The research trends of graphene/bio-polymer composites as scaffold for tissue engineering

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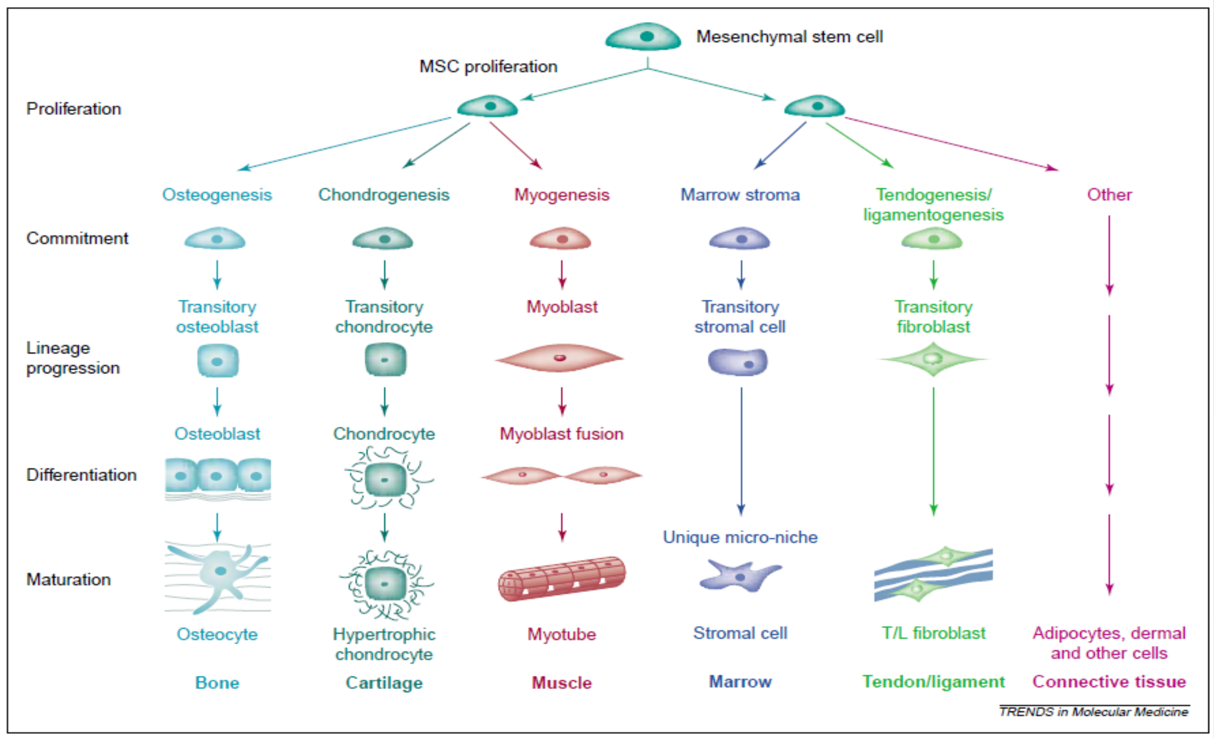
1.Tissue engineering

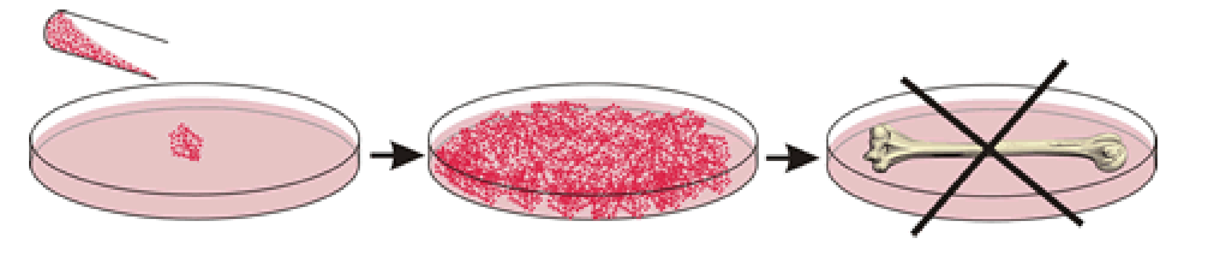


- Major segment of *Biotechnology*.
- ✓To create artificial organs (via biological material) for patients that need organ transplants.
- ✓Currently researching methods of creating such organs.
- ✓Bioartificial organs, which use both synthetic and biological components, are also a focus area in research, such as with hepatic assist devices that use liver cells within an artificial bioreactor construct.

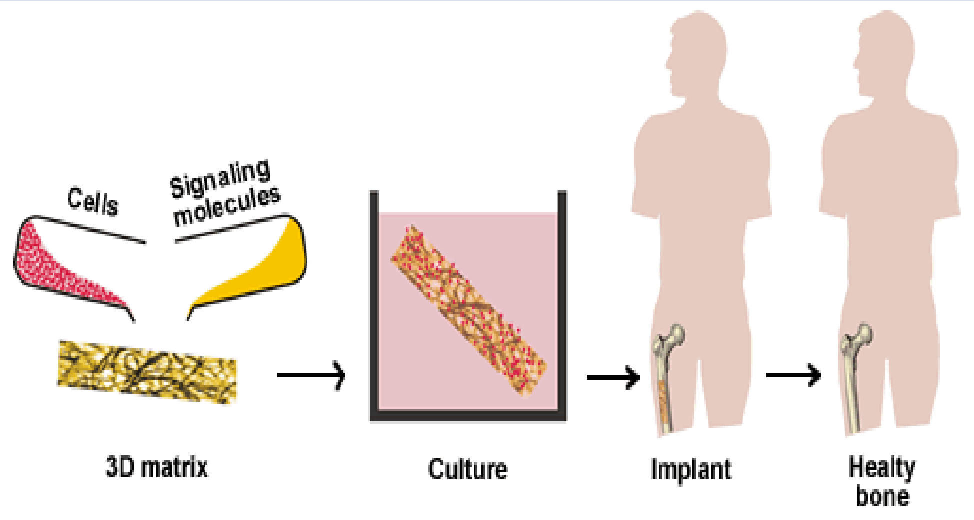
TRENDS in Molecular Medicine Vol.7 No.6 June 2001 and the free encyclopedia from Wikipedia.

2. What's the scaffolds?

- Simple culture techniques can't be used to grow organized tissue. Why**?**



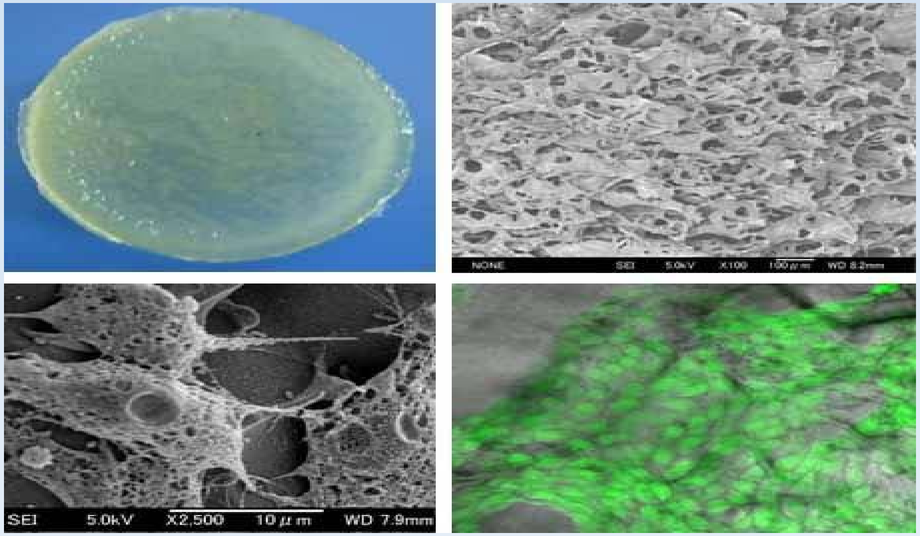
- Scaffold-guided tissue regeneration is required.

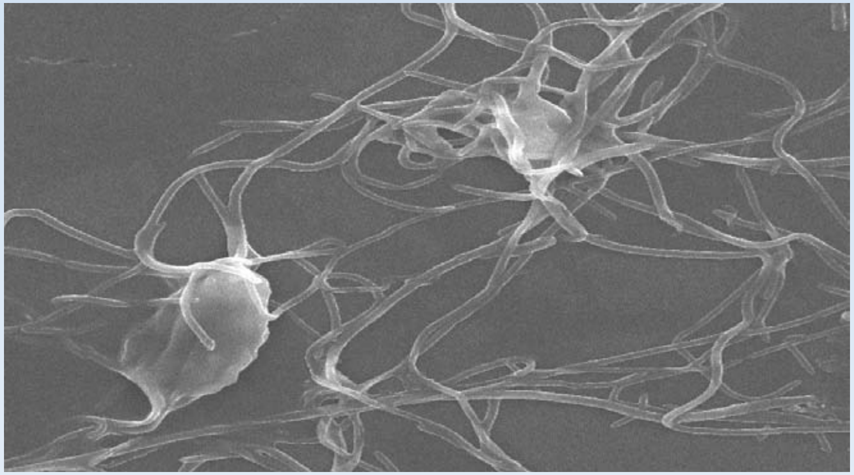


The Bone Tissue Engineering Center(BTEC) of Carnegie Mellon

3. Nanotechnologies to fabricate the nanocomposite scaffolds

- ➢ Fabrication processes of scaffolds
- ✓ Powder-forming process
- ✓ Sol-gel techniques
- ✓ Solid free-form techniques
- ✓ Electrospun nonwoven fiber techniques
- ✓ Materials: biopolymer, composite, ceramic, glass, and carbon scaffolds





Evaluate applicability of nanocomposite nanofiber s of PLGA and GO nanosheets to bioscaffolds for neuronal cell growth

Fungal chitosan scaffold Materials 2009, 2(2), 374-398;ADVANCED ENGINEERING MATERIALS 2009, 1, 1-12

4.The graphene/bio-polymer composite using scaffolds

➢Nanocomposite nanofibers of poly(D, L-lactic-co-glycolic acid) and graphene oxide nanosheets

- ✓Significant improvements in the thermomechanical and surface chemical properties of nanocomposite nanofibers of poly(D, L-lactic-co-glycolic acid) (PLGA)/graphene oxide (GO).
- ✓The significant enhancement of storage and loss moduli of the PLGA/GO (2 wt.%.) nanocomposite nanofibers by enhanced chemical bonding between the oxygenated functional groups of the highly dispersible GO nanosheets and the hydroxyl groups of the polymer chains in the PLGA matrix.
- ✓Enhanced hydrophilicity of nanocomposite nanofibers caused by embedded GO nanosheets also allowed for good biocompatibility of neuronal cells, resulting in enhanced cell proliferation and viability.

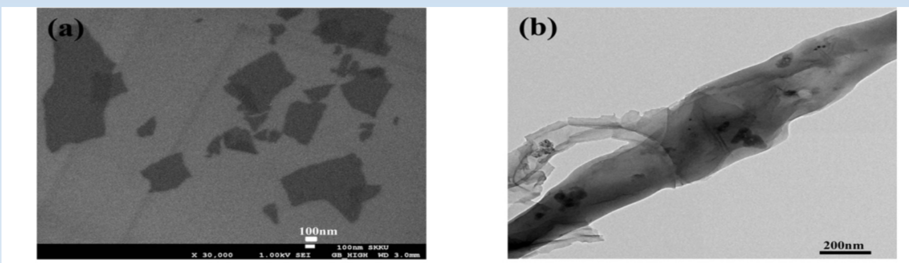


Fig.1 (a) FE-SEM images of GO nanosheets, (b) HR-TEM images of PLGA/GO (2 wt.%)

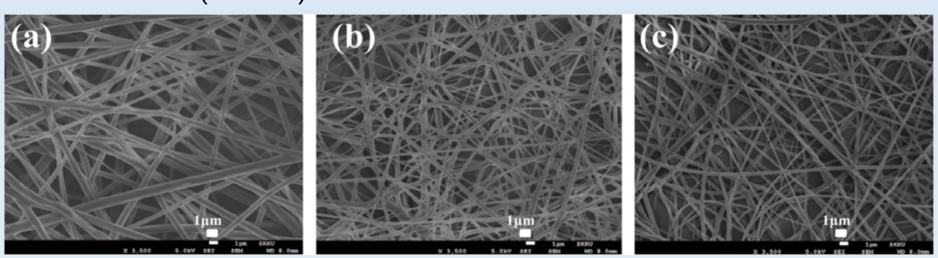


Fig. 2 FE-SEM images of (a) PLGA nanofibers, (b) PLGA/GO (1 wt.%.) nanocomposites, and (c) PLGA/GO (2 wt.%.) nanocomposites.

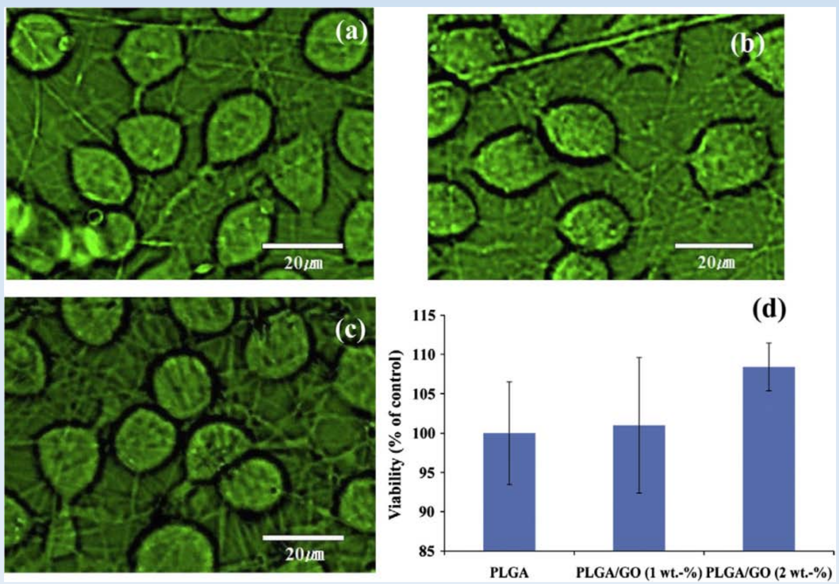


Fig. 3 Optical images of PC 12 cells on (a) PLGA nanofibers, (b) PLGA/GO (1 wt.%) nanocomposites, (c) PLGA/GO (2 wt.%) nanocomposites, and (d) cell proliferation and viability data obtained by WST-1 assay of the cells cultured for 2 days ($n = 12$, $p < 0.05$).

Composites: Part A , 2011, 42 , 1978–1984

➢Fabrication and characterization of graphene hydrogel via hydrothermal approach as a scaffold for preliminary study of cell growth

- ✓Study to determine the suitability of graphene hydrogel as a substrate for cell growth, which could potentially be used as building blocks for biomolecules and tissue engineering applications.
- ✓A three-dimensional structure of graphene hydrogel by a simple hydrothermal method using two- dimensional large-area graphene oxide nanosheets as a precursor.
- ✓The structure of the hydrogel by concentration and lateral size of the graphene oxide nanosheets.
- ✓The graphene hydrogel formed with larger-area graphene oxide nanosheets, at a lower concentration.
- ✓The three-dimensional graphene hydrogel matrix as a scaffold for proliferation of a MG63 cell line.
- ✓Demonstrating biocompatibility of the graphene hydrogel structure for bioapplications.

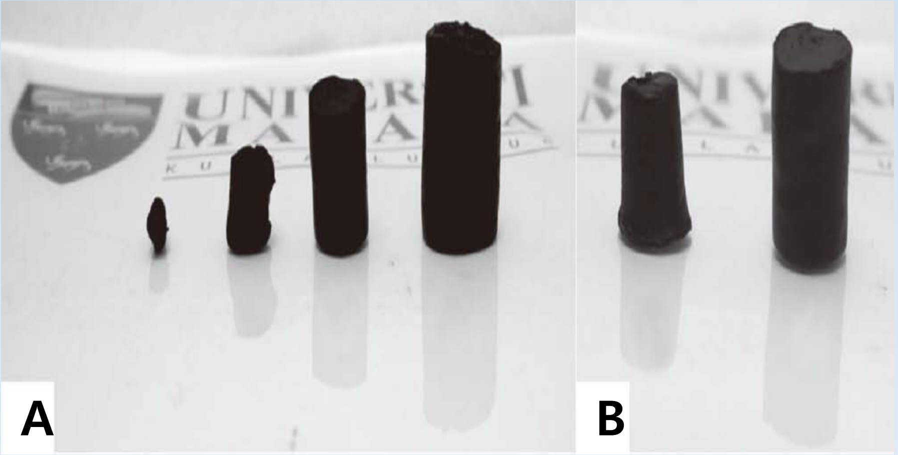


Fig.4 Photographs of (A) graphene HG-0.1 (i), graphene HG-0.5 (ii), graphene HG-1 (iii) and graphene HG-2 (iv), and (B) comparison of graphene HGS-2 (i) and graphene HG-2 (ii).

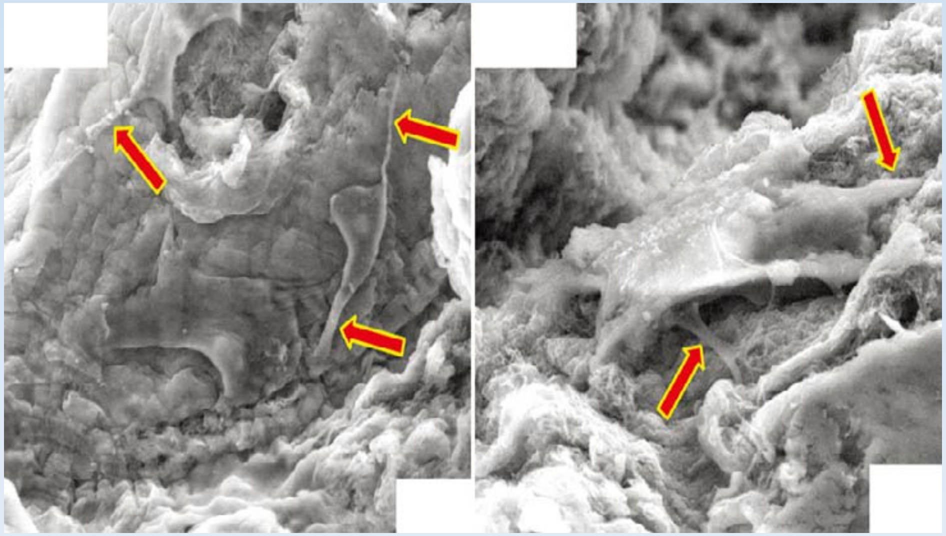


Fig. 5 Guided filopodia protrusions of MG63 on graphene HG-2 after 3 and 7 days of culture time observed at higher magnifications.

International Journal of Nanomedicine 2011:6 1817–1823

➤Fabrication, Mechanical Properties, and Biocompatibility of Graphene-Reinforced Chitosan Composites

- ✓The fabrication of graphene/chitosan films by solution casting method after dispersion of graphene in chitosan/acetic acid solutions.
- ✓The improved mechanical properties (over ~200%) of composite films with the addition of graphene (0.1-0.3 wt %) in chitosan.
- ✓The proven biocompatibility of graphene/chitosan composite films by tetrazolium-based colorimetric assays in vitro.
- ✓The increased cell adhesion of the L929 cell on the graphene/chitosan composite films as well as on pure chitosan film.
- ✓The graphene/chitosan composites as potential candidates of scaffold materials in tissue engineering.

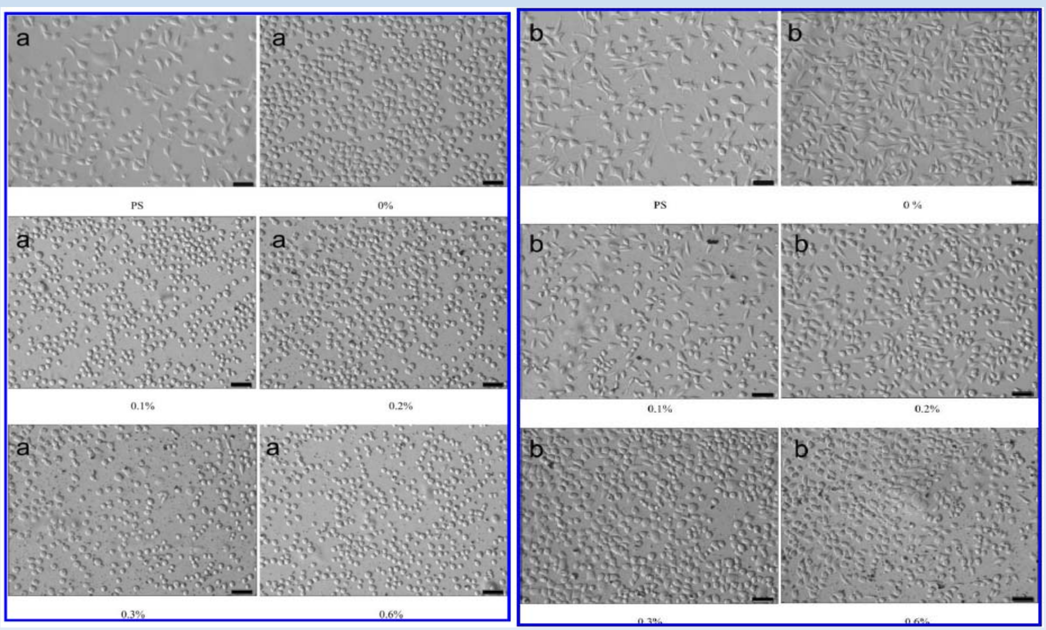


Fig. 6 (a) Cell phase contrast micrographs at 12 h. The scale bar represents 50 ***μm. (b) Cell phase contrast micrographs at 24** h. As time* increases, cells extend gradually. Cells on the lower concentration graphene/chitosan composite materials performed better. The scale bar represents 50 ***μ**m.*

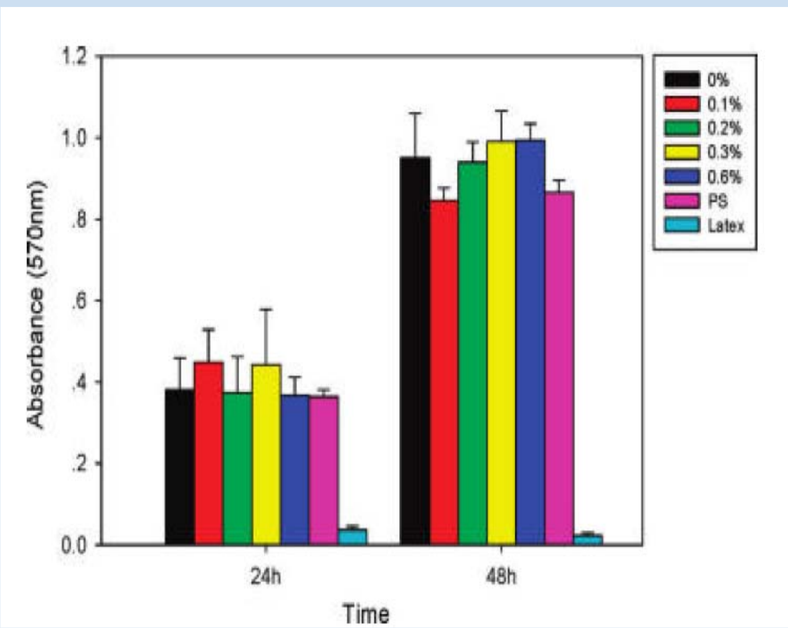


Fig. 7 Results of MTT assay of L929 cells incubated with composite films at 24 and 48 h. The bar represented standard deviation of three eplicates (*$p < 0.05$).*

Biomacromolecules, 2010, 11, 2345-2351

➢Structure–process–property relationship of the polar graphene oxide-mediated cellular response and stimulated growth of osteoblasts on hybrid chitosan network structure nanocomposite scaffolds

- ✓The structure–process–property relationship of graphene oxide-mediated proliferation and growth of osteoblasts in chitosan conjunction of graphene oxide with the physico-chemical, mechanical, and structural properties.
- ✓Chitosan–graphene network structure scaffolds by covalent linkage of the carboxyl groups of graphene oxide and the amine groups of chitosan.
- ✓Enhanced the biocompatibility and the degradation products of chitosan–graphene network structure scaffolds.
- ✓Improved cell attachment and proliferation and the stability against enzymatic degradation due to the high water retention ability, hydrophilic nature, and high degree of interconnectivity of the porous structure of chitosan–graphene oxide scaffolds.
- ✓The enhancing osteoblast–biomaterial interactions due to important factor of negatively charged and polar GO (6470 103 Debye) in chitosan–graphene network structure scaffolds for tissue engineering application.

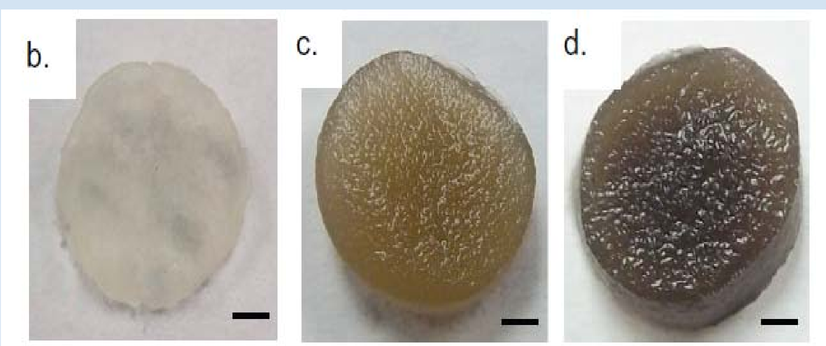


Fig. 8. Digital photographs of (b) pure CS, (c) CS–1 wt.% GO, and (d) CS–3 wt.% GO scaffolds after 28 days immersion in SBF (pH 7.4). Scale bar 1 mm.

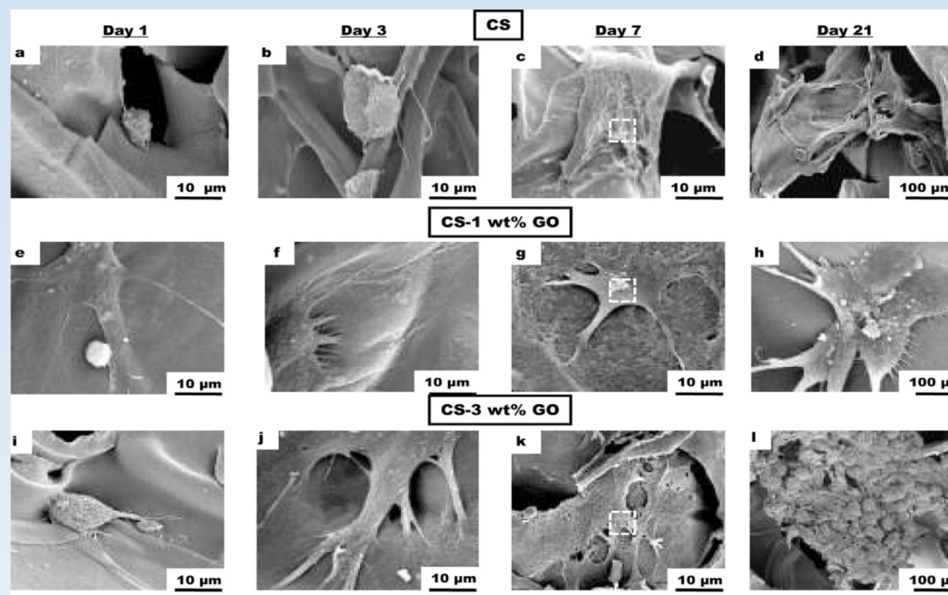


Fig. 9 (a–l) Scanning electron micrographs illustrating the morphology of pre-osteoblasts cells seeded on pure CS and CS–GO scaffolds after 1, 3, 7, and 21 days, respectively.

Acta Biomaterialia 7 (2011) 3432–3445

5. Conclusion

- The graphene/bio-polymer composites as scaffolds for tissue engineering :
  - ✓ Enhanced thermal, mechanical physical and chemical properties of graphene/bio-polymer composite for the extra cellular matrix
  - ✓ The bio-polymer composites incorporated graphene or graphene oxide improved biocompatibility, bio-affinity, cell attachment and proliferation
  - ✓ The graphene/bio-polymer composites as potential candidates of scaffold materials.