Chronicle of Bioresource Management 2024, 8(4): 137-140

Chronicle of Bioresource Management
An International E-magazine

December, 2024 *Popular Article*

Gold Mines of Osseous Engineering: Unveiling the Potential of Marine Sponge Biomaterials

Kurapati Nagendrasai[1*] and Kishore Kumar Krishnani[2]

Open Access
Corresponding Author
Kurapati Nagendrasai
e-mail: masternagendra123@gmail.com

Citation: Nagendrasai and Krishnani, 2024. Gold Mines of Osseous Engineering: Unveiling the Potential of Marine Sponge Biomaterials. Chronicle of Bioresource Management 8(4), 137-140.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

Keywords:

Biosilica, marine sponges, osseous tissue engineering, polyphosphate, spongin

Article History

Article ID: CBM5963
Received on 30th November 2024
Received in revised form on 15th December 2024
Accepted in final form on 24th December 2024

Abstract

Marine life and biodiversity are a rich source of possible new goods for mankind. Surprisingly, marine creatures remain a largely untapped resource for biotech applications. It is well recognized that compounds from marine sponges that are sedentary animals of the Porifera class have enormous therapeutic properties. Sponges feature a rich calcium phosphate-containing scaffold over which new cells develop due to their porosity and 3D grain structure making them appealing as bone replacements. Most species have an effective linked porous design facilitating fluid movement that aids in filtering large volumes of water to capture nutrients while also being similar to an ideal bone scaffold. Sponges contain spongin, which is similar to vertebral collagen, the most often employed natural polymer for tissue regeneration. Finally, sea sponges' osteogenic characteristics are enhanced by their mineral content, which includes bio-silica and other chemicals that can support cell proliferation while also stimulating bone formation and mineralization.

1. Introduction

The skeletal system is the most important foundation of the human body, providing proper shape, allowing locomotion, protecting internal organs and producing blood cells in the bone marrow. Generally, osseous (bone) tissue has the natural repair ability in response to any small injuries, but under critical cases like large fractures and diseases, this response may not be sufficient to reconstruct the damaged regions. Osseous resurrection is a multistage repair of damaged tissue regions during fractures, tumour resections, or osteo-disorders like bone cancer, arthritis, osteoporosis, osteomyelitis, and osteogenesis imperfecta (Yu et al., 2018). 'Osseous tissue engineering' is an interdisciplinary concept connecting genetics, clinical medicine, mechanical engineering, and material sciences. The NSF (National Science Foundation) was the pioneer in introducing this term in 1988. The idea of osseous (bone) tissue regeneration is understanding the structural

Author's Address

[1]Aquatic Environment and Health Management Division, ICAR-Central Institute of Fisheries Education, Mumbai, Maharashtra (400 061), India
[2]ICAR-Indian Institute of Agricultural Biotechnology, Ranchi, Jharkhand (834 003), India

Journal Home: *https://ojs.pphouse.org/index.php/CBM*

and functional components of the tissues to patch the defective region and return it to its original function (Chaudhari et al., 2016). Furthermore, 3-D scaffolds are considered the most promising approach for tissue resurrection and many materials like ceramics, metal alloys (mainly Titanium), polymers and composites are used to synthesize these scaffolds. However, high manufacturing costs lead to the search for alternatives with promising results. In this context, natural materials (bio-materials) with good biocompatibility and better surface interaction for cell attachment and growth showed up as a promising alternative (Lin et al., 2011).

Marine organisms are rich sources of biomaterials and are considered potential resources for many compounds (Nayak et al., 2022). Among diverse groups of marine life, marine sponges have remarkable therapeutic potential, and the natural compounds from sponges have antitumor (inhibits malignant neoplasms), antiviral (inhibits virus), anti-inflammatory and antibiotic properties. Apart from these properties, the remarkable interconnected porous structure facilitating the water flow (aquiferous system) for filter feeding mimics the ideal bone scaffold material that makes these marine sponges un-exploited gold mines for osseous tissue engineering.

2. Background Information

In the present era of modern lifestyle, the most ominous consideration of osseous engineering is the management of osteoporosis in elders over the age of 60 years (Zheng et al., 2021). In general, older women are more vulnerable than males due to the hormonal changes in females after menopause. Besides, the constraints and drawbacks of osseous material regeneration are based on the use of autografts and allograft techniques for transplanting in medical sectors, Currently, autograft transplantation is a gold standard procedure for osseous grafts, having the best-grade osseous material recovery for both trauma and dentistry areas owing to its histocompatibility and non-immunogenicity. These implants sometimes lead to secondary trauma due to changes in a donor (iliac or fibula) osseous material. Dental implants are derived from intraoral sites (jawline, maxillary tuberosity, ascending branch of the ramus) and extraoral sites (iliac or tibia). Auto implants reduce the chances of contagion and disease (hepatitis) transmission as they use cells from the same person for regeneration. Autografts sometimes lack vascularization, possible visceral injury during harvesting, infection at the donor site, high patient morbidity, pain, less quantity, and limited availability, but they have exceptional osteogenic, osteoconductive, and Osteo-inductive properties (Gibbs et al., 2014). On the contrary, the allograft technique of osseous material resurrection is done by procuring from another live individual or cadaver and can be used as demineralized or mineralized that is normally preserved under freezing in a tissue repository. Although has some beneficial aspects such as low inferior inductive ability due to lack of growth factor, wide range size accessibility, osteo-conductivity, and no donor site morbidity there are harmful aspects like the absence of osteogenic and vascularization properties, high cost (foot and ankle surgeries), high graft rejection, and risk of disease (human T-lymphotropic virus, hepatitis B&C, HIV, others) transmission from a donor. The *de novo* synthesis of osseous material by allografting lacks regenerative potential due to low Osteo-inductivity. Considering the above-mentioned ambiguities, the osseous tissue regenerative approaches demand the usage of compounds from alternative sources with fewer side effects.

3. Marine Sponges Composition: Biomaterials for Osseous Engineering

Marine sponges generally belong to the phylum Porifera and are classified into various classes like Calcarea, Hexactinellida, Demospomgiae and Homoscleromorpha, which are sessile multicellular, filter-feeding organisms found often in marine waters ranging from shallower regions to deep waters. The composition (Table 1) and potential role of different biomaterials in marine sponges (Figure 1) make them a golden source for bone tissue engineering. Table 1: Composition of marine sponges as bone resurrection material (Source: Granito et al., 2017).

4. Biosilica

Sponges naturally form siliceous spicules made of SiO_2, an amorphous material. Sponge biosilica has a high amount of water (up to 13%), Si, O and trace amounts of Al, Ca, Cl, Cu, Fe, K, Na, S and Zn. These spicules

Table 1: Composition of marine sponges as bone resurrection material (Source: Granito et al., 2017)

Biomaterials	Composition
Biosilica	Water (6-13%), Si, O and traces of Al, Ca, Cl, Fe, K, Na, S and Zn
Polyphosphate	Phosphorous
Spongin	Collagen

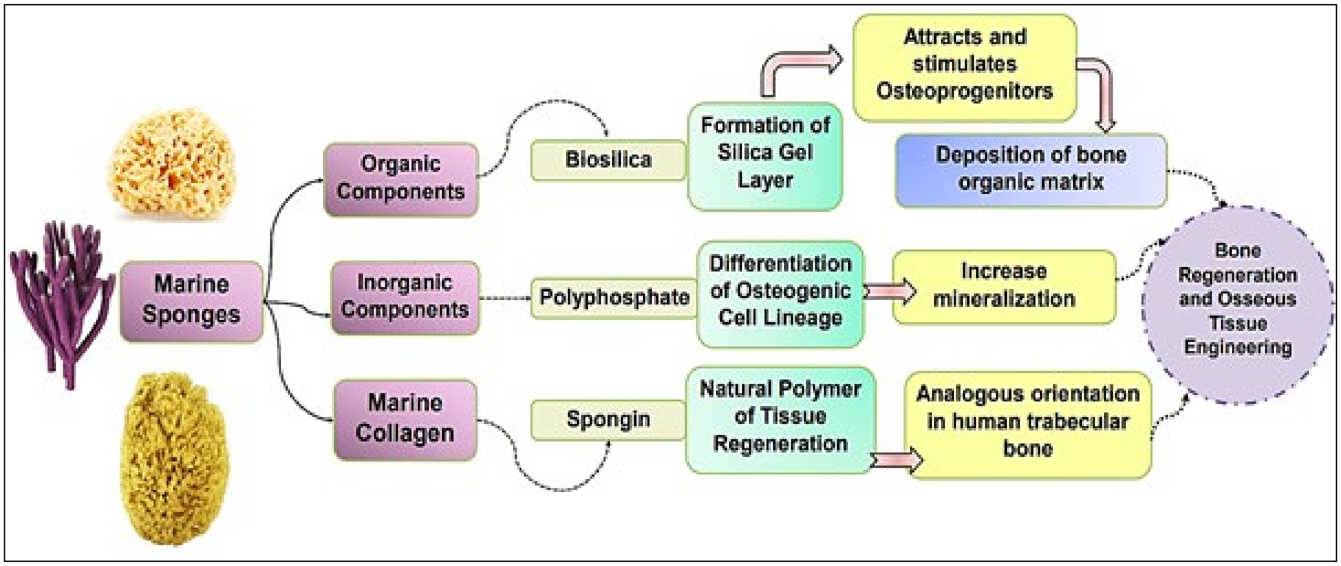

Figure 1: Role of marine sponge biomaterials in osseous tissue resurrection

are embedded into an organic matrix and have been considered to be non-toxic for mammalian cells, proving their biocompatibility. Silica ions are the most important elements that stimulate bone regeneration, making the biosilica derived from marine sponges a potential source for biomedical, bone replacement and osseous tissue engineering purposes. The bioactive silica can form bonds and integrate into osseous tissue through the formation of a silica gel layer, which attracts and stimulates osteoprogenitor cells to proliferate and differentiate into osteoblasts, initiating the formation and deposition of bone organic matrix and matrix mineralization (Odatsu, 2015).

5. Polyphosphate

Polyphosphate is an inorganic polymer found in the skeleton of marine sponges as tiny white clusters or granules containing phosphorous, which are formed by bacteria (captures P) during seawater processing through the water canal system in sponges (Zhang et al., 2015). This helps in the differentiation of human mesenchymal stem cells (hMSC) to osteogenic cell lineage and boosts mineralization potential.

6. Spongin

Spongin is the main organic component of marine sponges and it is similar to collagen type XIII (Lin et al., 2011). The morphological and biochemical studies unveil the similarities between the spongin matrix and vertebrate extracellular matrix, and the similarity in the orientation of collagen fibres within the sponge skeleton mimics the human trabecular bone. Moreover, the collagen obtained from marine sources reduces the risk of bovine spongiform encephalopathy and other diseases making it a potentially safe biomaterial (Silva et al., 2014). The collagen fibres of marine sponges form a suitable network for the attachment, migration and proliferation of osteoblasts.

7. Potential Marine Sponges in Osseous Tissue Engineering

In osseous tissue engineering, a variety of marine sponges have garnered attention for their biocompatible nature and osteogenic properties (Granito et al., 2017). The various studies unveiled the great potential of various compounds obtained from different marine sponges (Table 2) in enhancing the bone regeneration process.

Table 2: Different compounds developed from marine sponges having osteogenic potential (Source: Granito et al., 2017)

Species	Compound having osteogenic potential
Spongia sp.	Spongin
Suberites domuncula	Biosilica
	Silica-based components (Na-silicate, tetraethyl orthosilicate [TEOS], silica-nanoparticles)
	Biosilica, enzymatically synthesized from orthosilicate and polyphosphate (poly P)

Table 2: Continue...

Species	Compound having osteogenic potential
	β-TCP microspheres, supplemented with silica or silicatein
Callyspongiidae sp	Sponge skeleton with a collagenous fibrous network
Ircinia fusca	A novel tricomponent scaffold (Chi-Hap-MSCol) containing chitosan (Chi), hydroxyapatite (HAp) derived from *Thunnus obesus* bone and marine sponge (*Ircinia fusca*) collagen (MSCol)
Petrosia ficiformis	Sponges after calcination
Biemna fortis	Skeleton with collagenous fibrous network loaded or not with growth factors (IGF-1and BMP-2)

8. Conclusion

Marine sponges are an alternative and promising resource for osseous tissue engineering and for manufacturing biomedical compounds. The osteogenic ability of biomaterials obtained from marine sponges has shown promising biocompatibility and is considered a safer source of allografting in bone resurrection. Furthermore, the identification of potential species and implementation of various sustainable in-situ and ex-situ culture techniques can help in conservation and maximize exploitation of these little-explored gold mines of the marine waters ensuring their availability without harming natural stocks.

9. References

Chaudhari, A.A., Vig, K., Baganizi, D.R., Sahu, R., Dixit, S., Dennis, V., Singh, S.R., Pillai, S.R., 2016. Future prospects for scaffolding methods and biomaterials in skin tissue engineering: a review. International Journal of Molecular Sciences 17(12), 1974.

Gibbs, D.M., Vaezi, M., Yang, S., Oreffo, R.O., 2014. Hope versus hype: what can additive manufacturing realistically offer trauma and orthopedic surgery? Regenerative Medicine 9(4), 535–549.

Granito, R.N., Custódio, M.R., Rennó, A.C.M., 2017. Natural marine sponges for bone tissue engineering: The state of art and future perspectives. Journal of Biomedical Materials Research Part B: Applied Biomaterials 105(6), 1717–1727.

Lin, Z., Solomon, K.L., Zhang, X., Pavlos, N.J., Abel, T., Willers, C., Dai, K., Xu, J., Zheng, Q., Zheng, M., 2011. *In vitro* evaluation of natural marine sponge collagen as a scaffold for bone tissue engineering. International Journal of Biological Sciences 7(7), 968.

Nayak, G., Bhuyan, S.K., Bhuyan, R., Sahu, A., Kar, D., Kuanar, A., 2022. Marine sources as an unexplored bone tissue reconstruction material-A review. Egyptian Journal of Basic and Applied Sciences 9(1), 477–498.

Odatsu, T., Azimaie, T., Velten, M.F., Vu, M., Lyles, M.B., Kim, H.K., Aswath, P.B., Varanasi, V.G., 2015. Human periosteum cell osteogenic differentiation enhanced by ionic silicon release from porous amorphous silica fibrous scaffolds. Journal of Biomedical Materials Research Part A 103(8), 2797–2806.

Silva, T.H., Moreira-Silva, J., Marques, A.L., Domingues, A., Bayon, Y., Reis, R.L., 2014. Marine origin collagens and its potential applications. Marine Drugs 12(12), 5881–5901.

Yu, J., Xia, H., Teramoto, A., Ni, Q.Q., 2018. The effect of hydroxyapatite nanoparticles on mechanical behavior and biological performance of porous shape memory polyurethane scaffolds. Journal of Biomedical Materials Research Part A 106(1), 244–254.

Zhang, F., Blasiak, L.C., Karolin, J.O., Powell, R.J., Geddes, C.D., Hill, R.T., 2015. Phosphorus sequestration in the form of polyphosphate by microbial symbionts in marine sponges. Proceedings of the National Academy of Sciences 112(14), 4381–4386.

Zheng, Z., Yu, C., Wei, H., 2021. Injectable hydrogels as three-dimensional network reservoirs for osteoporosis treatment. Tissue Engineering Part B: Reviews 27(5), 430–454.