

Implant augmentation

Augmentation of implants with polymethylmethacrylate (PMMA) cement has been used for many years in orthopedic surgery. Traditional indications have been planned or unplanned salvage procedures with bone loss due to tumors or metastasis and revision surgeries. It is within the nature of those surgeries that the use of cement is unpredictable and not standardized. There is not much research available. Since osteoporosis essentially means bone loss, the concept of implant augmentation seems to be appealing for enhancing primary stability of fracture fixation under this condition as well.

Rationale: At the time of implant placement, two main factors determine its primary stability: the amount and quality of bone-implant contact and the compressive stresses induced by press-fitting at the bone-implant interface. Implant augmentation addresses the first. Because of the reduced number and thickness of trabeculae in osteoporotic metaphyseal bone, contacts between implant and bone are dramatically reduced compared to normal bone. The percentage of implant surface in contact with bone correlates, at least to some extent, with implant failures. PMMA cement, when utilized as implant augmentation, increases the surface and the interdigitation of the implant with the surrounding bone.

Biomechanics: The effect of in situ PMMA screw augmentation in proximal humeral fractures [1].

Objective: This in vitro study investigated the cutout resistance of PMMA-augmented screws for proximal humerus fractures stabilized with the proximal humerus internal locking system (PHILOS).

Material/methods: A simulated three-part humeral head fracture was stabilized with an angular stable plating system in twelve pairs of humeri. Local bone mineral density BMD in the humeral head was measured with qCT. One side was randomly treated with four cannulated screws, each augmented with 0.5 mL of PMMA-cement, whereas the contra lateral side served as a nonaugmented control. Specimens were loaded in varus-bending or axial-rotation using a cyclic loading protocol with increasing load magnitude until failure of the osteosynthesis occurred. Relative motion of the humeral head to the PHILOS was measured using a 3D motion analysis system. The effect of augmentation was analyzed with a paired *t* test. BMD, number of load cycles to failure, as well as BMD and the paired difference of load cycles to failure were correlated.

Results: For varus bending, the osteosynthesis failed after 5583.3 (SD 2273.6) in the conventional group and after 8516.6 (SD 951.6) cycles in the augmented group ($P = .014$). Correlation of failure cycle with BMD showed a strong positive correlation for the conventional group ($r = .893$, $P = .016$) and no correlation for augmented specimens ($r = .258$, $P = .621$). For axial rotation the conventional group failed after 2050 (SD 656.5) cycles and the augmented group after 3316.6 (SD 348.8) cycles ($P < .003$).

Correlation of the difference in failure cycle (augmented-nonaugmented) with BMD was significant for varus bending ($r = -.913$, $P = .01$) and axial rotation ($r = -.818$, $P = .047$).

Conclusion: It could be shown for both tested load cases (varus bending and axial rotation) that augmented specimens sustained a significant higher number of load cycles (and maximum load) until failure of the construct.

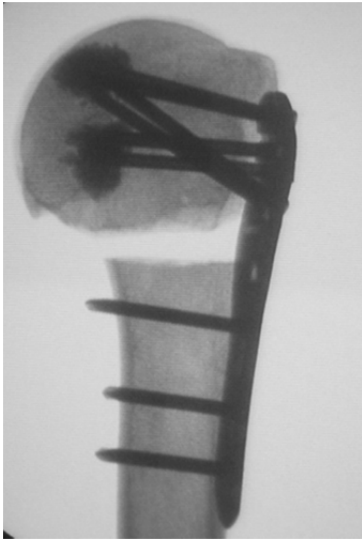


Fig 1: Simulated three part fracture, stabilized with a PHILOS plate and four most proximal screws augmented with 0.5 mL PMMA.

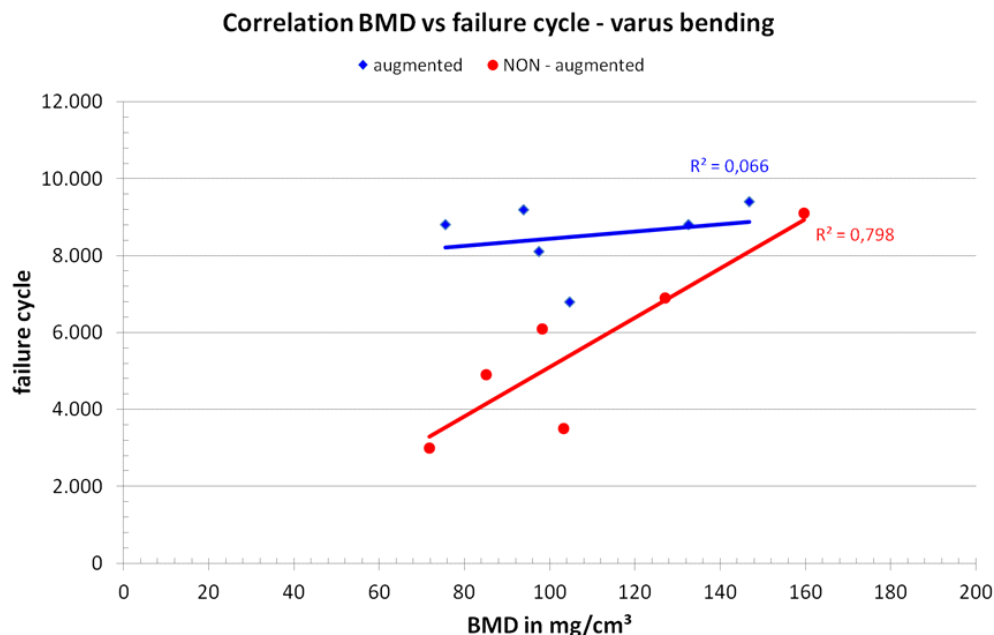


Fig 2: Correlation of trabecular BMD with number of load cycles to failure. Nonaugmented specimens showed a strong positive correlation, while augmented specimens did not show a correlation with BMD.

Amount of cement

Historically, the medical community has always been concerned with the use of bone cement to enhance implant anchorage. Most of these concerns were based on the interference with fracture healing due to excessive cement application, leading to osteocyte necrosis, and the presence of cement at the fracture site, leading to persisting non-reducible fracture gaps or blocking of the sliding mechanism of the implant.

Furthermore, the application of excessive amounts of bone cement might lead to osteocyte and chondrocyte necrosis. With the use of cannulated and perforated implants, the problem of cement distribution has been solved. Injecting bone cement through the implant can avoid intraarticular localization of bone cement and leakage of cement at the fracture site. In order to reduce the residual risks associated with the amount of bone cement (mainly toxic and thermal effects), it is of utmost importance to further reduce the volume of the cement used. Because chondrocytes might be more sensitive to the deleterious effects of PMMA than osteocytes, any subchondral localization of bone

cement should be avoided, and one should try to use just enough PMMA as needed to surround the implant.

Biomechanical studies on a foam model and in cadaveric bones show the beneficial effect of using a limited amount of PMMA on implant anchorage and cut-out resistance [2, 3]. A significant difference in numbers of cycles to failure was found between augmented and nonaugmented specimens with the use of maximum 3 mL of PMMA.

Heat generation

The use of PMMA bone cement to augment implants is associated with an exothermic reaction. The temperature distribution around an implant is influenced by variables such as the implant itself, cement layer thickness, and heat conductivity of involved materials, and others. Bone tissue necrosis can be expected when tissue is exposed to more than 60°C. At lower temperatures, damage depends on the exposure time. Recent in vitro studies have demonstrated that the augmentation of a hip implant with 3–6 mL is not associated with a risk of thermal bone necrosis [4, 5].

Clinical application of implant augmentation

Implant augmentation has been used for some time for transpedicular screw fixation of spinal disorders.

In other musculoskeletal fracture fixations, standardized implant augmentation has only been developed and applied for the blade of the PFNA. The blade is therefore delivered in a perforated version.

In the near future, cannulated locking head screws with the PHILOS plate will be used for fixation of proximal humerus fractures.

Implant removal after augmentation

Implant removal has never shown to be a problem after augmentation. The cement sticks much firmer to the bone than to the implant and simply breaks at the perforation holes of the implant.

Recommended reading

1. **Unger S, Erhart S, Kralinger F, et al.** The effect of in situ augmentation on implant anchorage in proximal humeral head fractures. *Injury*. 2012 Oct;43(10):1759–1763.
2. **Sermon A, Boner V, Boger A, et al.** Potential of polymethylmethacrylate cement-augmented helical proximal femoral nail antirotation blades to improve implant stability—a biomechanical investigation in human cadaveric femoral heads. *J Trauma Acute Care Surg*. 2012 Feb;72(2):E54–E59.
3. **Sermon A, Boner V, Schwieger K, et al.** Biomechanical evaluation of bone-cement augmented Proximal Femoral Nail Antirotation blades in a polyurethane foam model with low density. *Clin Biomech (Bristol, Avon)*. 2012 Jan;27(1):71–76.
4. **Boner V, Kuhn P, Mendel T, et al.** Temperature evaluation during PMMA screw augmentation in osteoporotic bone—an in vitro study about the risk of thermal necrosis in human femoral heads. *J Biomed Mater Res B Appl Biomater*.; 2009 Aug;90(2):842–848.
5. **Fliri L, Lenz M, Boger A, et al.** Ex vivo evaluation of the polymerization temperatures during cement augmentation of proximal femoral nail antirotation blades. *J Trauma Acute Care Surg*. 2012 Apr;72(4):1098–1101.

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