**Supplementary Material for Biocompatible Nanocapsules for Self-Healing Dental Resins and Bone Cement**

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## Determination of Materials Parameters from Mechanical Tests

From the tensile tests, the displacement in the specimen was measured within the straight central portion of the constant cross section over the gauge length, $L_i$. The strain, $\varepsilon_{ENGR}$, of the specimen was determined by computing the change in the gauge length divided by the original length, as seen in Equation 1. The axial force that had to be applied to achieve the displacement rate varied as the test proceeded; however, this force was recorded and called the load. This force, P, was divided by the cross-sectional area, $A_i$, of the gauge region to obtain the stress, $\sigma_{ENGR}$, in the specimen. This is shown in Equation 2.

$$\varepsilon_{ENGR} = \frac{\Delta L}{L_i} \qquad \text{Equation 1}$$

$$\sigma_{ENGR} = \frac{P}{A_i} \qquad \text{Equation 2}$$

Stress and strain, based on the initial (non-uniform) dimensions $A_i$ and $L_i$, are known as engineering stress and strain. It was necessary to find the true stress and strain and thereby account for the changing gauge length and cross-sectional area as the test proceeded. True strain, $\varepsilon_T$, is found via Equation 3, and true stress, $\sigma_T$, is found via Equation 4.

$$\varepsilon_T = \ln\left(1 + \varepsilon_{ENGR}\right) \qquad \text{Equation 3}$$

$$\sigma_T = \sigma_{ENGR}(1 + \varepsilon_{ENGR}) \qquad \text{Equation 4}$$

Stress-strain curves were made to compare the mechanical properties of the two types of resins. The stress-strain curves were made by plotting the true stress versus the true strain for each sample.

## West System Epoxy Resin

The West System 105 epoxy resin is based on Bisphenol A diglycidyl ether, and it exhibits comparable properties to methacrylate-based bone cements and dental resins.

The epoxy consists of oxirane, 2,2'-[(1-methylethylidene)bis(4,1-phenyleneoxymethylene)]bis-, homopolymer (CAS #25085-99-8) at a concentration percentage between 60 to 80. The 105 epoxy resin also contains 10 to 30% benzyl alcohol (CAS #100-51-6) by concentration and 5 to 10% phenol-formaldehyde polymer glycidyl ether (CAS #28064-14-4) by concentration. The West System 209 extra slow hardener contains 30 to 60 HPR % fatty acids, C18-unsaturated, dimers, polymers with tall-oil fatty acids and triethylenetetramine (CAS #68082-29-1). It also contains 10 to 30 HPR % cyclohexanamine, 4,4'-methylenebis (CAS #1761-71-3), 10 to 30 HPR % propylene glycol diamine, 2-amino-, diether with Propylene (CAS # 9046-10-0), 7 to 30 HPR % formaldehyde, polymer with benzenamine, hydrogenated (CAS #135108-88-2), 3 to 7 HPR % formaldehyde, oligomeric reaction products with phenol and m-phenylenebis(methylamine) (CAS #57214-10-5), 1 to 5 HPR % 1,3-Benzenedimethanamine (CAS #1477-55-0), and 1 to 5 HPR % triethylenetetramine (CAS #112-24-3). 190 proof ethanol (04-355-454, Fisher) was also used to form the resins.

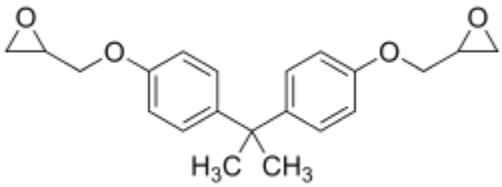


**Figure S1: Bisphenol A diglycidyl ether (CAS 25085-99-8)**

## Impact of Nanocapsules on Mechanical Properties of the Resin

**Table S1. The mechanical properties for the resin samples without capsules are shown.**

| | Samples with No Capsules | | | |
|---|---|---|---|---|
| | Elastic Modulus ($N/mm^2$) | 0.2% Offset Yield Strength ($N/mm^2$) | Ultimate Tensile Strength ($N/mm^2$) | Strain to Fracture (mm/mm) |

| | | | | |
|---|---|---|---|---|
| Sample 1 | 836.6 | 12.008 | 17.4 | 0.0885 |
| Sample 2 | 809.8 | 13.2 | 17.9 | 0.0814 |
| Sample 3 | 848.9 | 11.3 | 17.5 | 0.123 |
| Sample 4 | 801.1 | 11.1 | 17.3 | 0.112 |
| Sample 5 | 947.6 | 13.3 | 19.1 | 0.107 |
| Sample 6 | 852.3 | 14.1 | 19.3 | 0.108 |
| Sample 7 | 786.3 | 11.0 | 17.6 | 0.185 |
| Sample 8 | 987.2 | 11.3 | 16.9 | 0.0753 |
| Sample 9 | 813.6 | 12.5 | 17.1 | 0.108 |
| Sample 10 | 742.6 | 12.6 | 17.0 | 0.0941 |
| Sample 11 | 882.8 | 14.2 | 18.8 | 0.0818 |
| Sample 12 | 695.8 | 11.7 | 16.5 | 0.125 |
| **Average** | **833.7 +/- 80.4** | **12.4 +/- 1.1** | **17.7 +/- 0.9** | **0.107 +/- 0.0294** |

## Samples with monomer capsules

**Table S2. The mechanical properties for the monomer capsule system with BPO mixed directly in the matrix**

| | Pre-Self-Healing | | | |
|---|---|---|---|---|
| | Elastic Modulus ($N/mm^2$) | 0.2% Offset Yield Strength ($N/mm^2$) | Ultimate Tensile Strength ($N/mm^2$) | Strain to Fracture (mm/mm) |
| R1 | 217.2 | 2.8 | 3.6 | 0.0733 |

| | | | | |
|---|---|---|---|---|
| R2 | 408.8 | 3.3 | 4.3 | 0.168 |
| R3 | 288.2 | 3.5 | 4.3 | 0.125 |
| R4 | 322.6 | 3.5 | 4.4 | 0.127 |
| **Average** | **309.2 +/- 79.6** | **3.3 +/- 0.3** | **4.2 +/- 0.4** | **0.123 +/- 0.0388** |

R1 and R2 exhibited self-healing and were retested

**Table S3. The mechanical properties for the monomer capsule system with BPO mixed into the resin post self-healing**

| | Post Self-Healing | | | |
|---|---|---|---|---|
| | Elastic Modulus ($N/mm^2$) | 0.2% Offset Yield Strength ($N/mm^2$) | Ultimate Tensile Strength ($N/mm^2$) | Strain to Fracture (mm/mm) |
| R1 | 615.5 | 0.7 | 1.2 | 0.0118 |
| R2 | 508.1 | 0.9 | 2.1 | 0.100 |
| **Average** | **561.8 +/- 75.9** | **0.8 +/- 0.1** | **1.6 +/- 0.6** | **0.0559 +/- 0.0624** |

## Dual Capsule System

**Table S4. The mechanical properties for the resin samples containing the dual nanocapsule system of the monomer and initiator capsules are listed.**

| | Pre-Self-Healing |
|---|---|

| | Elastic Modulus ($N/mm^2$) | 0.2% Offset Yield Strength ($N/mm^2$) | Ultimate Tensile Strength ($N/mm^2$) | Strain to Fracture (mm/mm) |
|---|---|---|---|---|
| R1 | 366.6 | 4.5 | 5.7 | 0.145 |
| R2 | 511.4 | 5.3 | 6.6 | 0.100 |
| R3 | 512.5 | 5.6 | 6.8 | 0.140 |
| R4 | 506.2 | 5.8 | 7.0 | 0.0943 |
| R5 | 505.3 | 5.7 | 6.7 | 0.156 |
| R6 | 427.2 | 4.7 | 6.2 | 0.157 |
| **Average** | **471.5 +/- 61.0** | **5.3 +/- 0.5** | **6.5 +/- 0.5** | **0.132 +/- 0.0278** |

**Table S5. The mechanical properties for the dual capsule samples after self-healing are shown.**

| | Post Self-Healing | | | |
|---|---|---|---|---|
| | Elastic Modulus ($N/mm^2$) | 0.2% Offset Yield Strength ($N/mm^2$) | Ultimate Tensile Strength ($N/mm^2$) | Strain to Fracture (mm/mm) |
| R4 | 421.5 | 0.5 | 0.6 | 0.0341 |
| R5 | 516.8 | 0.7 | 1.2 | 0.0812 |
| **Average** | **469.2 +/- 67.4** | **0.6 +/- 0.1** | **0.9 +/- 0.4** | **0.0576 +/- 0.0333** |

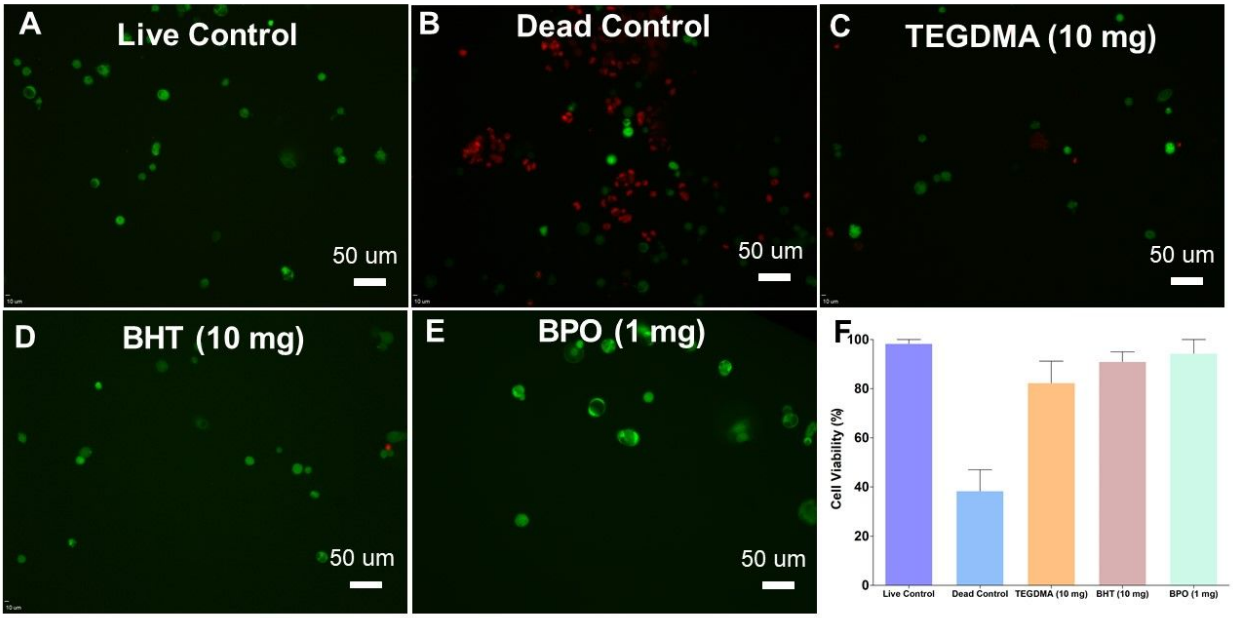


**Figure S2: Results of a live/dead assay in which the cells were exposed to 1 mg or 10 mg of the various encapsulated compounds. 14,500 CaCO2 cells were seeded per well. (A) Live control (cells cultured in media) (B) Dead control (10% ethanol) (C) 10 mg of TEGMA was added to each well. (D) 10 mg of BHT was added to each well. (E) 1 mg of BPO was added to each well. Quantification of the results of the live/dead assay can be seen in (F).**