Acta Scientific Dental Sciences (ISSN: 2581-4893)
Volume 7 Issue 4 April 2023
Research Article

NanoTechnology, Regenerative Medicine and, Tissue Bio-Engineering

Omid PANAHI[1]*, Fatmanur KETENCİ ÇAY[2] and Amirreza Ghanbary[3]

[1]*Yeditepe university, Department of Oral and Maxillofacial Surgery, Istanbul, Turkey*
[2]*Yeditepe university, Department of Oral and Maxillofacial Radiology, Istanbul, Turkey*
[3]*Faculty of Pharmacy, Tehran University of Medical Sciences, Tehran, İran*

***Corresponding Author:** Omid PANAHI, Yeditepe university, Department of Oral and Maxillofacial Surgery, Istanbul, Turkey.

Received: March 03, 2023
Published: March 30, 2023

Abstract

The appearance of regenerative medicine (RM) and tissue engineering (TE) opened new areas in medical science. This rapidly expanded field focuses on the restoring function of damaged tissues and organs. Due to their multidisciplinary identity, RM and TE are closely related to stem cell biology, cellular therapy, bioengineering and nanotechnology. Nanotechnology has provided new structures with unique biochemical, mechanical and electrical properties. With the advancement in nanotechnology, direct connection with cells has become possible, offering exciting medical therapy possibilities.

Keywords: Nanotechnology; Regenerative Medicine; Tissue Bioengineering

Introduction

Nanotechnology is the term used to cover the design, construction, and utilization of functional structures with at least one characteristic dimension measured in nanometers [1,2]. Nowadays, Nanotechnology and biotechnology play a critical role in various medical sciences, and regenerative medicine is one of these branches. Regenerative medicine is a rehabilitation medical science that uses stem cells that can repair, restore and repair lost portions of the person by one's stem cells, which their stem cells play an essential role. The body's innate healing response may also be leveraged to promote regeneration, although adult humans possess limited regenerative capacity compared to lower vertebrates [3]. Recently, stem cells have gained much attention for treating devastating injuries and damage caused by degenerative disease, diabetes and ageing [4]. Tissue bioengineering combines biology and medicine sciences and engineering, including repairing and replacing damaged cells (Figure 1). The general principles of tissue engineering involve three essential components: identifying appropriate cells, developing three-dimensional (3D) scaffolds and inductive morphogenic signals to regenerate tissues and restore normal organ function [5].

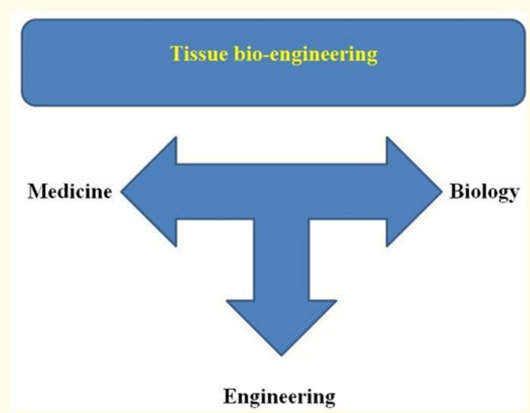

Figure 1: Tissue bioengineering structure.

Discussion

Nowadays, tissue engineering (TE) and regenerative medicine (RM) is a rapidly expanding topics of research directed towards replacing tissue and organs when required. Commonly TE and RM are utilized equivalently. The committee defines regenerative medicine on the Biological and Biomedical Applications of Stem Cell Research as "methods seeks to understand how and why stem cells, whether derived from human embryos or adult tissues, can develop into specialized tissues and seeks to harness this potential for tissue-replacement therapies that will restore lost function in damaged organs [6]. In brief, it is based on regenerating and replacing damaged tissues and organs [7,8]. Langer and Vacanti introduced the term tissue engineering in 1993 [9]. Tissue engineering is the persuasion of the body to heal itself through the delivery to the appropriate sites of molecular signals, cells and supporting structures [10]. Distended research that has been done contributed to developing and creating organs and tissues that can be applied in the case of defective or diseased tissues and organs [11-13]. Encouraging results of regenerative medicine in the healing and replacement of a wide range of tissues and organs have been declared worldwide.

Nanotechnology is a familiar word in today's life, and we can see its products everywhere with various applications (Figure 2). Nanotechnology, with the feature of "mimic nature", commenced a new therapy field and has dramatically improved regenerative medicine and tissue engineering. The unique properties of nanomaterials make them superior to traditional materials. Some of these unique properties are larger specific surface areas, mechanical, optical, electrical, and magnetic. Nanomaterials show reliable performance in both medical diagnosis and disease treatment. The detection methods include sensing, cell sorting, bio-separation, enzyme immobilization, transfection immunoassays, purification, and magnetic resonance imaging. Nanomaterials therapy involves drug/gene delivery, hyperthermia/thermal ablation/phototherapy, tissue repair, and radiotherapy [14]. Various nanomaterials, nanofibers, and nanofilms have been utilized to develop tissue and targeted delivery at the nanoscale [15-21].

Nanobiomaterials describe biomaterials with a size between 1 and 100 nm in at least one dimension or can be defined as materials interacting with and influencing the biological microenvironment at a nanointerface [22,23]. Nanobiomaterials, by introducing and presenting novel biocompatible, biodegradability and noninvasive surfaces and materials, have become an indispensable part of biomedical science. As a result of the similar size, structure, and chemical properties of nanomaterials to biomaterials, they play essential roles in the studies, including identifying biological systems [24]. Inorganic, physical, polymeric, metallic, organic/carbon, and ceramic are the most common types of biomaterials used for health care, including tissue regeneration [25,26], dental/bone implantation [27-29], drug delivery [30], cancer therapy [31], Gene delivery/therapy [32]. Bone is significant in the skeletal system and is crucial in reserving minerals, protecting organs and the body, and creating blood cells [33]. Bone diseases like bone cancer, osteoporosis, nonunion bone fractures and osteoarthritis disturb the regular activity of osteoblasts cells responsible for renewing bone tissues. In bone cancer treatment, nanoparticle-based drug delivery, specially AuNPs, is wildly applied due to low toxicity and ease of surface modification [34,35]. AuNPs modified with alendronate (ALD) treat osteoporosis [36].

Photothermal therapy (PT) is a non-invasive technique for cancer treatment by applying heat to destroy sick cells. AuNPs-based photothermal therapy in cancer treatment has attracted attention in the recent decade. In the presence of a laser beam, AuNPs absorb and convert into heat efficiently, leading to better cancer treatment results [38].

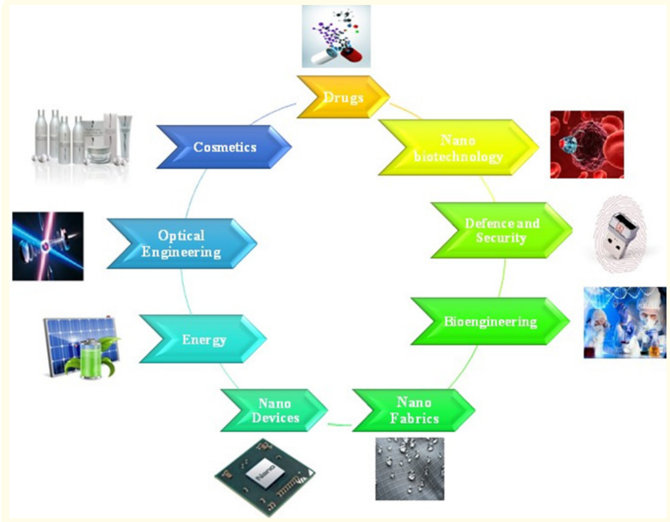

Figure 2: Various applications of nanotechnology.

The first idea of 3D printing belonged to Charles (Chuck) Hull in 1986 [39]. 3D printing by providing suitable organs and tissues for transplantation has become an inseparable part of regenerative medicine [40]. The steps of 3D printing are illustrated in (Figure 3).

3D bioprinting is a fully active area of research in tissue engineering. It consists of the precise layering of cells, biological scaffolds, and growth factors to create bioidentical tissue for numerous utilizations and develop new organs [41]. There are three main kinds of 3D bioprinting: inkjet bioprinting, microextrusion bioprinting, and laser-assisted bioprinting [42].

The first delivered bioprinter was 2D inkjet printing [43]. Inkjet 3D bioprinting, also called drop-on-demand printers, is designed based on a non-contact technique like thermal, piezoelectric, or electromagnetic forces to layer biomaterials droplets onto a substrate that fabricate 2D or 3D structures [44]. The main advantages of this method are high resolution, the drop size and density are adjustable, and drop length and drop deposition can be directed electrically. The disadvantage is the restriction in using low viscous bio-ink and the long process duration as the consequences of low droplet volume (picoliter) [45].

Microextrusion 3D-bioprinting, as the most common method, is based on a temperature-controlled biomaterial dispensing system which employs mechanical and pneumatic power to generate continuous beads of materials directed by CAD-CAM software. One of

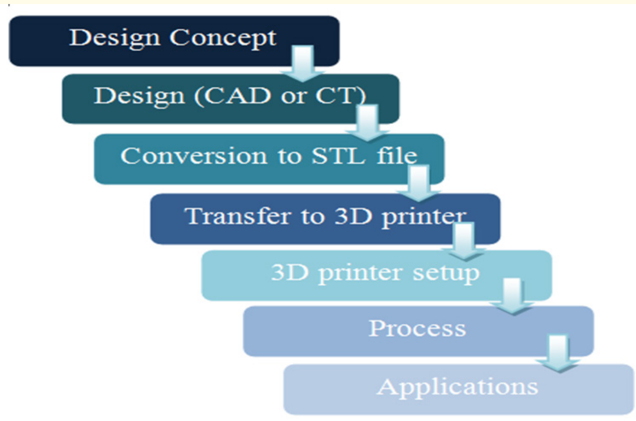

Figure 3: The steps of 3D printing process.
(CAD: Computer-Aided Design; CT: Computer Tomography).

the superiority of this method over the previous one is the possibility of applying a wide range of highly viscous biomaterials, which results in facile scale-up 3D structure creation [46].

Laser-assisted bioprinting (LAB) is noticed as the least common bioprinting method. This non-contact method is built on laser-induced forward transfer, and high-resolution patterns are achievable. LAB consists of a pulsed laser beam through a "ribbon" comprising a layer of biological materials. The significant drawbacks are low cellular viability, and the ribbon preparation step is a rather time-consuming procedure [47]. A considerable number of studies have confirmed the beneficence of applying 3D bioprinting in various organ systems consists, of skeletal, muscular, nervous, lymphatic, endocrine, integumentary, respiratory, digestive, urinary, and circulatory system.

Conclusion

The regenerative medicine and tissue bioengineering future can be an essential step for medical and dental treatment and the appropriate solution for reconstructing wounded and injured sections of patients, which should be selectively provided to the patient. The future of regenerative medicine and tissue engineering relies on the ability of scientists and clinicians to "mimic nature" or "work with nature" in coming up with innovative biomaterials and technologies, such as nanotechnology, to advance this field [48]. With the development of this science and the use of stem cells, it will eventually improve the quality of lives of millions of persons by improving examinations and medical treatments with new technologies.

Future Works

Since Nanotechnology in Regenerative medicine is one of the new and effective branches, it should have more exhaustive research on nanomaterials to be more effective in medical and biological sciences.

Bibliography

1. Cui D J (2007): 1298.
2. Pan B., *et al*. *The Journal of Physical Chemistry C* (2007): 12572-12576.
3. Kami D and Gojo S. "Tuning cell fate: From insights to vertebrate regeneration". *Organogenesis* 10.2 (2014): 231-240.
4. Slack JMW. "Stem cells in epithelial tissues". *Science* 287.5457 (2000): 1431-1433.
5. La Noce M., *et al*. "Dental pulp stem cells: state of the art and suggestions for a true translation of research into therapy". *Journal of Dentistry* 42 (2014): 761-768.
6. Commission on Life Sciences. "Stem Cells and the Future of Regenerative Medicine". Washington, DC: National Academy Press (2002).
7. A Atala. "Advances in tissue and organ replacement". *Current Stem Cell Research and Therapy* 3 (2008): 21-31.
8. A Mendelson and PS Frenette. "Hematopoietic stem cell niche maintenance during homeostasis and regeneration". *Nature Medicine* 20.8 (2014): 833-846.
9. Langer R and Vacanti JP. "Tissue Engineering". *Science* 260 (1993): 920-926.
10. Williams DF. "The Williams Dictionary of Biomaterials". Liverpool, University Press, Liverpool (1993a).
11. Akhyari P., *et al*. "Myocardial tissue engineering: The extra cellular matrix". *European Journal of Cardio-Thoracic Surgery* 34 (2008): 229-241.

12. Delaere P., *et al*. "Tracheal allotransplantation after withdrawal of immunosuppressive therapy". *New England Journal of Medicine* 362 (2010): 138-145.

13. Hamilton N., *et al*. "Tissue engineering airway mucosa: A systematic review". *Laryngoscope* 124 (2014): 961-968.

14. Jurj A., *et al*. "The new era of nanotechnology, an alternative to change cancer treatment". *Drug Design, Development and Therapy* 11 (2017): 2871-2890.

15. Alarc E., *et al*. "Recreating composition, structure, functionalities of tissues at nanoscale for regenerative medicine". *Regenerative Medicine* 11 (2016): 849e58.

16. Engel E., *et al*. "Nanotechnology in regenerative medicine: the materials side". *Trends in Biotechnology* 26 (2008): 39-47.

17. Mohammadian F., *et al*. "New state of nanofibers in regenerative medicine". *Artificial Cells, Nanomedicine, and Biotechnology* 45.2 (2017): 204-210.

18. Moonhyun Choi., *et al*. "Inkjet-based multilayered growth factor-releasing nanofilms for enhancing proliferation of mesenchymal stem cells *in vitro*". *Journal of Industrial and Engineering Chemistry* 50 (2017): 36-40.

19. Mohamed Mousa., *et al*. "Clay nanoparticles for regenerative medicine and biomaterial design: A review of clay bioactivity". *Biomaterials* 159 (2018): 204-214.

20. Stephanie Vial., *et al*. "Recent advances using gold nanoparticles as a promising multimodal tool for tissue engineering and regenerative medicine". *Current Opinion in Solid State and Materials Science* 21 (2017): 92-112.

21. Merkoc A. "Nanobiomaterials in electroanalysis". *Electroanalysis* 19 (2007): 739-741.

22. Hasirci V., *et al*. "Nanobiomaterials: a review of the existing science and technology, and new approaches". *Journal of Biomaterials Science, Polymer Edition* 17.11 (2006): 1241-1268.

23. Kumar P., *et al*. "The Chemo-Biological Outreach of Nano-Biomaterials: Implications for Tissue Engineering and Regenerative Medicine". *Current Pharmaceutical Design* 23.24 (2017): 3538-3549.

24. Bogunia-Kubik K and Sugisaka M. "From molecular biology to nanotechnology and nanomedicine". *Biosystems* 65.2 (2002): 123-138.

25. S Mclaughlin., *et al*. "Nano-Engineered Biomaterials for Tissue Regeneration: What Has Been Achieved So Far?" *Frontiers in Materials* 3 (2016): 1-28.

26. S Das and AB Baker. "Biomaterials and Nanotherapeutics for Enhancing Skin Wound Healing". *Frontiers in Bioengineering and Biotechnology* 4 (2016): 82.

27. AP Tomsia., *et al*. "Nanotechnology Approaches for Better Dental Implants". *The International Journal of Oral and Maxillofacial Implants* 26 (2011): 25-49.

28. S Priyadarsini., *et al*. "Nanoparticles used in dentistry: A review". *Journal of Oral Biology and Craniofacial Research* 8.1 (2018): 58-67.

29. A Grumezescu. "Nanobiomaterials in Dentistry, Applications of Nanobiomaterials 11, 1st Edition". William Andrew, Elsevier (2016): 498.

30. Garg A. "Therapeutic applications of nanobiomaterials". In: Novel Approaches for Drug Delivery (2016): 390.

31. Rengan AK., *et al*. "*In vivo* analysis of biodegradable liposome gold nanoparticles as efficient agents for photothermal therapy of cancer". *Nano Letters* 15 (2015): 842-848.

32. MK Riley and W Vermerris. "Recent Advances in Nanomaterials for Gene Delivery-A Review". *Nanomaterials (Basel)* 7.5 (2017): 94.

33. Sims NA and Martin TJ. "Coupling the activities of bone formation and resorption: a multitude of signals within the basic multicellular unit". *BoneKEy Reports* (2014): 3.

34. Ghosh P., *et al*. "Gold nanoparticles in delivery applications". *Advanced Drug Delivery Reviews* 60 (2008): 1307-1315.

35. Khan AK., *et al*. "Gold nanoparticles: synthesis and applications in drug delivery". *Tropical Journal of Pharmaceutical Research* 13 (2014): 1169.

36. Komatsu K., *et al*. "Alendronate promotes bone formation by inhibiting protein prenylation in osteoblasts in rat tooth replantation model". *Journal of Endocrinology* 219 (2013): 145-158.

37. LC Kennedy., *et al*. "A new era for cancer treatment: gold-nanoparticle-mediated thermal therapies". *Small* 7 (2011): 169-183.

38. AK Rengan., *et al*. "*In vivo* analysis of biodegradable liposome gold nanoparticles as efficient agents for photothermal therapy of cancer". *Nano Letters* 15 (2015): 842-848.

39. Hull CW. "Apparatus for production of three-dimensional objects by stereolithography". *US Patent* 4.575 (1986): 330.

40. X Zhang and Y Zhang. "Tissue Engineering Applications of Three-Dimensional Bioprinting". *Cell Biochemistry and Biophysics* 72 (2015): 777-782.

41. ES Bishop., *et al*. "3-D bioprinting technologies in tissue engineering and regenerative medicine: current and future trends". *Genes Dislocation* 4 (2017): 185-195.

42. Murphy SV and Atala A. "3D bioprinting of tissues and organs". *Nature Biotechnology* 32.8 (2014): 773-785.

43. Boland T., *et al*. "Cell and organ printing 2: fusion of cell aggregates in threedimensional gels". *The Anatomical Record Part A Discoveries in Molecular Cellular and Evolutionary Biology* 272.2 (2003): 497-502.

44. Mohebi MM and Evans JR. "A drop-on-demand ink-jet printer for combinatorial libraries and functionally graded ceramics". *Journal of Combinatorial Chemistry* 4.4 (2002): 267-274.

45. Phillippi JA., *et al*. "Microenvironments engineered by inkjet bioprinting spatially direct adult stem cells toward muscle- and bone-like subpopulations". *Stem Cells* 26 (2008): 127-134.

46. Panwar A and Tan LP. "Current status of bioinks for microextrusion-based 3D bioprinting". *Molecules* 21.6 (2016): 685.

47. Daniel L Cohen., *et al*. "Direct freeform fabrication of seeded hydrogels in arbitrary geometries". *Tissue Engineering* 12 (2006): 1325-1335.

48. Kevin Dzobo., *et al*. "Advances in Regenerative Medicine and Tissue Engineering: Innovation and Transformation of Medicine". *Stem Cells International* (2018): 1-24.