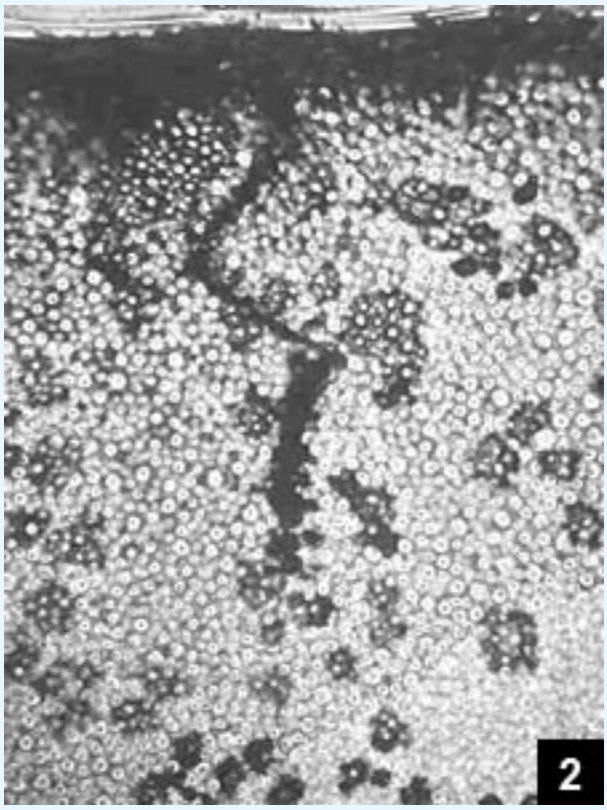


Figure 1: Test apparatus. Cement poured into well (A). Plunger introduced onto central rod and inserted (B). Cross-sectional view of stage B highlighting the cement extrusion path (C). Plunger fully inserted and cement spreading radially (D). Cement removal (E). Cement fully removed and a section microscopically visualized (F).

Based on the results of the pilot data, we modified the method in two ways. First, we attempted to recreate the extrusion pathway that cement experiences during the insertion of a cemented implant. This was achieved by the apparatus shown in Figure 1. The apparatus includes a centralized peg that maintains a 2-mm cement mantle at the circumference of the cylinder (diameter=12.75 mm) and a difference of 2 mm between the trough depth (11 mm) and centralized cylinder (13 mm), to create a 2-mm-thick cement mantle underneath the viewing disc of the peg (Figure 2). The viewing area is 4 mm wide. The second modification to the study was the use of a widely available PMMA bone cement (Simplex P; Stryker Howmedica, Rutherford, NJ).

The cement was vacuum mixed for 1 minute, and 1.5 mL immediately were poured into each trough. Following introduction onto the centralizing rod, the peg was fully inserted into the trough. The excess cement was removed by the same three soft removal methods described above, at intervals of 5 and 7 minutes. These timings were easy to identify because at 5 minutes the cement was “tacky” and adherent to a latex glove on contact, and at 7 minutes it was “doughy” and nonadherent on contact.

When cement removal was complete an acetone based black dye was introduced to the exposed edges of the cement. The specimens were viewed with a light microscope, at a magnification of 20× (Olympus CK40, Tokyo, Japan). Cement defects were counted; and specifically the number of cracks were statistically analyzed, first with a two way analysis of variance (ANOVA), followed by a one way ANOVA and the posthoc test described by Tukey-Kramer.



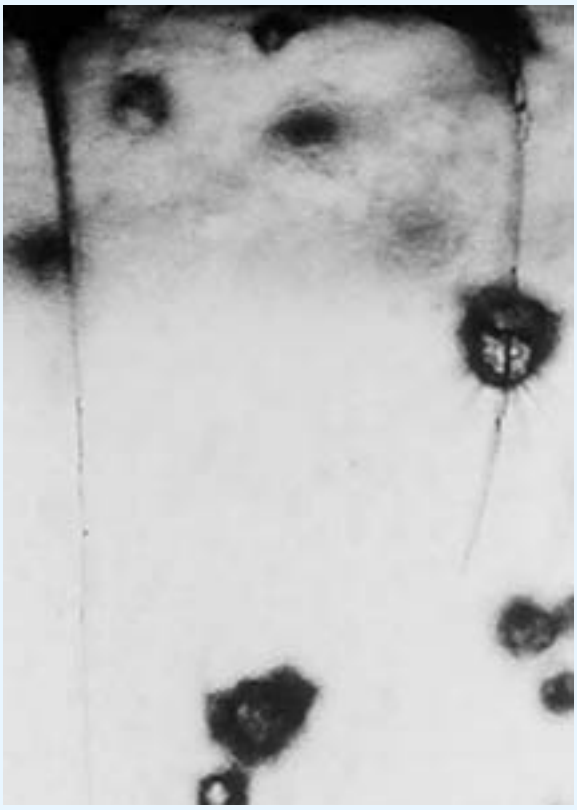


Figure 2: PMMA dental resin scraped at 7 in. **Figure 3:** Scraping at 7 in. Cracks that encounter pores deflect and penetrate less deeply into the mantle.

Results

Pilot study data revealed no differences between the soft removal techniques between 1 and 5 minutes of mixing. Furthermore, 1-mm-thick cement mantles consistently developed cracks >1000 μm in length, with scraping beyond 7 minutes (Figure 2). These findings led us to test a vacuum mixed 2-mm cement mantle at 5 and 7 minutes, which relates clinically to when implant positioning is secured, cement setting is awaited, and cement removal often undertaken. Defects within the cement mantle have descriptively been termed: pores (small circular defects), interconnected pores (recognizable pores connected by cracks), voids (longitudinal wide defects), and cracks.

Cutting and scraping at 5 minutes produced a smooth surface, whereas thumbing produced a sloping shelf of excess cement extending beyond the test area. Cutting and thumbing at 5 minutes showed minimal differences in the quality of the superficial subsurface cement mantle with an average of <2 pores, and either <100 μm cracks or no cracks respectively (Table 1).

We defined the superficial subsurface layer as that part of the cement mantle extending 1000 μm from the exposed surface. The quality of the mantle at the edge of the test area, with thumbing at 5 minutes, was free of defects. Cutting at 7 minutes retained the smooth edge characteristic, but produced a moderate (<10) number of small pores in the superficial part of the subsurface mantle, and cracks of <100 μm length. Thumbing beyond 7 minutes produced a narrower extension beyond the test area, and had a minimal number of pores in the subsurface, and no cracks. The excess cement remaining outside the test area was prone to fracture once fully hardened, although no examples of free cement bodies resultant from this source were detected.

Scraping at 5 minutes produced a less smooth surface than cutting, but also had a moderate (<10) number of defects, pores, voids and cracks <100 μm in length. At 7 minutes the surface was rough, with a subsurface containing a major (>10) number of defects, including circular pores, interconnected pores, voids oblique to the surface, and cracks >100 μm in length (Figure 3). Cracks that encountered pores did not appear to penetrate as deeply into the mantle, compared to those that encountered no pores. The crack–pore interaction resulted in some continuance of the original path, with a multitude of subsidiary cracks, emanating from the pore circumference, in a divergent pattern (Figure 3). Cementotomy performed after the cement had fully hardened produced a jagged surface with no subsurface defects.

The number of visible stained cracks were counted as a function of the method an time of removal (Tables 1, 2). Statistical analysis with a two way ANOVA test revealed statistically significant differences between the method and time of removal, and of the removal method as a function of time (P<.001). A subsequent one way ANOVA test with a Tukey-Kramer posthoc analysis revealed a statistically significant difference between cutting and thumbing compared to scraping for crack sizes >100 μm, and significance between thumbing and scraping for cracks <100 μm. No statistical difference was present between cutting and scraping for cracks <100 μm. No statistical differences were noted between cutting and thumbing for any crack size. Posthoc testing also revealed that cracks, both >and <100 μm, were statistically significant (P<.05) when comparing the two time intervals of 5 and 7 minutes from cement mixing.

Table 1

Cracks <100 µm per 2 cm periphery

	5*	7*	Set
Cut	0.5	8	-
Thumb	0	0	-
Scrape	1.5	18	-
Osteotome	-	-	0

*Minutes

Table 2

Cracks >100 µm per 2 cm periphery

	5*	7*	Set
Cut	0	0	-
Thumb	0	0	-
Scrape	0	5	-
Osteotome	-	-	0

*Minutes

Discussion

The basis for aseptic loosening of cemented prosthetic implants is thoroughly established[6] and its prevention is an area of intense investigation. An intact cement mantle is believed to impede the movement of particulate debris from the joint cavity to the site of osteolysis by acting as a seal.[11] The defects, thought to contribute to such loosening, have been documented to exist as early as 3 years following arthroplasty,[10] or five million cycles.[13] Our current findings may implicate such defects at a much earlier stage of implant life.

Large pores and voids have previously been attributed to air entrapment during mixing[14] and small pores due to monomer evaporation during the curing process.[15] They are thought to act as stress risers[14,16] and have been associated with fractures of the cement mantle, with small fractures occurring as early as 3 years after implantation, and larger fractures after 10 years.[10] Findings from this study reveal that voids also may be attributed to the shear stresses caused by more traumatic methods of excess cement removal, most notably scraping after 7 minutes. Their appearance at an early stage of the cement lifetime is a cause for concern, but appears to be preventable. This removal method, at later times, also has resulted in pore to pore cracks and cracks originating from the same pore, findings previously documented at light microscope[13] and electron microscope levels.[10]

Cracks perpendicular to the exposed mantle surface were seen when cutting at 7 minutes and scraping at both 5 and 7 minutes. With a similar dental resin, McCormack and Prendergast[13] assumed that surface cracks could penetrate into the depth of the cement—an assumption borne out by our findings. The relevance of the surface cracks extending into the cement mantle depth has yet to be confirmed, but their potential for progression exists. Cracks originating from pores led to the conclusion strengthening the case for vacuum mixing cement.[13] However, cracks that encountered pores were shorter than those that formed in defect free cement. An experimental limitation was the inability to accurately measure the length of cracks, because we recognized that cracks were underestimated by our dye and light microscopy technique, and occur in three dimensions. On encountering a pore there was some persistence of the original path, but also a multidirectioned "sunburst" of smaller cracks originating from the pore circumference. This observation from our study implies that poreless cement has less resistance to depth penetration than that with pores. Such cement cracks are also thought to be progressive and a source of PMMA particulate debris.[10]

Conclusion

The findings of clinical relevance, are that the exposed cement mantle should be removed within 5 minutes of mixing or left alone until fully hardened. However, it is recognized that cutting is not always possible

due to the access of different areas from different joint exposures. Thumbing produces a defect-free mantle at the implant edge, but also produces a tapered shelf of excess cement. The concern with this latter finding is that these thin tapers may produce loose flakes of PMMA material, with the potential for third body wear and particulate debris formation; thus the most consistent exposed mantle can be created by the initial thumbing of all areas, within 5 minutes, followed by cutting the excess tapered shelf in accessible areas, and scraping with appropriate curved instruments in inaccessible areas. When fully cured, cementotomy produces a defect-free exposed mantle, although the jagged edge may prove to be a source of free particulate debris. Cutting excess cement with a sharp scalpel, under 5 minutes, appears to produce the most consistent surface and subsurface at the implant edge.

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