New understanding of avian eggshell attachment has implications for medical, egg industries

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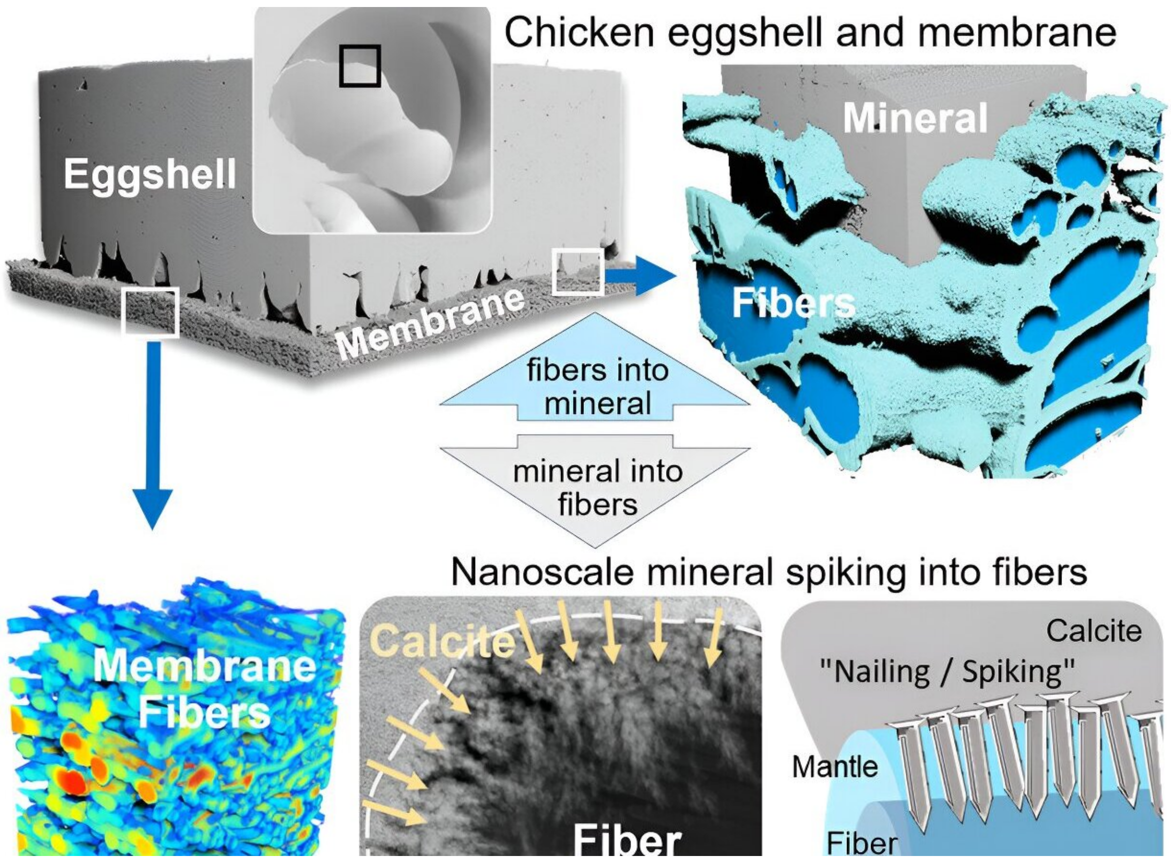

Graphical abstract. Credit: *iScience* (2023). DOI: 10.1016/j.isci.2023.108425

Athletes often suffer injuries to ligaments in their knees, particularly to the anterior cruciate ligament or ACL. While surgery to replace these torn ligaments is becoming increasingly common around the world it often needs to be repeated. That's because it has proved challenging to anchor fibrous, soft and wet ligament grafting material into hard bone.

Now, McGill University researchers have new information from the eggshell membrane in chicken eggs that could help change this picture thanks to the potential it offers for improvements in tissue engineering and biomaterial grafts.

Their findings also have the potential to reduce losses for commercial egg and poultry producers.

Anchoring soft and wet fibers by 'nailing' them in place

The researchers discovered how the hard shell of a bird egg attaches to the underlying wet fibrous membrane of the egg (the thin membranous layer found inside the shell seen when peeling a hard-boiled egg). By using advanced 3D imaging X-ray and electron microscopes together with cryo-preservation methods the research team was able to peer into this interface in three dimensions to visualize and quantify the interlocking phenomenon.

"Until now, no one had considered how this interface between these two very dissimilar substances, one a hard biorock, and the other a soft fibrous membrane, might be secured at the nanoscale," says Marc McKee, a professor in the Faculty of Dental Medicine and Oral Health Sciences, the principal investigator of the study conducted by doctoral student Daniel Buss and published recently in *iScience*.

"What we found about this soft-hard interface is quite remarkable."

Nanospikes increase the surface area of contact between soft and hard materials and ensure food safety

The McGill team discovered that, at a certain stage in the development of an egg prior to laying, the shell sends mineral nanospikes into the soft and compliant surface fibers of the underlying eggshell membrane. This membrane surrounds the soft contents of the egg interior, being either the egg white and yolk from table eggs, or the developing chick embryo in a fertilized and incubated egg.

This nanospiking attachment process between two highly dissimilar materials substantially increases the surface area of the interface between the soft and wet organic fibers and the hard and largely dry inorganic mineral. Such an attachment importantly anchors and secures this soft-hard interface to prevent slipping and sliding of the fibers within the shell.

Otherwise, detachment of the membrane from the shell can be lethal for the embryonic chick, can weaken the shell, and/or can allow the invasion of pathogens (such as salmonella) into the interior contents of the egg. Food safety of the table egg relies on an intact shell that is well-integrated with its underlying membrane.

Implications for medical procedures and commercial egg production

With this new understanding of the shell-membrane interface as being a characteristic feature of strong, safe and healthy eggs, losses for table egg producers and poultry breeders might be reduced through the establishment of commercial genetic breeding programs that maintain or maximize this interfacial structure.

The findings might also potentially lead to new engineered, hybrid composite material designs, and to new procedures to improve the outcomes of various medical and dental reconstructive surgeries, both of which may require attaching soft wet fibers to hard materials.

More information: Daniel J. Buss et al, Attaching organic fibers to mineral: The case of the avian eggshell, *iScience* (2023). DOI: 10.1016/j.isci.2023.108425

Provided by McGill University

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