COMMENTARY

HARDNESS OF THREE RESIN-MODIFIED GLASS-IONOMER RESTORATIVE MATERIALS AS A FUNCTION OF DEPTH AND TIME

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So what did these authors want to know? Did they really get an answer to their question? One of the key features for any experimental design is to mimic the real situation as much as possible when you are asking questions about potential clinical performance. What happens far too often is that experimentalists choose methods that are convenient and not necessarily ones that will provide the best or most appropriate information. There are four things about the current experiment that might have been done differently:

1. Specimens could have been more appropriate in design to allow the authors to assess post-curing as a true function of depth.
2. Specimens could have been conditioned differently.
3. Controls could have been introduced to provide a perspective for the results.
4. Chemical analysis could have been conducted to monitor phase changes during the experimental changes.

After the fact, the authors did acknowledge some of these potential effects. These difficuluties are not unique just to this particular experiment. Let us look at each of these four things.

First, the authors followed a time-tested method for evaluating the "immediate" depth-of-cure effects for a light-polymerized system. Their experimental model was a disk. They compared the hardness of the top with the bottom surfaces after top-side light polymerization. Different thicknesses of disks were used to assess thickness effects. This would have been fine if the only concern was for initial differences in top and bottom surfaces. However, these authors had an experimental question that searched for differences as a function of depth over times up to 1 year. Stated differently, the authors were not investigating the differences between the top and bottom surfaces of a 2-mm thick restoration but rather the difference between the top surface and 2 mm into a bulk specimen that might be several millimeters thick. For that reason, their design did not produce the answers they were really seeking. A bottom surface of a 2-mm thick disk and a 2-mm deep position within a thicker specimen see different environments over time. Surfaces are directly exposed to conditioning media. Interior environments depend on complex diffusion events with both inward and outward diffusion.

Over time, both superficial and bulk materials are subject to several continuing chemical reactions or mechanical events but not necessarily at the same rate:

1. There are continued curing reactions that the authors seemed most interested in evaluating.
2. There is diffusion of water into the material that may affect portions of the bulk differently depending on the distance from the surface. This situation was not mimicked by the authors experiment. Water may contribute to chemical changes and also to mechanical plasticization of the mass.
3. There are exchange reactions taking place with ions in saliva moving into the material and fluoride ions traveling out. These are not mimicked in the present experiment. Bulk changes will most likely not occur at the same rate as superficial ones.
4. There are unwanted chemical reactions that could take place in the material over long periods of time because of the variety of constituents changing. An example might be the formation of hydroxide phases at the boundaries of ceramic glass phases.
5. There could be continuing exposure to visible light in the real situation which could contribute to post-curing. The authors suppressed these changes by storing their specimens in the dark.

To begin to get at the real question, a larger specimen design would be more appropriate. To obtain measurements, an alternative specimen would then be bisected at each specific inspection time and the hardness measured at various depths (see Figure 1). Presumably, the specimens should ensure the same amount of diffusion distance from all exterior surfaces to the test zone. To test a 2-mm deep zone, a cylindrical specimen would need to be at least 4 mm in

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diameter and 4-mm thick. For testing any depth, a specimen could then be bisected along the long axis of the cylinder and measured along the central core at each depth of interest. In the present experiment, the bottom surfaces were far away during the initial curing event but were top surfaces for all the other events of water diffusion and secondary reactions.

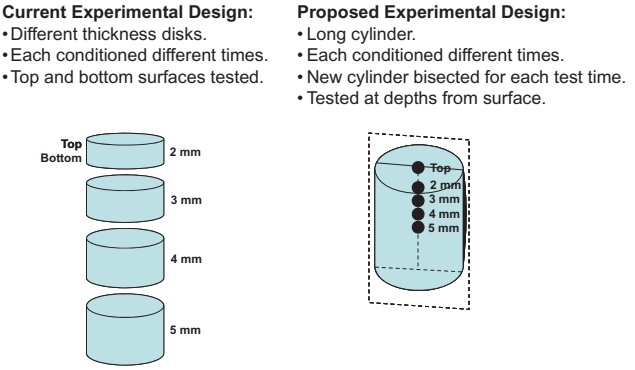

Figure 1. Comparison of experimental design of authors (left) to proposed design (right) that would more accurately determine the true bulk properties occurring at different depths.

Second, conditioning should have involved immersion. Specimens in the present experiment were stored in a humidor at 98% humidity. This is not the situation in the mouth. Materials should be bathed in saliva-like solutions so they imbibe water and are exposed to ions at concentrations typical of saliva. Storage solutions should allow F release and be changed often to maintain large diffusion gradients. While water probably coated the surfaces of the specimens in the humidor as a result of the high humidity, the film did not contain saliva ions and was not replenished quickly to facilitate outward F diffusion and prevent local superficial F concentration. Therefore, the surfaces that the authors were testing would not have mimicked the clinical situation very faithfully.

Third, it would have been very helpful to include additional controls for these experiments. As designed, the top surfaces were considered the reference value for the bottom surfaces. Yet, the top surfaces were not typical for the clinical situation as pointed out earlier. An alternative set of controls could have been the same specimens cured, immersed in water, and left in ambient light. Their values should have been the reference ones. Another possible control could have been another set of specimens made from 1-mm increments (to create a fully cured material) and then conditioned over time.

Finally, for complex microstructures such as those of resin-modified glass-ionomers, it is crucial to include some sort of phase analysis (metallurgical or chemical) to begin to understand what reactions might be occurring at what rates. Chemical curing reactions could be making things stronger. Water diffusion could be making things weaker. Secondary reactions could be making things stronger or weaker. It is potentially possible that many reactions are taking place but no net change in mechanical properties is being observed. The authors might be concluding from their hardness value that no changes had occurred at all.

These types of problems are not ones unique to this experiment but very common to all dental materials testing. What is important is perhaps to invest more in experimental planning to be able to understand events. It is not scientifically sound, as it appears in most dental materials publications, to simply conclude that the events could not be fully understood and that more research is needed. Experiments should be designed to reveal all the needed information to truly explain an answer to the question.

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