Human Mesenchymal Stem Cell Morphology, Migration, and Differentiation on Micro and Nano-Textured Titanium

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Introduction

Early attachment, rapid migration, and improved differentiation of osteoblasts are necessary to colonize the surface of biomedical implants, preventing biofilm formation and implant-associated infection. This study characterized the morphology, migration and differentiation of human mesenchymal stem cells (hMSCs) on smooth (Ti6Al4V and PEEK), specifically engineered macro-micro rough (MM) and macro-micro-nano rough (MMN) topographies.

Methods

hMSCs were cultured following established methods. Epifluorescence microscopy was used to quantify morphology from 2 - 72hrs (data not shown) and migration over a 10-hour window beginning at 6hrs post seeding. Differentiation was assayed through expression of early marker alkaline phosphatase, ALP, and mature marker osterix, OSX. Significance was determined via ANOVA.

Results

hMSCs demonstrated shifting morphologies, Figure 1, with smooth surfaces moving towards elongated morphologies typical of fibroblasts indicated by low roundness and high aspect ratios. In contrast, hMSCs on MM surfaces demonstrated low roundness and low aspect ratios typical of cuboidal osteoblasts. Finally, hMSCs on MMN surfaces demonstrated the highest roundness coupled with low aspect ratios typical of stellate morphologies observed in mature osteoblasts/osteocytes and reached a steady-state stellate morphology by 24hr, whereas the other surfaces didn't demonstrate steady-state morphology until 72hrs. An evaluation of the migration revealed hMSC velocity was highest on MMN surfaces coupled with low directionality indicating rapid random migration, Figure 2.A.&B. Finally, differentiation outcomes correlated well with morphology results showing significantly higher expression of early osteoblast marker, ALP, at 3 days and maturing osteoblast marker, OSX, at 10 days on MMN surfaces as compared to all other surfaces, Figure 2.C.&D.

Conclusions

These outcomes demonstrate the combined macro-micro-nano topography of the MMN surface

Learning Objectives

By the conclusion of this session, participants should be able to: 1. Describe the importance of surface topography on stimulating rapid migration and morphology shifts of stem cells on the surfaces; 2. Discuss how early changes in stem cell morphology correlate to long term stem cell differentiation, and how rapid colonization through migration minimizes biofilm formation; and 3. Identify surface topographies that can exploit these migration and morphology mechanisms to improve implant success.

References

Figure 1

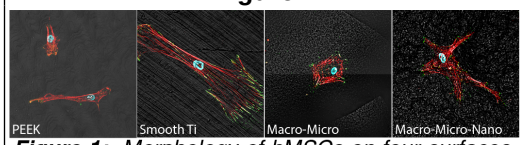

Figure 1: *Morphology of hMSCs on four surfaces, demonstrating a spindle or fibroblastic morphology on both PEEK and Smooth Ti, a cuboidal morphology on Macro-Micro and a stellate morphology typical of mature osteoblasts on Macro-Micro-Nano.*

Figure 2

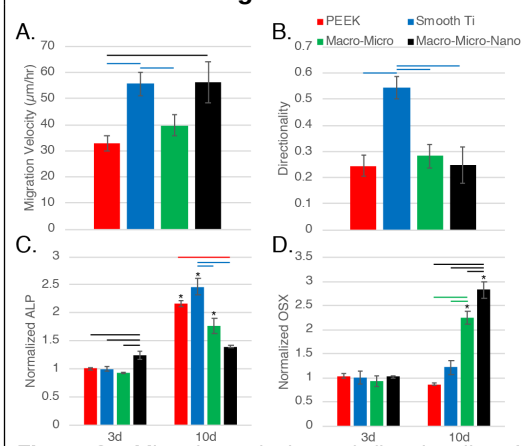

Figure 2: *Migration velocity and directionality of hMSCs on the four surfaces (A. & B. respectively), and the early and maturing osteoblast markers, ALP and OSX (C. & D. respectively). Bars indicate significance, p<.05.*