# 3D Printing of Bioactive Graded Nanostructured Scaffolds for Osteochondral Regeneration

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## Introduction

Since natural tissue are nanometer in dimension [1], the incorporation of biomimetic nanomaterials within 3D scaffolds can mimic the properties of natural tissues leading to more physiologically relevant implants. Thus, the main objective of this study is to create novel 3D printed nanostructured scaffolds for the induction of directed cell behavior and osteochondral tissue regeneration. For this purpose, we 3D printed graded and homogeneously distributed nanocrystalline hydroxyapatite (nHA) hydrogels. In addition, bioactive transforming growth factor-β1 (TGF-β1) was incorporated within the smooth articulating layer for enhanced MSC chondrogenesis.

## Materials and Methods

A novel table-top stereolithography (SL) 3D printer (Figure 1) was developed and used in the manufacture of bioactive 3D nano osteochondral scaffolds with spatially distributed nHA and soluble TGF-β1. nHA was synthesized via a wet chemistry method with a hydrothermal treatment producing particles exhibiting biologically-relevant morphology and chemical composition. The hydrothermally-treated nHA and TGF-β1 were incorporated into the porous poly(ethylene glycol)-diacrylate (PEG-da) scaffold and human bone marrow derived mesenchymal stem cell (MSC) adhesion, proliferation, and two-week differentiation were evaluated *in vitro*.

Scaffold porosity and nHA spatial distribution was characterized via scanning electron microscopy for MSC adhesion and proliferation.

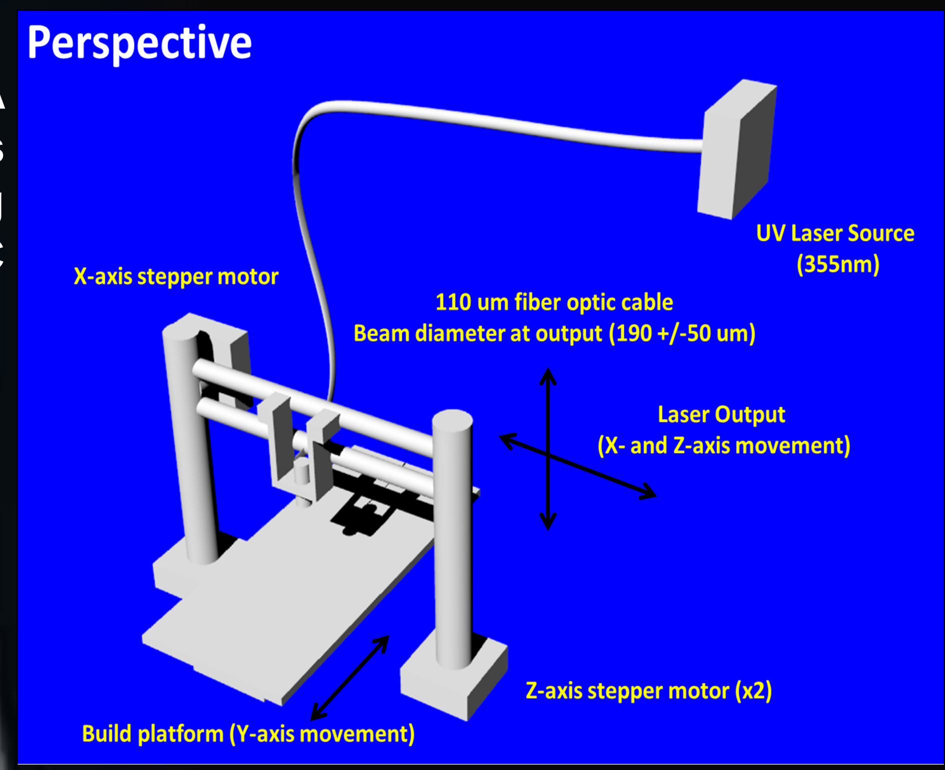
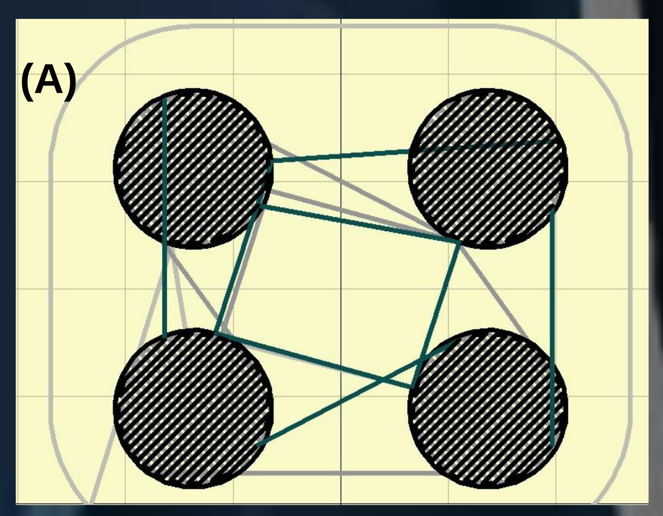



Figure 1: Diagram of the table-top SL system for the fabrication of bioactive hydrogel-based 3D scaffolds.



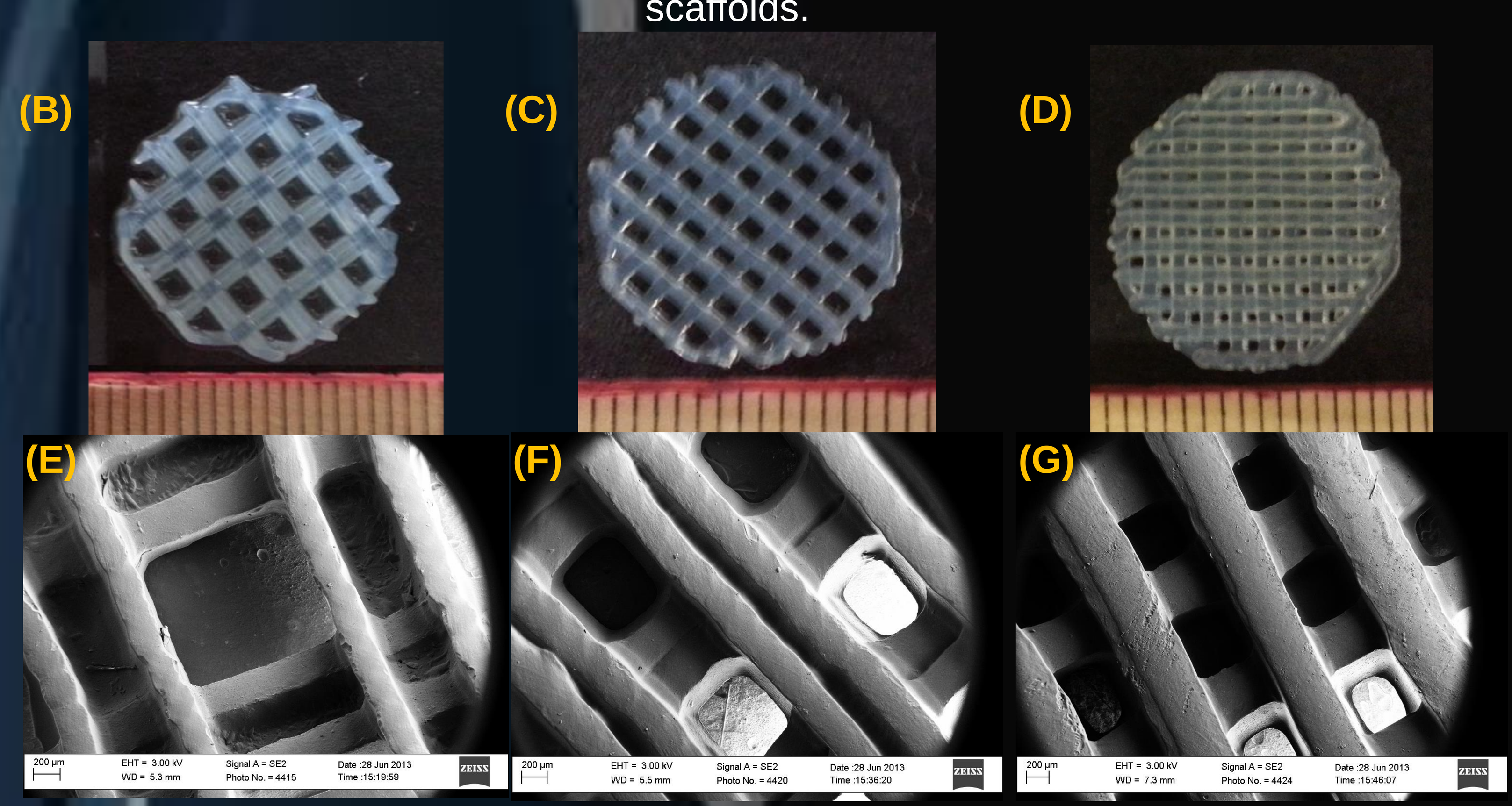




Figure 2: (A) 2D CAD model. Photo and SEM images of 3D printed porous hydrogel scaffold via our novel table-top SL apparatus with (B)-(E) 40%:60%; (C)-(F) 60%:40%; and (D)-(G) 80%:20%fill density/porosity.
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## Results

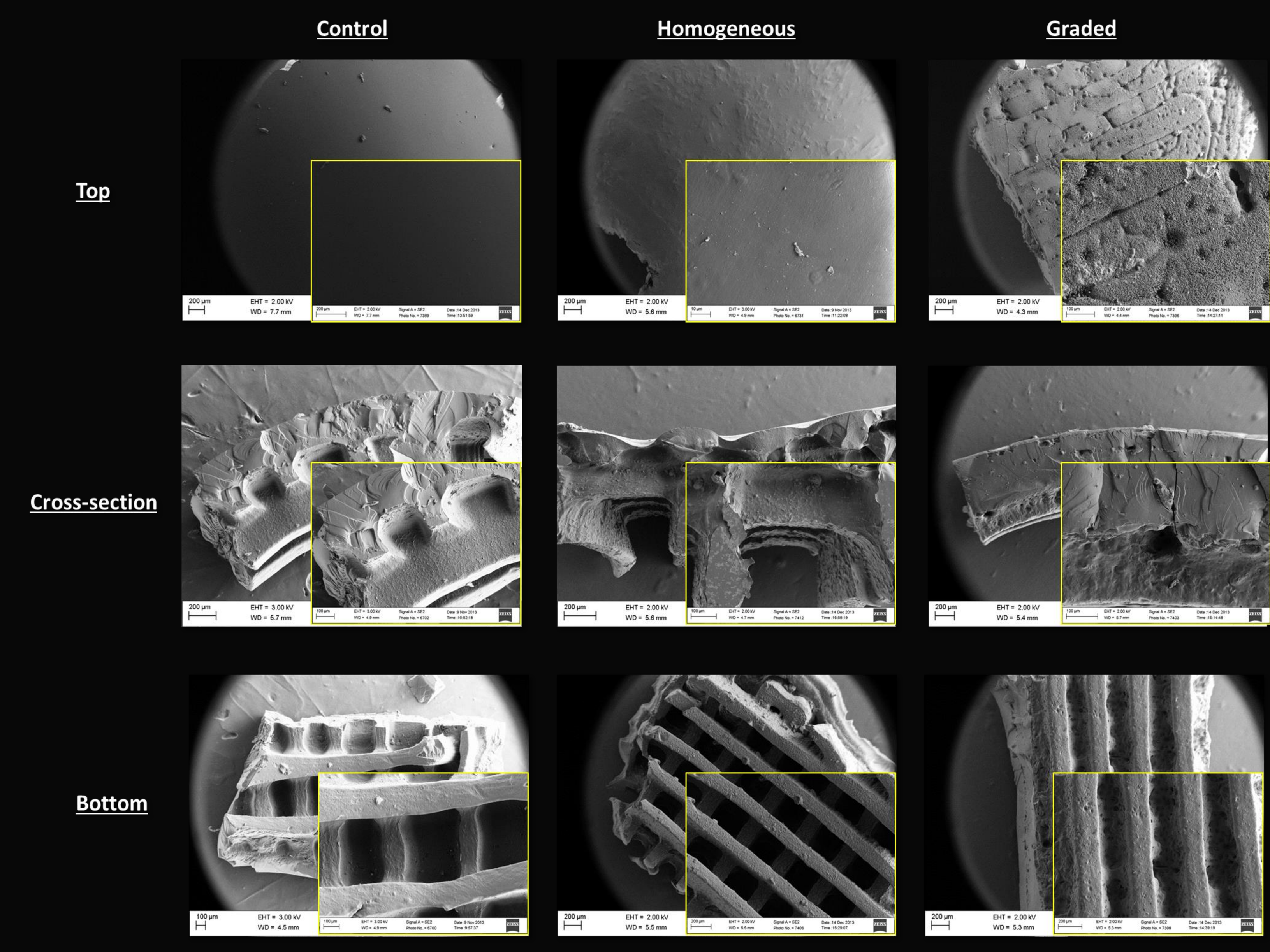


Figure 3: Scanning electron micrographs of SL 3D printed bioactive nanocomposite PEG-da osteochondral scaffolds.

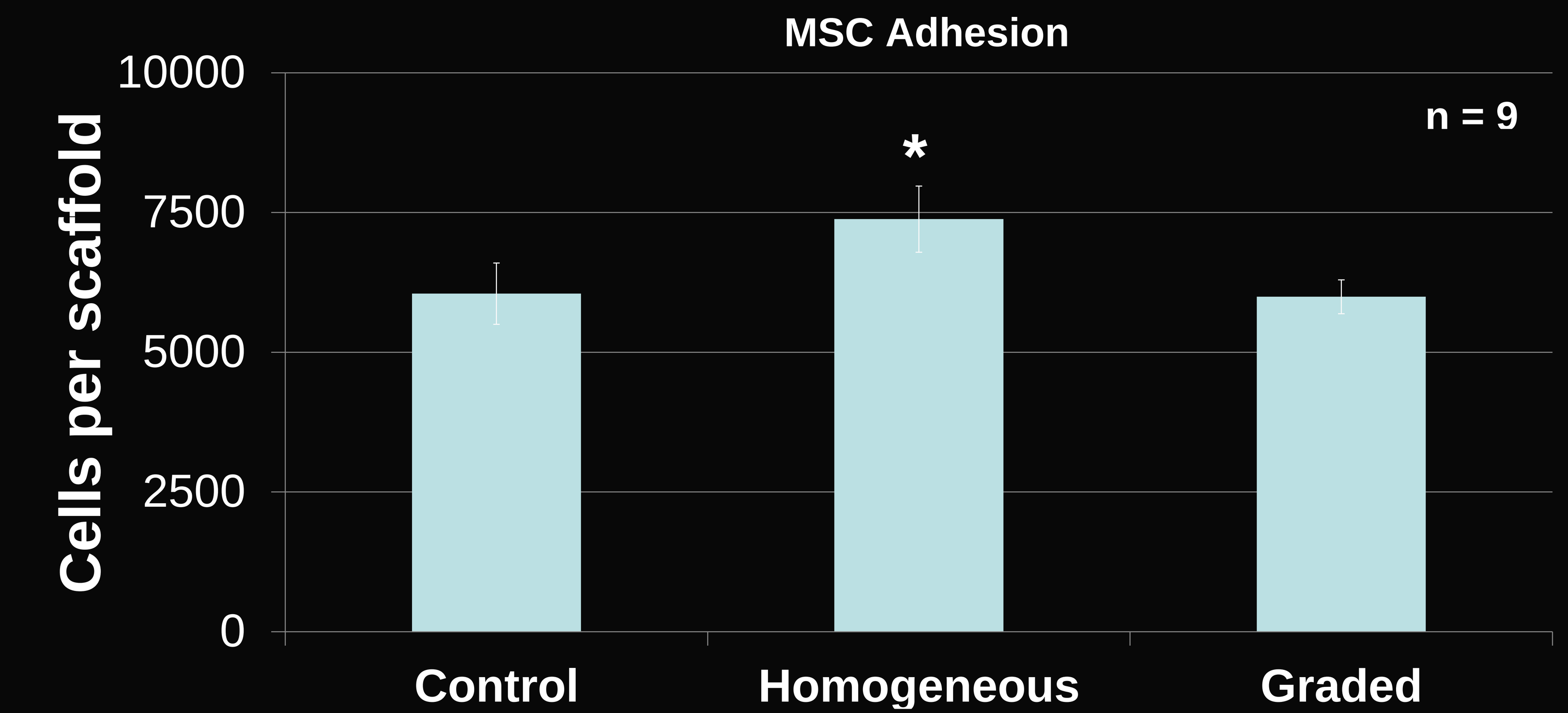


Figure 4: MSC adhesion on 3D printed scaffolds. Data are ± standard error mean, *p>0.05 when compared to all other scaffolds.

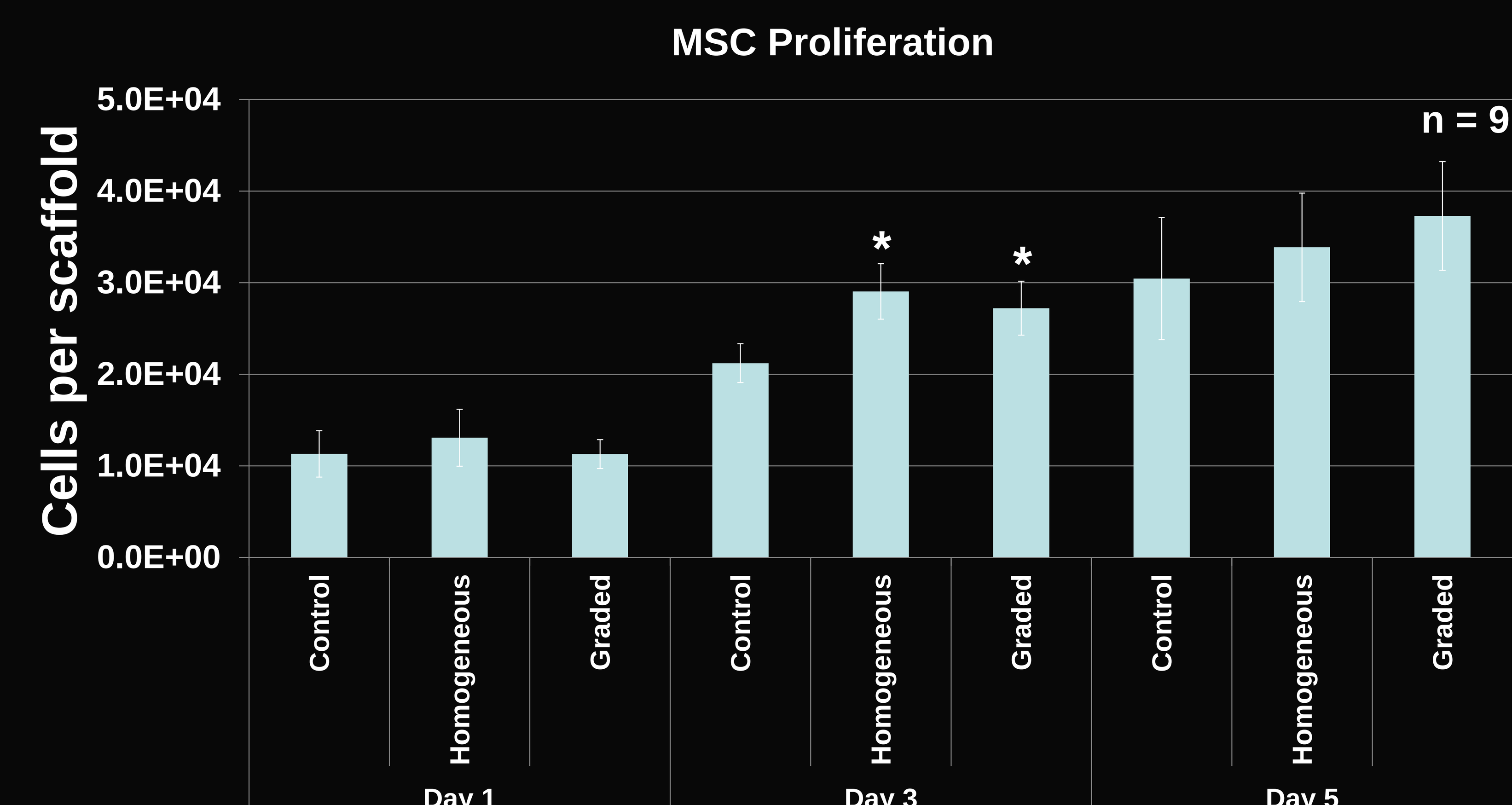


Figure 5: MSC proliferation on 3D printed scaffolds. Data are ± standard error mean, *p>0.05 when compared to controls at Day 3.

## Results

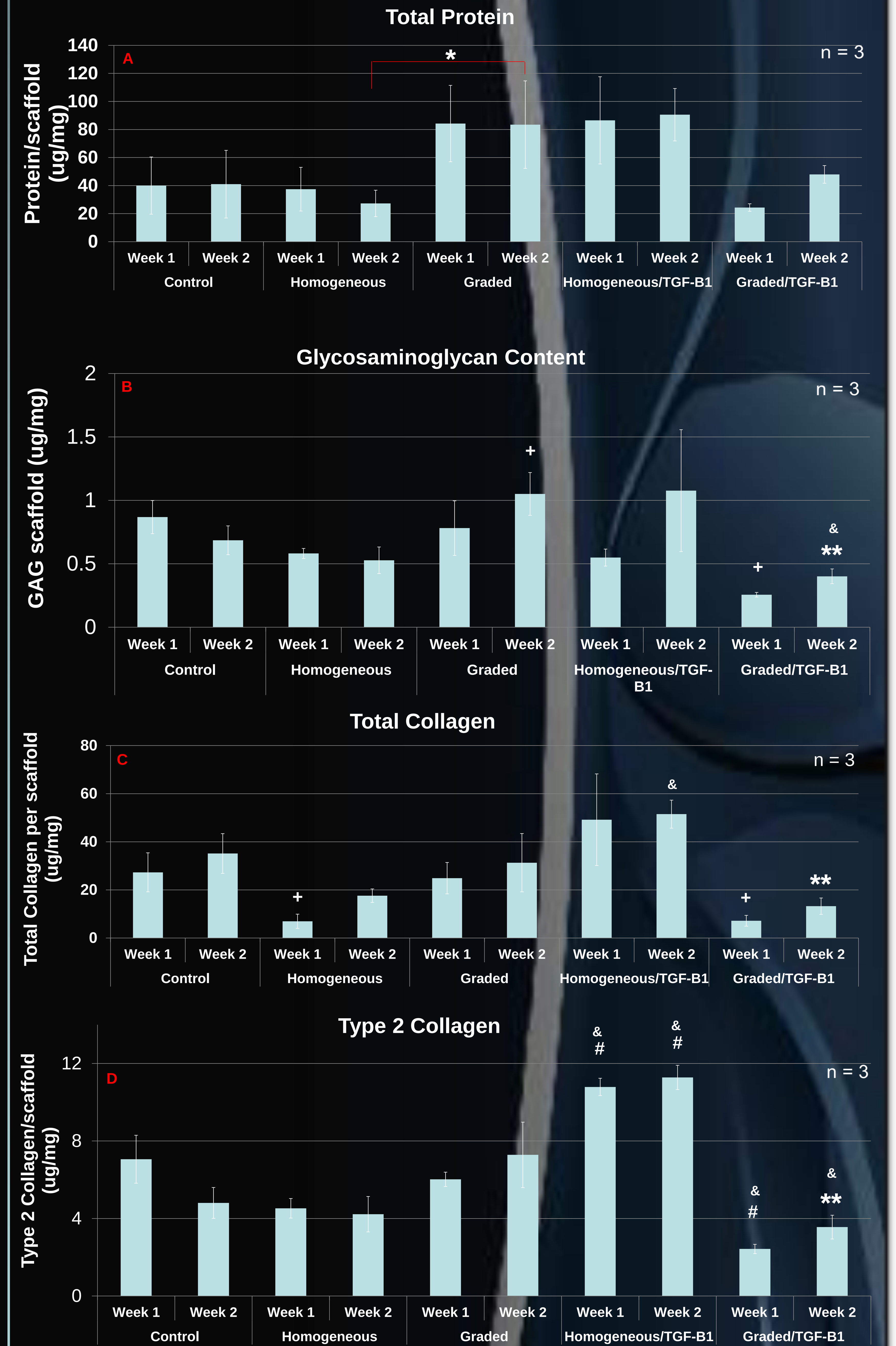


Figure 6: Two-week MSC differentiation study of SL 3D printed bioactive nanocomposite osteochondral scaffolds. Data are ± standard error mean. "&" indicate significant difference between growth factor and non-growth factor containing scaffolds, "*" when compared to the highlighted group, "**" when compared to week 1, "#" when compared to all groups, and "+" when compared to control..

## Acknowledgements

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## References

[1] Zhang, L., et al. *Nanotoday*, 2009: 4(1):66-80.