A nanophenomenon that triggers the bone-repair process

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Researchers of the ICN2 Oxide Nanophysics Group led by ICREA Prof. Gustau Catalan have resolved one of the great unknowns in bone remodelling: how the cells responsible for forming new bone tissue are called into action. Their work reveals the possible role of an electromechanical phenomenon at the nanoscale, flexoelectricity, not only in stimulating the cell response, but in precisely guiding it throughout the fracture repair process.

The researchers have discovered that bone is flexoelectric, positing the possible role of flexoelectricity in the regeneration of bone tissue in and around the kind of microfractures incurred in bones on a daily basis. Their findings, published today in *Advanced Materials* with lead author Fabián Vásquez-Sancho, have potential implications for the prosthetics industry and the development of biomimetic self-healing materials.

Bones were already known to generate electricity under pressure, stimulating self-repair and remodelling. First reported in the late 1950s, this was initially attributed to the piezoelectricity of bone's organic component, collagen. However, studies have since observed markers of bone repair in the absence of collagen, suggesting that other effects are at play. In this work ICN2 researchers have revealed just such an effect: the flexoelectricity of bone's mineral component.

Flexoelectricity is a property of some materials that causes them to emit a small voltage upon application of a non-uniform pressure. This response is extremely localised, becoming weaker as you move away from the point of maximum stress along a strain gradient. In microfractures it is localised to the leading edge or tip of the crack, an atomically small site that, by definition, concentrates the maximum strain a material is able to withstand before full rupture. The result is a an electric field of a magnitude that, at this local level, eclipses any background collagen piezoelectric effect.

By studying strain gradients in bones and pure bone mineral (hydroxyapatite), the researchers have been able to calculate the precise magnitude of this flexoelectric field. Their findings show that it is sufficiently large within the required 50 microns of the crack tip to be sensed by the cells responsible for bone repair, which would directly implicate flexoelectricity in this process.

Furthermore, since the cells responsible for synthesising new bone tissue (osteoblasts) are known to attach close to the tip, it would appear that the electric field distribution signals this point as the centre of damage, becoming a moving beacon for repair efforts as the crack is healed.

These results hold promise for the prosthetics industry, where new materials that reproduce or amplify this flexoelectric effect could be used to guide tissue regeneration and enable a more successful assimilation of implants.

More information: Fabian Vasquez-Sancho et al. Flexoelectricity in Bones, *Advanced Materials* (2018). DOI: 10.1002/adma.201705316

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