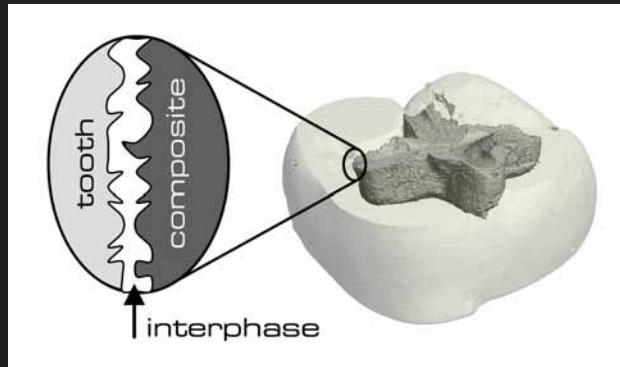


Dental Materials

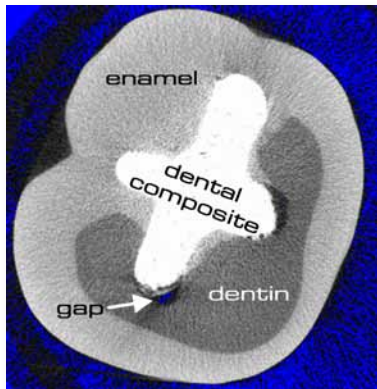
Objective

Our goal is to provide reference materials and clinically relevant measurement methods to facilitate a rational approach to dental materials design, thus enabling improvements in the clinical performance of dental materials. In particular, methods for determining long-term performance of polymeric dental materials are needed to provide predictive information regarding the clinical longevity of materials being developed, including materials with cariostatic and regenerative properties.



Impact and Customers

- The Center for Disease Control reports that over 40 % of children aged 5 to 17, and most adults, have dental caries (tooth decay). The annual US cost for treating tooth decay amounts to billions of dollars.

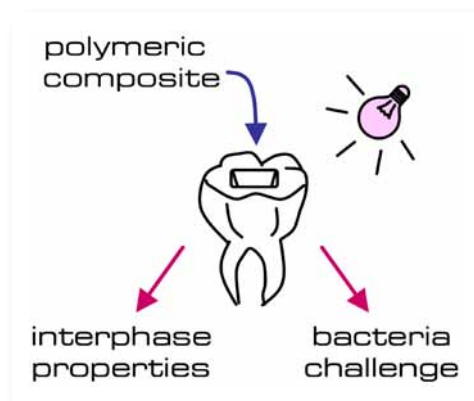


- Standard materials and clinically relevant measurement methods developed at NIST will enable and accelerate the improvement of polymer-based dental materials, the fastest growing segment of the dental materials market.
- With a program in dental materials dating back to 1919, collaborations with the American Dental Association (ADA) since 1928, and collaborations with NIH since 1964, NIST has a long history of impact in addressing measurement needs for dental materials.
- Customers include the National Institute of Dental and Craniofacial Research (NIDCR), the ADA Foundation, the Food and Drug Administration (FDA), the dental materials industry, and academic research laboratories.

Approach

Polymer-based dental materials are increasingly used to treat dental caries. Yet, restorations are often replaced due to secondary caries at the tooth-composite interphase. Current test methods do not predict these clinical outcomes and are not consistent among labs. To address these issues, we are developing and will disseminate clinically relevant methods for evaluating critical aspects of dental materials related to the tooth-composite interphase. We are discussing our method development efforts with dental materials manufacturers and the FDA to ensure the methods are relevant.

Our current focus is on the development of two standard methods: one for a material's resistance to microleakage at the tooth-composite interphase, and the other for resistance to bacteria challenge. Together, these tests will quantify a significant portion of a material's ability to resist secondary caries. The methods will be sufficiently versatile to handle simple screenings and will lead to quantitative evaluation and prediction of material performance. These measurements will be straightforward both in instrumentation / technique, and in interpretation of results for relevance and usefulness in a variety of laboratories, from small research groups to large corporations.

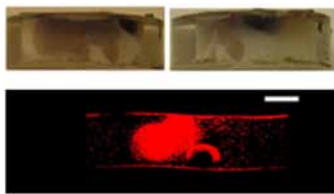


Accomplishments

We are in the second year of a five year plan to provide modernized tools for the characterization of dental composite materials.

Shrinkage and Leakage Characterization

We have established protocols that use X-ray microcomputed tomography (μ CT) to quantify and map two parameters that change upon polymerization and may affect restoration longevity: 1) polymerization shrinkage, and 2) the resultant gaps that appear between the material and tooth structure and often produce leakage. For a given material, polymerization shrinkage was not affected by sample volume or geometry (degree of constraint), but leakage formation was greatly affected.



Leakage visualization and prediction

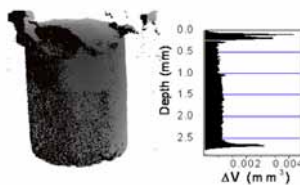
Leakage was quantified for the first time in terms of absolute area and percentage of the composite-cavity interphase. An automated imaging process was developed to convert 3D leakage predictions into 2D leakage maps. Leakage areas predicted by image analysis of μ CT images agreed well with those observed by dye penetration (Figure above). Leakage occurs in spatially non-uniform ways.



2D μ CT image and 3D reconstruction

μ CT imaging was also applied to evaluate shrinkage and leakage for composites placed in extracted human teeth. The second figure shows a 2D μ CT image slice that clearly distinguishes the composites (white) from dentin (dark gray) and enamel (light gray), and a 3D reconstruction of two restoratives in the same tooth to eliminate tooth-to-tooth variations.

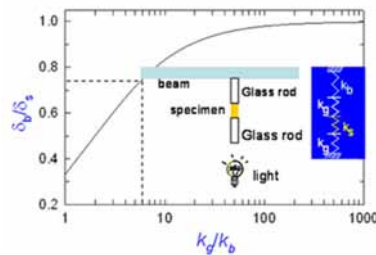
Analysis in teeth showed results in terms of polymerization shrinkage and leakage profiles comparable to those obtained in model cavities. Leakage was presented in 3D (below, in black). The corresponding shrinkage (ΔV), measured as a function of sample depth is also shown.



3D Leakage prediction

Characterization of Stress Development

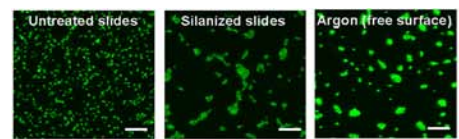
Mechanics theories were used to assess the sensitivity and accuracy of an existing instrument for measuring polymerization stress. Analysis revealed that modifications in instrument configuration (i.e., aspect ratio and beam stiffness) are needed to optimize sensitivity. After optimization, effects of sample geometry on stress development will be evaluated.



Beam sensitivity to polymerization stress

Bacterial Challenge

We have found that slight variations in polymer fabrication protocol alter the surface hydrophobicity, surface chemistry, and the resultant initial bacterial colonization on films prepared from the same dental polymer. This work is part of our effort to develop methods for simulating the oral environment through bacterial challenge. As a first step, we have evaluated bacterial colonization on dental polymers using *Streptococcus mutans*, a commonly studied oral bacterium that contributes significantly to tooth decay. Material surface preparation had a surprisingly large impact on the bacteria colonization pattern. We plan to correlate the colonization behaviors with the corresponding biofilm structures.



Scale bars = 10 μ m

S. mutans colonization on polymer films

Combinatorial Approach

In support of the material characterization and cell-material interaction work, we have developed various two dimensional (2D) combinatorial platforms for rapidly screening the properties of dental polymers/composites.

Ensuring Relevance

In order to ensure that the methods we develop can be used in an industrial lab environment, we have met with and discussed our method development efforts with industrial customers, other government agencies, and academia. We are actively involved in the American Dental Association-Standards Committee for Dental Products (ADA-SCDP).

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Learn More

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Publications

Lin NJ, Hu H, Sung L and Lin-Gibson S *Quantification of Cell Response to Polymeric Composites Using a Two-Dimensional Gradient Platform* Combinatorial and High Throughput Chemistry, in press (2009)

Lin-Gibson S, Sung L, Forster AM, Hu H, Cheng Y and Lin N *Effects of Filler Type and Content on Mechanical Properties of Photopolymerizable Composites Measured Across Two-Dimensional Combinatorial Arrays* Acta Biomaterialia, DOI information: 10.1016/j.actbio.2009.01.043 (2009)

Sun J, Eidelman N and Lin-Gibson S *3D Mapping of Polymerization Shrinkage Using X-ray Micro-Computed Tomography to Predict Microleakage* Dental Materials, 25: 314 (2009)

Sun J and Lin-Gibson S *X-ray Microcomputed Tomography for Measuring Polymerization Shrinkage of Polymeric Dental Composites* Dental Materials, 24:228 (2008)