**Synthesis of A Novel Star-hyperbranched Poly(acrylic acid) for Improved Dental GIC Restoratives**

Dong Xie, Jun Zhao and Yiming Weng
Department of Biomedical Engineering, Purdue School of Engineering and Technology
Indiana University-Purdue University at Indianapolis, Indianapolis, IN 46202, USA

## Introduction

Glass-ionomer cements (GICs) have been successfully applied as dental restoratives for more than 29 years [1]. An acid-base reaction between calcium and/or aluminum cations released from a reactive glass and carboxyl anions pendent on polyacid describes the setting and adhesion mechanism of GICs [2]. Much effort has been made to improve the mechanical strengths of conventional GICs. Light-cured GICs are improved resin-modified GICs with reduced moisture sensitivity, improved mechanical strengths, extended working time and ease of clinical handling [3]. Redox-initiated GICs have also shown attractive properties such as improved mechanical strengths and controllable curing time [4]. The strategy of increasing MW of the polyacid by either introducing amino acid derivatives or N-vinylpyrrolidone has also shown enhanced mechanical strengths [5-6]. More recently, we developed a light-curable glass-ionomer system composed of the 4-arm star polymer with substantially enhanced mechanical properties [7].

The objective of this study was to synthesize and characterize a new star-hyperbranched poly(acrylic acid), use the polymer to formulate the cements with glass fillers, and evaluate the mechanical strengths of the formed cements.

## Materials and Methods

Synthesis of the star-hyperbranched poly(acrylic acid) followed the procedures described elsewhere [5,7]. The initiators and polymers were characterized using FT-IR and NMR. The reaction kinetics was investigated. The effects of arm number and branching were studied as well. A two-component system (liquid and powder) was used to formulate the cements [5,7]. The liquid was made by simply mixing the synthesized polymer with distilled water at a ratio of 70/30 (by weight). Fuji II LC glass powder was used to formulate the cements with a powder/liquid (P/L) ratio of 2.7/1. Fuji II LC was used as control. Specimens were prepared in different molds for the corresponding mechanical testing. After blue-light curing, the specimens were conditioned in distilled water at 37 $^{o}$C for 24 h prior to testing. Compressive strength (CS), diametral tensile strength (DTS), flexural strength (FS), fracture toughness (FT), Knoop hardness number (KHN), attrition and abrasion tests were used to evaluate the mechanical properties of the formed cements. One-way analysis of variance (ANOVA) with the post hoc Tukey-Kramer multiple-range test was used to determine significant differences of the measured properties among the materials in each group. A level of $\alpha = 0.05$ was used for statistical significance

## Results

The results showed that both arm number and branching showed significant effects on viscosity and mechanical strengths. It was found that the more the arm number and branching that the polymer has, the lower the viscosity of the polymer aqueous solution as well as the mechanical strengths of the formed cement. Within the limitations of this study, the experimental cement formulated with the newly synthesized star-hyperbranched polymer exhibited significantly higher mechanical strengths than commercial Fuji II LC (see attached Table). The experimental cement was 51% in CS, 55% in compressive modulus, 118% in DTS, 82% in FS, 18% in FT and 85% in KHN higher than Fuji II LC. The experimental cement was only 6.7% of abrasive and 10% of attritional wear depths of Fuji II LC in each wear cycle. It appears that this novel experimental cement is a clinically attractive dental restorative and may potentially be used for high-wear and high-stress-bearing site restorations.

Comparison between Fuji II LC and EXPGIC

| Property | Fuji II LC | EXPGIC |
|---|---|---|
| CS [MPa] | 212.7 (15) | 320.2 (9.4) |
| Modulus [GPa] | 5.33 (0.09) | 8.27 (0.1) |
| DTS [MPa] | 31.2 (2.2) | 67.9 (2.7) |
| FS [MPa] | 55.8 (4.1) | 101.4 (7.6) |
| FT [$MPa \cdot m^{0.5}$] | 0.94 (0.01) | 1.11 (0.18) |
| KHN | 31.7 (1.0) | 58.5 (0.6) |
| Abrasion [$nm \cdot cycle^{-1}$] | 3.90 (0.81) | 0.26 (0.05) |
| Attrition [$nm \cdot cycle^{-1}$] | 7.21 (1.99) | 0.73 (0.20) |

## Acknowledgement

This work was sponsored by NIH challenge grant (RC1) DE020614-01.

## References:

1. Davidson et al., Advances in glass-ionomer cements. 1999.
2. Wilson et al., Glass-ionomer cements. 1988.
3. Wilson AD. Int J Prosthodont 1990;3:425-429.
4. Xie et al., Eur Polym J 2004;40:343-351.
5. Xie et al., Biomaterials 2004;25:1825-1830.
6. Xie et al., JMS, Pure Appl Chem 1998;A35:1615-1629.
7. Xie et al., Dent Mater 2007: 23:994-1003.