

Local curvature reveals geometry-specific cytoskeleton and nucleus adaptations in hMSCs

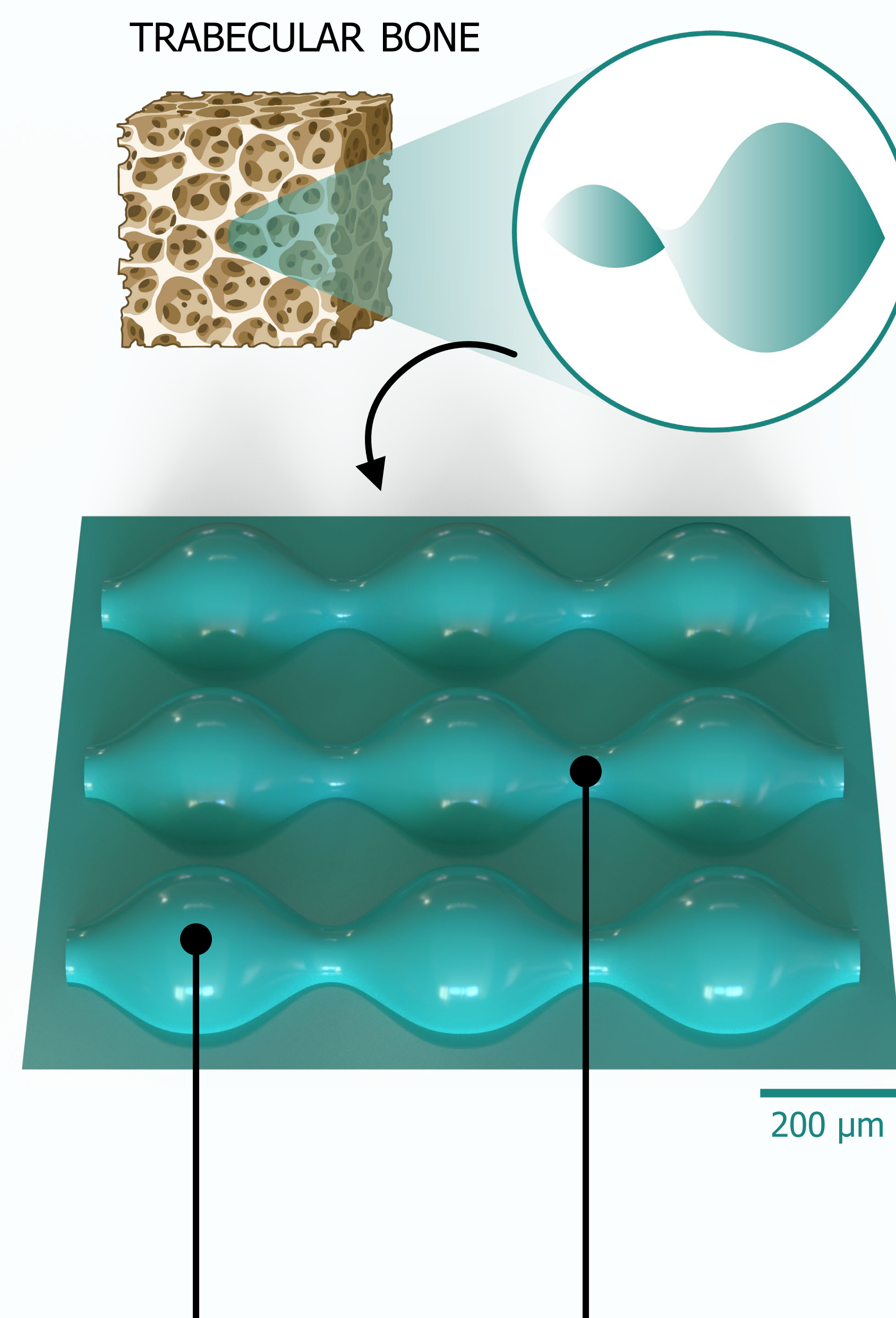
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INTRODUCTION & AIM

Current orthopedic implants often fail to achieve sufficient osseointegration, limiting their long-term success [1]. Biomaterial surface modification can improve implant-tissue integration, with geometrical cues like curvature emerging as a powerful tool [2].

Surface curvature can shape human mesenchymal stromal cell (hMSC) fate via cytoskeleton and nucleus reorganization [3]. Nevertheless, trabecular bone is rich in both convex and locally concave curvatures [3,4], motivating our investigation into how changing local curvature affects hMSC behavior at the single-cell level.



METHOD

Convex and concave unduloid fields were fabricated on polystyrene (PS) using 3D-printed molds and replica molding into PDMS and PS. hMSCs were cultured on curved and flat surfaces for 24 hours, stained for F-actin and nuclei, and imaged by confocal fluorescence microscopy.

The local principal curvatures (κ_1 , κ_2) were extracted at the nucleus centroid using MATLAB and ImageJ, and linked to the 2D and 3D morphological descriptors:

- Cell and nucleus area (n=74)
- Cell aspect ratio (n=74)
- Nucleus height (n=64)
- 3D nucleus shape index (n=64)

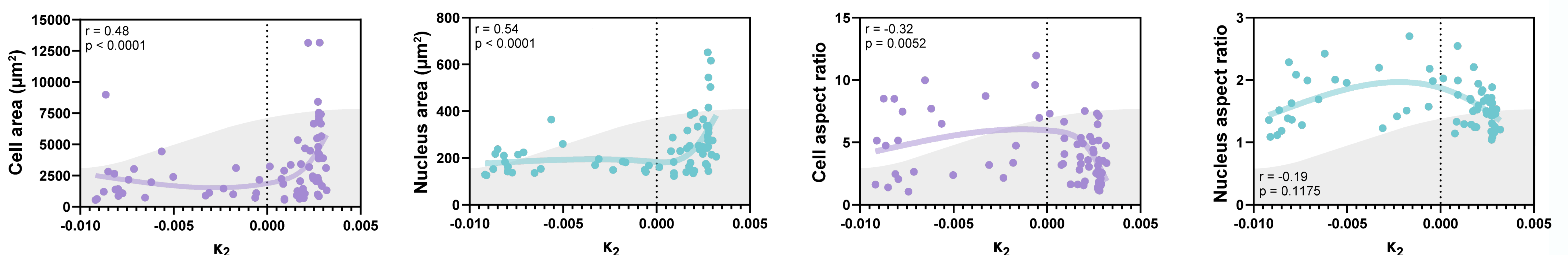
CONVEX PEAK ($\kappa_1 > 0$, $\kappa_2 > 0$)

Cells and nuclei are larger and spread. The nucleus flattens significantly, with apical actin cap formation.

SADDLE AREA ($\kappa_1 > 0$, $\kappa_2 < 0$)

Cells and nuclei are smaller and more elongated. The nucleus adopts an elongated, spindle shape.

2D METRICS: CONVEX UNDULOIDS

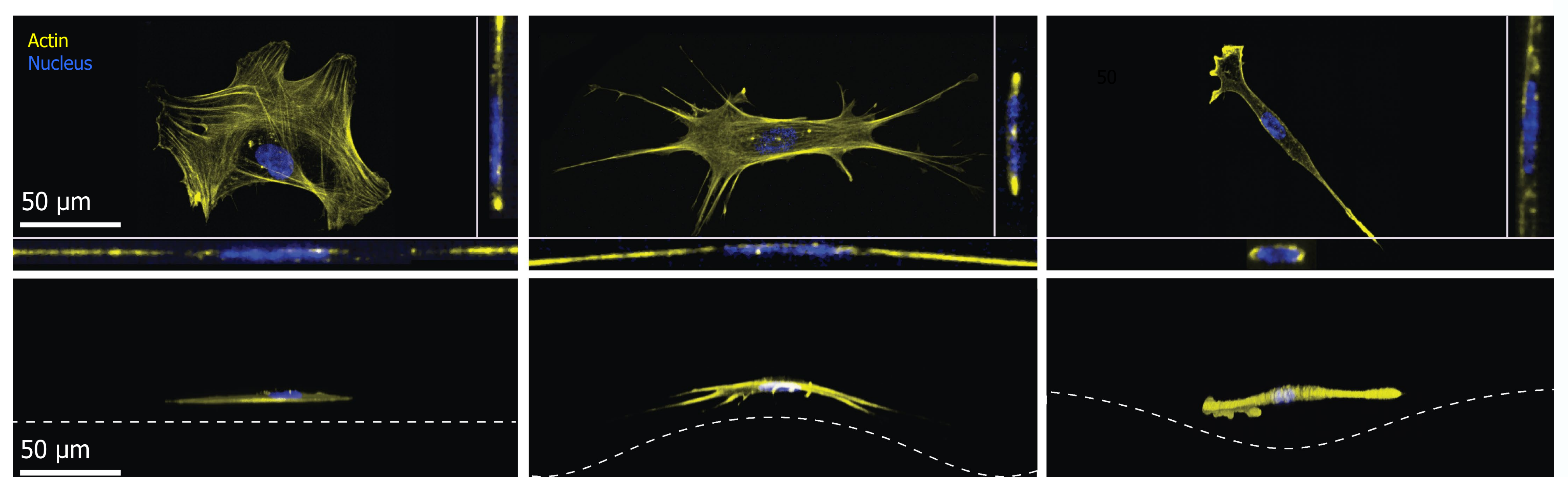
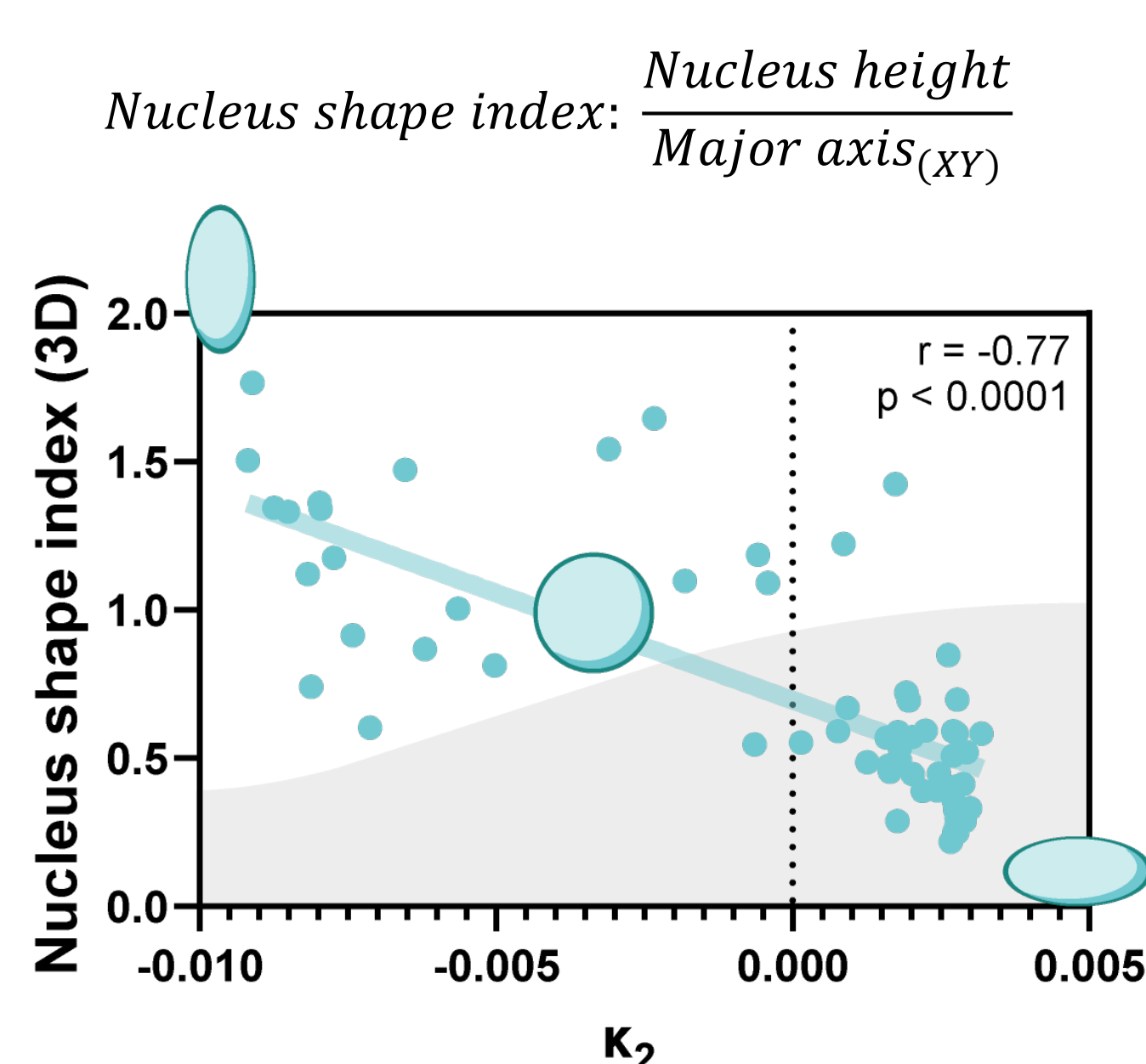


3D METRICS: CONVEX UNDULOIDS

FLAT CONTROL

CONVEX PEAK

SADDLE AREA



WHAT ABOUT CONCAVE UNDULOIDS?

On concave samples, most cells stretched over the concavities, resulting in no significant curvature sensing and effects.

CONCLUSIONS

Local surface curvature strongly influences cell and nucleus morphology in the case of convex unduloids. Whether mechanotransduction translates these changes into hMSC commitment remains to be investigated. These findings position curvature as a powerful parameter for cell-instructive biomaterials used in orthopedics.