Potting Media Selection for Biomechanical Testing: a Pilot Study for Long Bones Subject to Axial Loads

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INTRODUCTION: Potting is used to stabilize specimens during biomechanical testing and has been instrumental in gaining accurate and effective results for many years. This method allows for bones of distinctive shapes to be used for testing because the media can mold to the shape of any object potted within it. Different types of potting media that are easily attainable include polyester resins, polyepoxides resins, and polyurethane elastomers; these have been described as the primary potting media in numerous biomechanical studies. Polyester resin has been described for use in a potting medium due to its ease of handling, lack of heat sensitivity, and short curing periods. Polyepoxide resin has been a reliable media due to its high modulus and high strength but with the downsides of increasing curing time and lower fracture toughness. Polyurethane elastomers are also frequently utilized due to its 2-part compound which allows for characteristically low temperature polymerization and flexibility. In light of the heterogeneity of the potting media used, comparison among studies of the measured variables is limited by the differences in potting media used with resultant impact on the experimental results. Therefore, the main goal of this study is to determine, among the most common media commercially available, which media results in the highest construct stiffness in the execution of mechanical testing of long bones. We hypothesize that the configurations potted with polyepoxide resin will result in the highest stiffness due to having the highest tensile modulus as declared by the manufacturers.

METHOD: For the purpose of the experiment, we considered constructs mimicking the testing of long bones subject to tension loads. The bone surrogate was composed by a square aluminum tube 5in long with 1in side dimension and a wall thickness of 0.25in. The surrogate was potted into a 3x3x3in aluminum box and stabilized with a 0.125in rod at a depth of 1.5in in the potting media. The media considered in the study were Bondo Body Filler (3M Company), Bondo Fiberglass (3M Company), and Smooth-Cast 300 (Smooth-On Company) respectively representing polyester resins, polyepoxide resins, and polyurethane elastomers followed by actual bone cement Simplex P (Howmedica Osteonics Corp., Mahwah, NJ) used as reference. Each medium was tested in bending and tension with an execution of three repetitions for a total of 18 experiments (see Figure 1). Plate fixtures previously designed in Fusion360 (Autodesk, Software Corporation) were used to ensure centering of the bone surrogates in the potting and for interfacing the surrogate to the Instron 8872 Servohydraulic Testing System (Instron Corporation). Tensioning was performed by rigidly connecting the bone surrogate to the actuator of the mechanical testing system (see Figure 1). Instron displacement was imposed at a rate of 20 mm/min until failure while recording load-displacement data at a frequency of 100 Hz. Recorded peak loads, construct stiffness evaluated from the linear regression and the load at which the correlation coefficient dropped below the value of 0.96 were used to characterize the biomechanical performances. Differences among the groups were evaluated using Analysis of Variance (ANOVA) while specific differences were evaluated using T-test with a level of significance set at 5%.

RESULTS: The peak loads ranged from 4119N±500 for the polyester to 9869N±406 for the polyepoxide ($p<0.01$). The latter was also superior to the polyurethane that has shown a peak load of 8350N±155, and comparable to the load found for the Bone cement ($p=0.32$) see Figure 2a. The media with highest stiffness was the bone cement that with a value of 3916N/mm±337 ($p>0.05$). No differences were noted between polyepoxide and polyurethane with values respectively of 2875±234 and 2929N/mm±423 ($p=0.07$) while the polyester revealed to be the softer ($p=0.05$, see Figure 2b). Similarly, the limit identified for the linearity was the lowest in the polyester resin with a value of 2600N±361 ($p<0.05$, see Figure 2c).

DISCUSSION: The results demonstrate a strong influence of the potting media on the construct stiffness. The construct potted with polyepoxide resin has shown high stiffness as hypothesized. The polyester resin was found to be the least suitable for biomechanical testing when compared to the other tested media. While the testing conditions here were particularly designed for long bones, the results can be broadly applied to other types of bones. Some limitations within this study include a small sample size, only considering axial loading of the materials, and not measuring temperatures which can induce soft tissue damage from the exothermic reaction of the chosen media.

SIGNIFICANCE/CLINICAL RELEVANCE: The considered surrogates did not match the performances of bone cement. In comparing experimental data from heterogenous sources, potting media should be considered as source of variability.

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Figure 1: Experimental setup

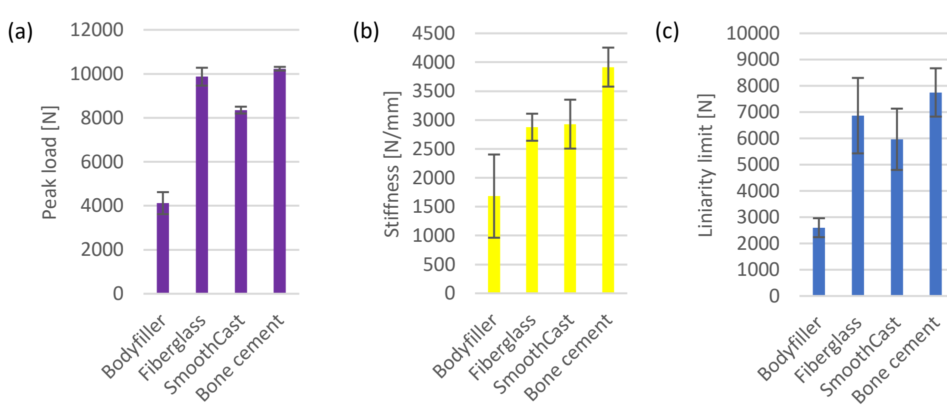

Figure 2: Obtained results in terms of Peak load (a), Stiffness (b), and Linearity limit (c)