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Microstructurally Refined Ti-6Al-7Nb via High-Pressure Sliding Modulates Osteoblast Adhesion and Proliferation

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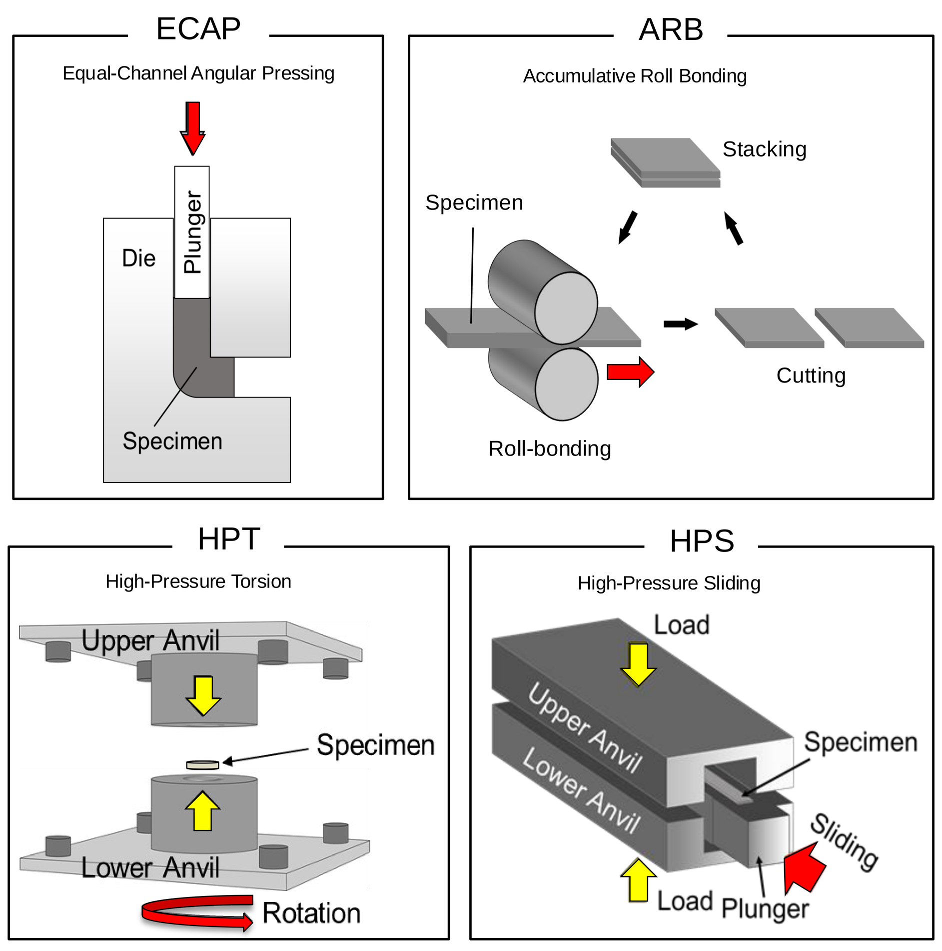
INTRODUCTION & AIM

The demand for dental implants continues to increase with aging populations, creating a need for titanium alloys with improved mechanical reliability.

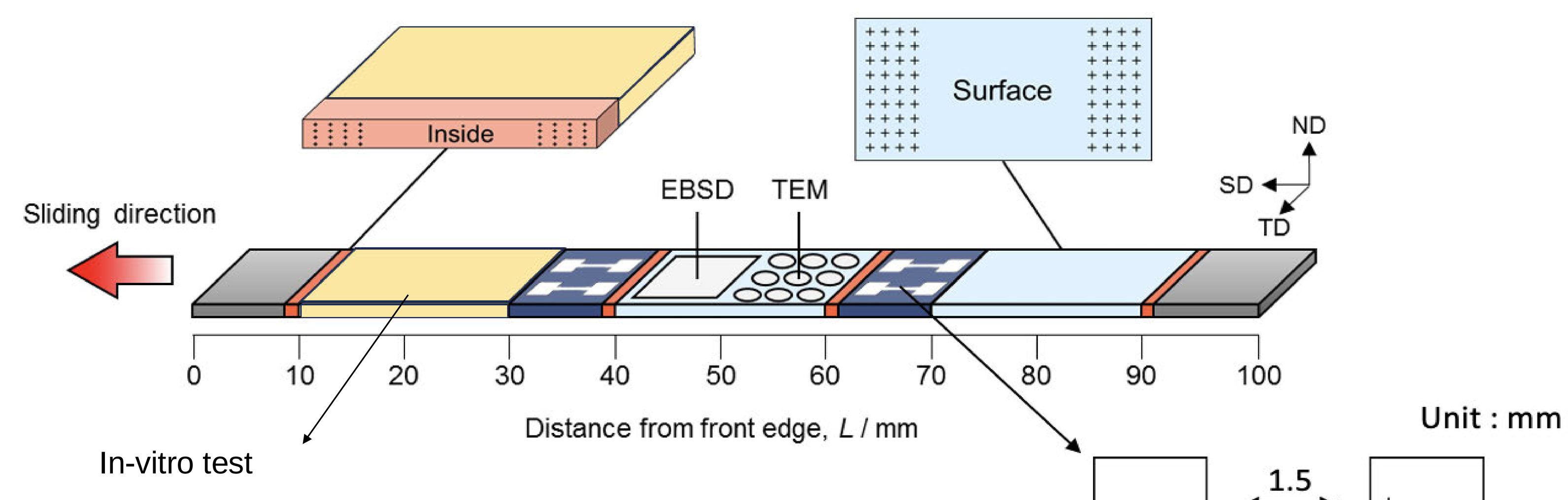
Various strengthening approaches have been developed to produce ultrafine-grained structures through severe plastic deformation (SPD).

While these techniques effectively enhance mechanical properties, High-Pressure Sliding (HPS) is a promising SPD technique capable of processing larger specimens while achieving significant grain refinement.

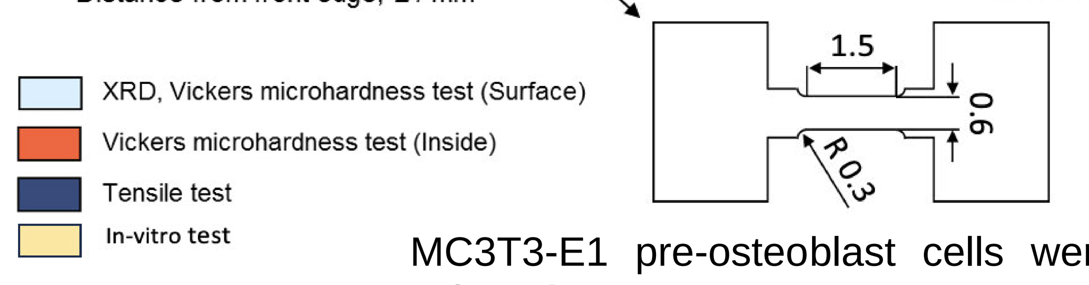


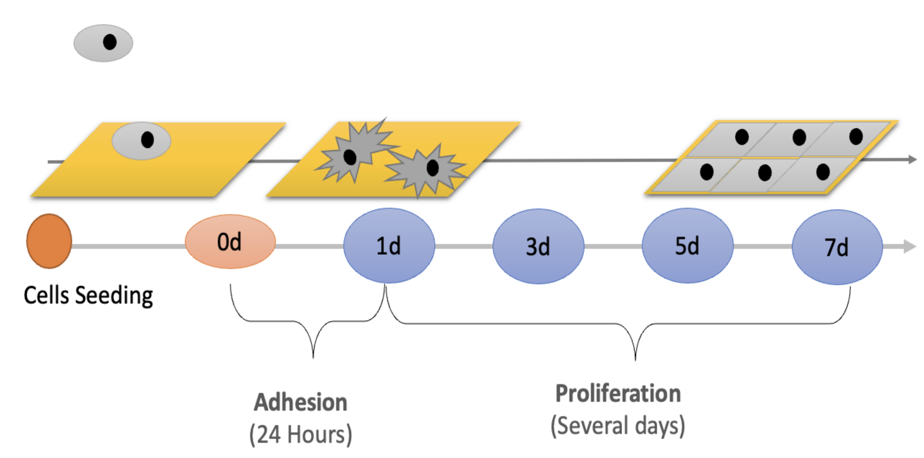
To investigate how HPS-induced microstructural evolution influences mechanical properties and biological responses, with particular attention to the relationship between microstructure, surface/interface characteristics, and early-stage cell–material interactions.

METHOD



Temperature	room temperature
Pressure, P	3 GPa
Sliding speed, v	1 mm s^{-1}
Sliding distance, X	5, 10, 15, 20 mm

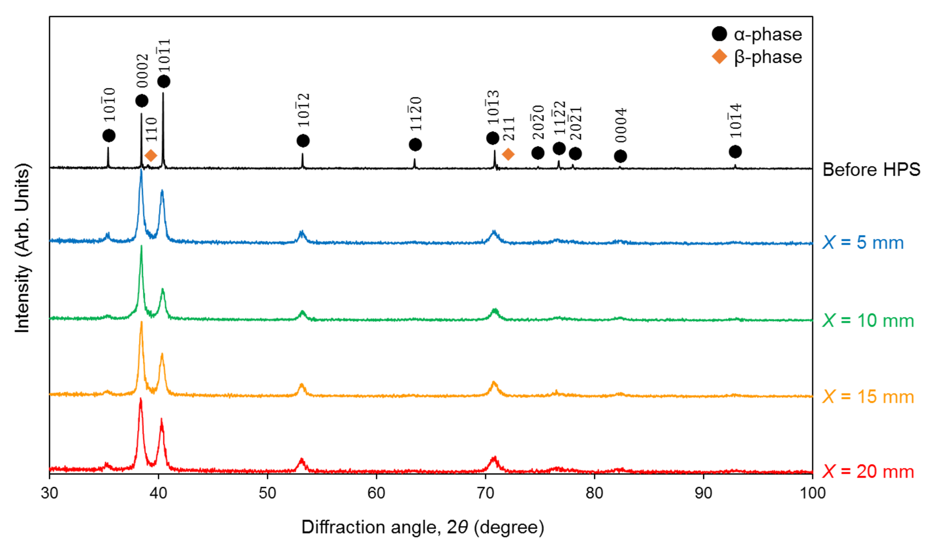




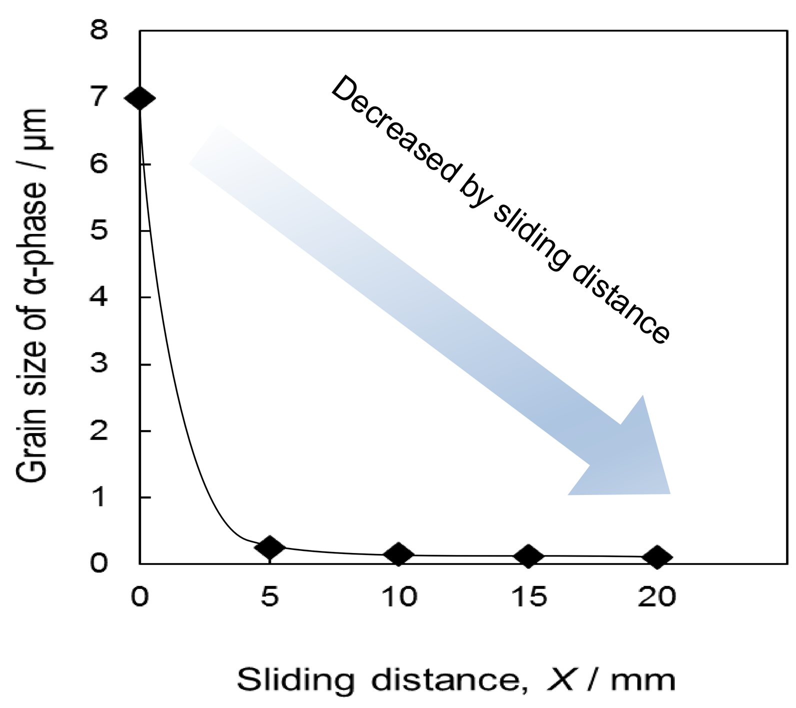
MC3T3-E1 pre-osteoblast cells were cultured on HPS-processed specimens.
Cell adhesion was examined before 24h, while cell proliferation was evaluated at 1, 3, 5, and 7 days using the WST-8 assay.

Osteogenic-related gene expression, including **RUNX2, Akp2** and **COL1α**, was analyzed by real-time polymerase chain reaction (RT-PCR) to investigate the influence of HPS-induced microstructural changes on cellular activity and osteogenic response.

RESULTS & DISCUSSION

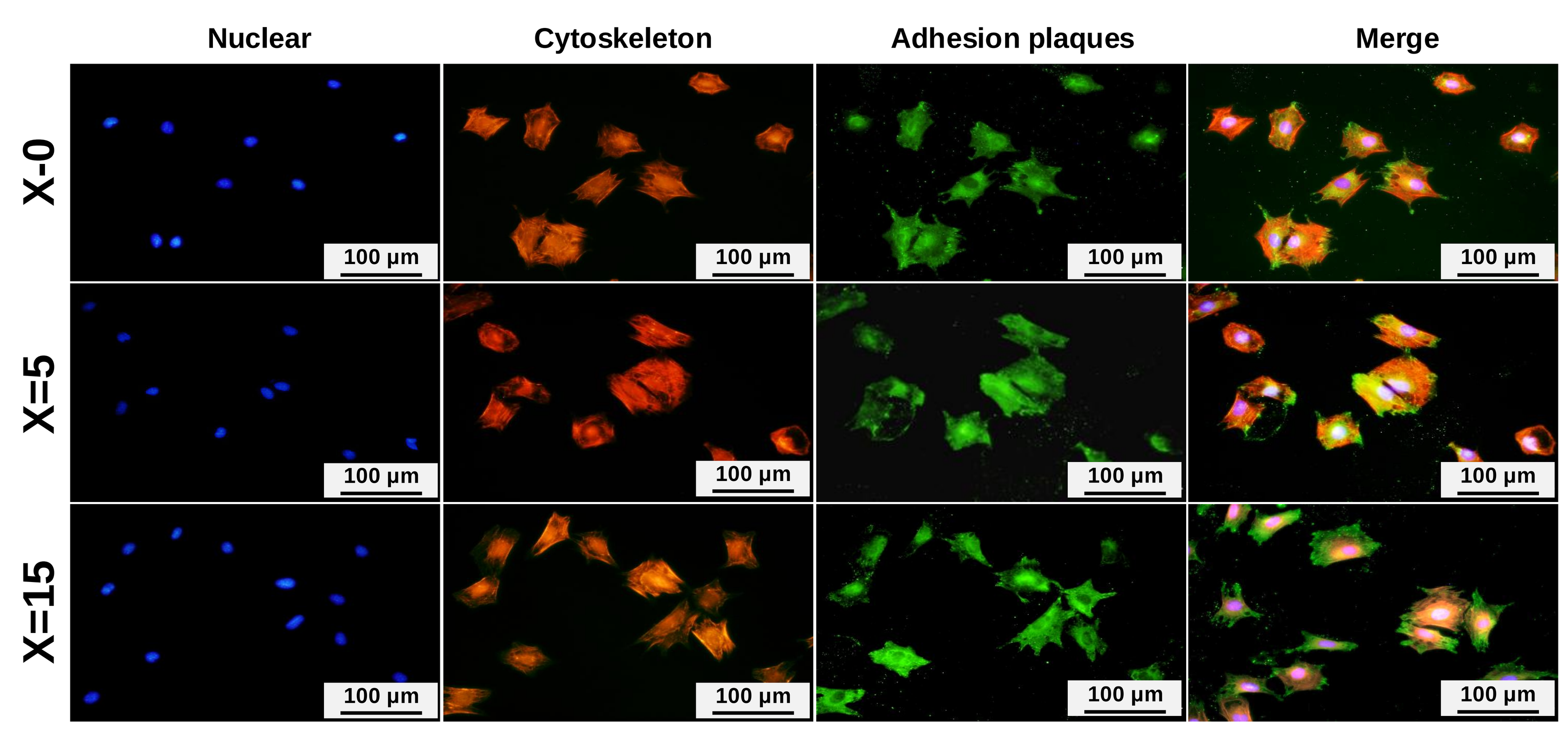


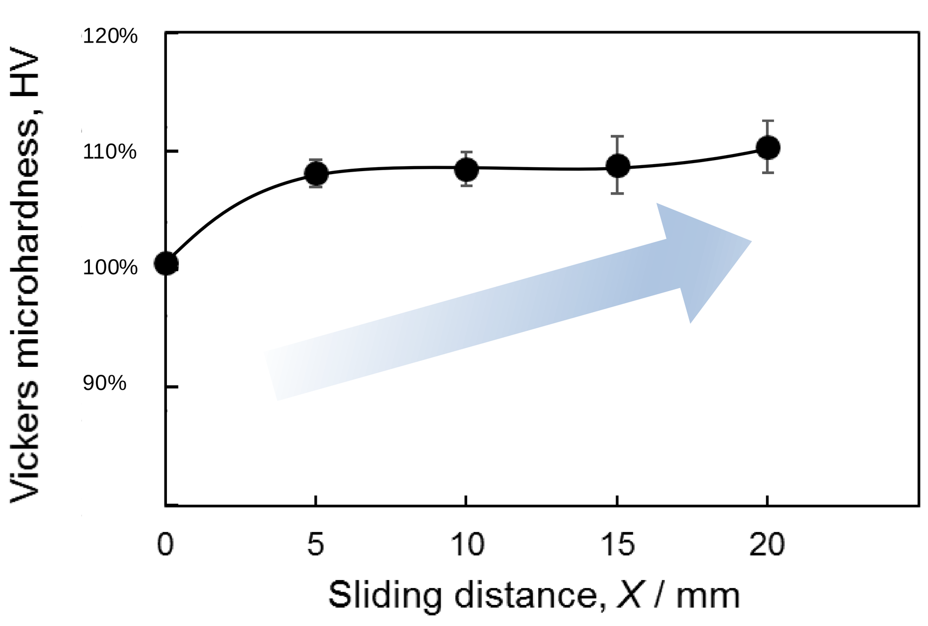
XRD patterns of Ti-6Al-7Nb alloys before and after HPS processing:
The α+β phase structure was maintained after HPS processing, and no phase transformation was observed.



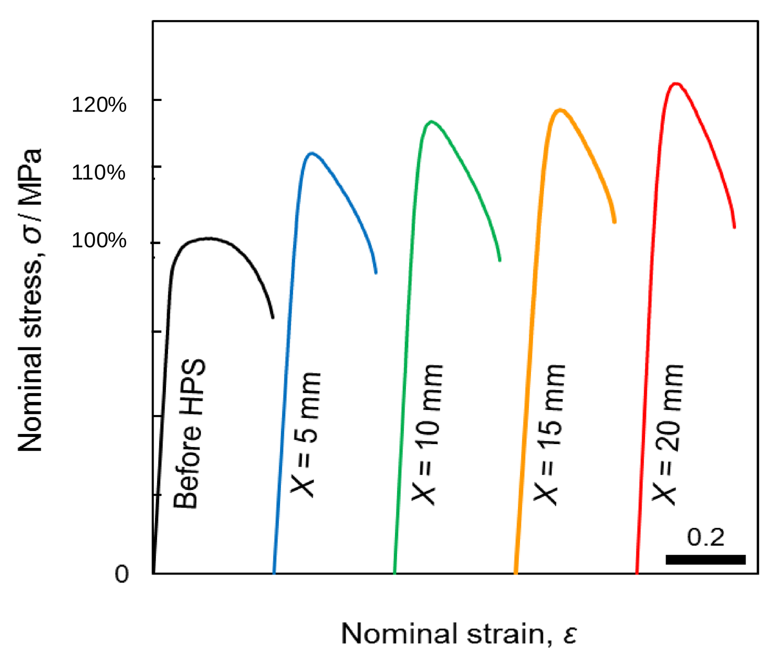
Grain refinement occurred rapidly during the early stage of deformation and gradually approached saturation at larger sliding distances.

These microstructural changes shown early may also modify surface characteristics, potentially influencing subsequent cell–material interactions.

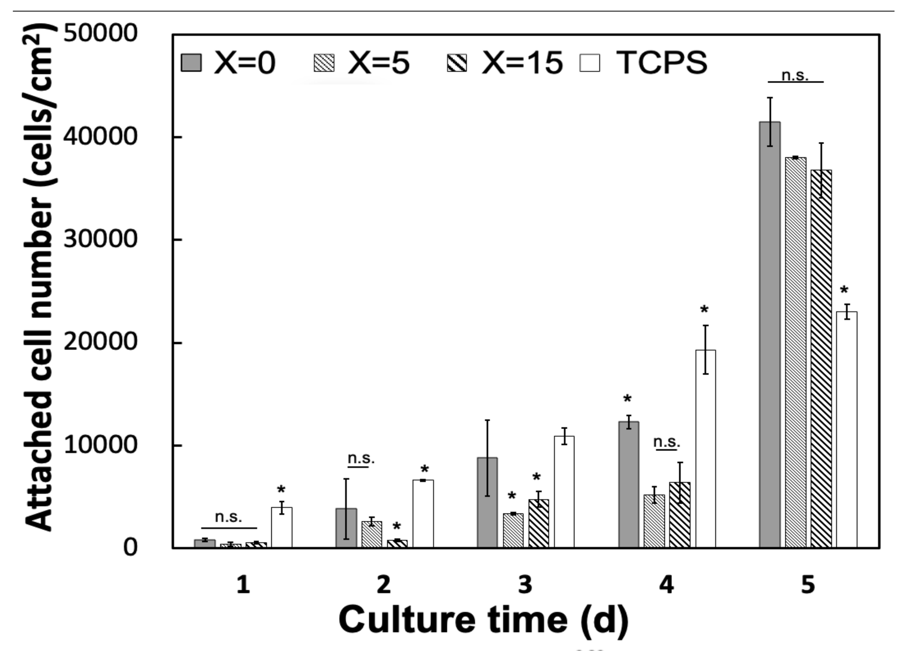




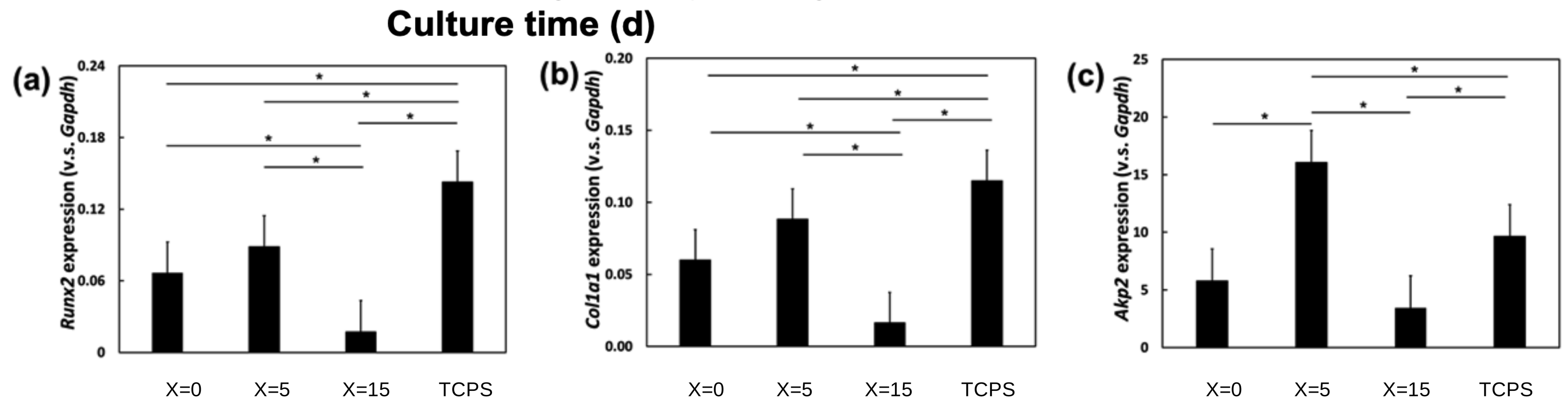
HPS processing significantly increased the tensile strength of Ti-6Al-7Nb alloys while maintaining considerable ductility. The highest tensile strength exceeded 110% after processing at X = 20 mm.
(Normalized value = 100%)



Vickers hardness increased from 100% to 110% after HPS processing and remained relatively stable with increasing sliding distance.
(Normalized value = 100%)



Distinct proliferation responses were observed on differently processed surfaces, suggesting a potential relationship between HPS-induced microstructural evolution and cellular activity



Variations in osteogenic-related gene expression suggest that HPS-induced microstructural changes may influence cellular functions associated with osteogenic activity.

CONCLUSIONS

HPS processing successfully produced ultrafine-grained Ti-6Al-7Nb alloys with enhanced hardness and tensile strength while maintaining adequate ductility.
HPS-induced microstructural evolution and texture development altered osteoblast focal adhesion distribution, accompanied by enhanced proliferation and osteogenic-related gene expression.

These findings suggest that HPS can simultaneously alter mechanical properties and biological responses through microstructural engineering of Ti-6Al-7Nb alloys.

FUTURE WORK

- Further investigate whether directional deformation during HPS processing introduces anisotropic surface characteristics beyond conventional grain refinement effects.

- Examine how microstructural evolution influences protein adsorption, focal adhesion organization, and early-stage cell attachment behavior.