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Applications of Different Bioactive Glass and Glass-Ceramic Materials for Osteoconductivity and Osteoinductivity

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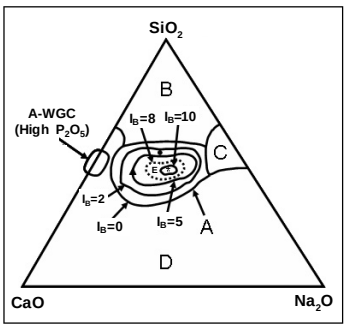
ABSTRACT

Throughout the world, research has been carried out in development of new methods and materials involving multidisciplinary approach for effective bone tissue repair and regeneration. Amid various biomaterials, bioactive glass material has drawn considerable attention due to their superior biocompatibility, degradability, ion leaching phenomena and propagation of osteogenic cells. In this concise review, effort has been made to summarize different material combinations available as composition to elaborate their biological properties both *in vitro* and *in vivo*, reaction kinetics in simulated body fluid, effect of different constituents of bioactive glass and glass-ceramic compositions, porosity, etc and finally these materials' applications as bone graft substitutes and various clinical applications have been detailed. In this review an attempt has been made to sum up the recent advancement of different bioactive glass and composite materials for osteoconductivity and osteoinductivity in orthopaedic surgical challenges.



[Keywords: Bioactive glass, Bioglass®, Osteoconductivity, Osteoinductivity, Hydroxycarbonate apatite, 45S5, S53P4, Bone graft]

Introduction

For effective bone tissue repair and regeneration research has been carried out in designing of new materials involving multidisciplinary approach. Numerous scaffold systems for bone tissue engineering have been introduced with novelty in scaffolds' design, drug and protein growth factors impregnation, mechanical strength and neo bone forming ability, etc. Nonetheless, autograft has still no alternative way for bone tissue repair. Autografts fail to meet in general medical requirement for orthopaedic implants. Alternative sources of allograft and xenograft are detrimental as may cause disease transmission and immune rejection. Accordingly, synthetic material plays a crucial role to meet the vast demand, apart from its limitations of strength, properties of osteoconduction, osteoinduction, osseointegration and biodegradation. To overcome such drawbacks, current research has been paying attention on improvement of newer biomaterials, enhanced alteration of structural and mechanical properties, performance enhancement of biocompatibility, osteoinductivity and addition of osteogenic cells onto scaffolds to trigger bone renewal.

During bone healing, extracellular matrix (ECM) containing collagen fibre and mineralized calcium phosphate is released from osteoblasts.[1, 2] A biomaterial scaffold having three-dimensional (3D) fibrous structure mimicking the ECM is prerequisite for successful bone regeneration in non load bearing defects.[3–5] Moreover, the scaffolds should not show any inflammatory or immunogenic reaction, be bioactive (ability to bond with bone) and bioresorbable, permit new bone formation, be cost effective, easily sterilizable, have optimal mechanical properties[6–9] and controllable interconnected porosity with pore diameter of no less than 100 μm (allow cells to grow within pores and angiogenesis).[10–12]

In bone tissue engineering, a number of biomaterials are presently being used as bone graft alternatives that include bioceramics, magnesium phosphate, sulfate, carbonate, calcium silicate and collagen. Some other materials, like metal alloys (titanium, cobalt-chrome), ceramics (zirconia, alumina), are also being used for the same purpose, but having the drawbacks of resorbability and impaired osseointegration at the bone-implant

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interface. However, synthetic biodegradable polymers, like polycaprolactone (PCL), polyethylene glycol (PEG) and polylactic-co-glycolic acid (PLGA), show positive interaction with cells without any deleterious effects in body system.[13, 14]

Amid various biomaterials, bioactive glass material has drawn considerable attention due to their superior biocompatibility, degradability, ion leaching phenomena, enhancing the adhesion and production of osteogenic cells.[15, 16] Mechanism of ion leaching includes exchange of monovalent cations (Na^+ or K^+, with H_3O^+) from glass, increase in pH of solution as a consequence which enables osteoblast synthesis subsequently.[17, 18] The macroporous structure with large surface areas of bioactive glass favours bone bonding.

Pores of bioactive glass are also advantageous for resorption and bioactivity[19] with nearly ten times more strength than the contact osteogenesis.[20] High modulus and brittle nature limits its potential widespread application and thus used widely as coating of metal implants which forms calcium-deficient carbonated calcium phosphates with time.

The aim of this review is to summarize the current advancement of different bioactive glass and glass-ceramic materials for osteoconductivity and osteoinductivity in orthopaedic surgical challenges.

Bioactive Glass Materials

Prof. L. L. Hench discovered (in the year 1969) that various compositions of glasses, when implanted to living tissues, could bond chemically with bone.[21–43] These 'bioactive glasses', since discovery, have mostly been used as bone substitutes for repair of damaged tissues;[31, 44] certain compositions of the same formed bond with soft tissues and bone as well.[40, 41, 45] Kinetic modification of surfaces when implanted *in vivo*,[26, 29] and formation of hydroxycarbonate apatite (HCA) on top leading to bonding at interface with tissues are some of very interesting characteristics of these bioactive glasses. An interface is developed between materials and tissues that oppose considerable mechanical forces. Faster surface reaction leads to faster bonding with living tissues, however, with low mechanical properties.

To make the glass surface with enhanced surface reactivity in contact with physiological fluids, high amounts of CaO and Na_2O are added (with relatively high CaO/P_2O_5 ratio).[46] Bioactive glasses with no Na or with novel dopants have also been developed over last few years which include fluorine,[47] magnesium,[48, 49] strontium,[50–52] iron,[53] silver,[54–57] boron,[58–61] potassium[62] or zinc.[63, 64] Ag_2O impregnated bioactive glass compositions reduce microbials due to antimicrobial efficacy of Ag^+ ions.[56, 65] Texture of the matrix could be tailored by using sol-gel method to obtain controlled Ag^+ delivery. B_2O_3 in $CaO\text{-}SiO_2$ system enhances bioactivity due to presence of more soluble boric compounds, leading to supersaturation of Ca^{2+} ions of SBF (simulated body fluid) and thus Si-OH groups of borosilicate glass helped apatite formations as it acted as nucleation sites.[66] Moreover, zinc addition helps in better cell attachment by maintaining the pH of SBF solution as well as causes osteoblast proliferation. Figure 1 shows $Na_2O\text{-}CaO\text{-}P_2O_5\text{-}SiO_2$ glass composition (constant 6 wt% of P_2O_5) dependence for hard and soft-tissue bonding. Region A is the bioactive-bone bonding boundary, composition of which forms bond with bone. Region B (e.g. composition of those silica glasses have applications including window, bottle or slides of microscope) behaves almost inert and forms fibrous morphology at implant-tissue interface. Region C compositions are resorbable, which, within a day disappears when implanted. Region D is not practical technically and not tested *in vivo*. Collagen part of soft-tissues usually adheres strongly in case of glass compositions shown in region E (Fig. 1).

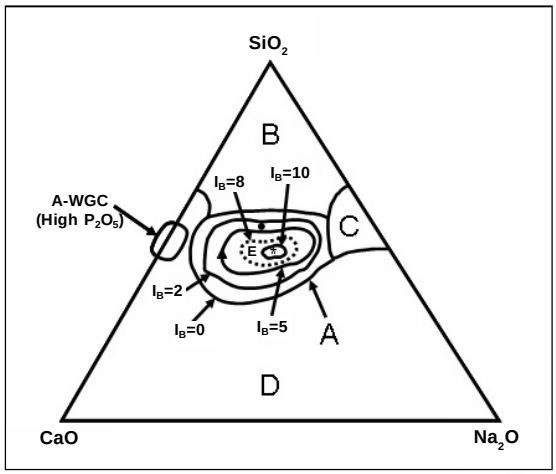

Fig. 1 – $Na_2O\text{-}CaO\text{-}P_2O_5\text{-}SiO_2$ based bioactive glass and glass-ceramics compositions and their influence on hard and soft tissue bonding; Region A has constant 6 wt% P_2O_5 composition, soft tissue bonding at region E is inside dashed line with bioactivity index (level of bioactivity of a material related to the time with >50% of interface bonded) I_B>8 [*: 45S5 Bioglass®, ▲: Ceravital®, ●: 55S4.3 Bioglass®, (....): soft-tissue bonding; $I_B=100/t_{0.5bb}$, where $t_{0.5bb}$ is the time with more than 50% of implant surface bonded to surrounding bone[29,46]]

Melt-quench is still the most popular method to develop bioactive glasses[67–73] followed by sol-gel method.[74, 75] In the sol-gel method, metal-organic and metal-salt precursors are used for sol preparation first, followed by gel formation with time which includes completion of reaction and/or aggregation and finally heat treatment with stepwise drying, removal of organics and crystallization.[76] It is a low temperature phenomenon for development of porous glasses with high specific surface area.[77] Recently, both micron and nano-scale particles have been developed as a part of this application[57, 78, 79] including, combining biodegradable polymers and bioactive glass.[80–85] Bioactive glass-ceramics having both osteoconduction and osteoinduction properties are classified as Class A bioactive materials[44, 71, 86, 87] and only osteoconductivity

as Class B materials. Bioactive glass, if heated above its crystallization temperature (610°-630°C), produces bioactive glass-ceramics[71, 78, 88, 89] and during the heating process, parent glass shrinks, porosity reduces and mechanical strength increases.[87] However, bioactive glasses are not being used presently as an alternative to load-bearing implants owing to their limited strength and low fracture toughness,[44, 87, 88, 90] and thus, it still remains an orthopaedic challenge.[91, 92]

Reaction Kinetics

Bioactive glass, when comes in contact with simulated body fluid (SBF) or tris buffer saline (TBS), following simultaneous reactions occur[20, 46, 86, 93–95] (Fig. 2):

1) Exchange of H^+ or H_3O^+ with alkali or alkaline earths of glass network with interfacial pH typically more than 7.4.
2) Local release of silicic acid [$Si(OH)_4$] by actions of hydroxyl ions with -Si-O-Si-O-Si-. For glasses with >60% silica content, dissolution rate decreases with increase of bridging oxygens of such glasses. Subsequently, there is structural rearrangements of Si-OH by polycondensation and silica rich gel.
3) Formation and precipitation of amorphous calcium-phosphate rich layer came from glass and solution and further crystallization to carbonated hydroxyapatite (HCA).

Hydrated silica actually helps for growth of HCA and it is almost established that above reaction mechanisms are neither dependent on presence of living tissues nor *in vivo* conditions and can occur in contact with water as well. However, subsequent bond with surrounding tissues depends on the following:

1) Attachments of biological substance on HCA-SiO_2 layer
2) Activity of macrophages or phagocytes
3) Stem cell attachment
4) Differentiation
5) Cell matrix formation and
6) Mineralization

To study the silicate glasses, which is considered to be an inorganic silicon 'polymer' cross-linked by oxygen, elucidation of network connectivity or cross-link density is vital.[96] Network connectivity refers average number of additional cross-linking bonds (essentially more than two) other than oxygen, which forms network anchor. This is based on comparative number of network-forming oxides (bridging oxygens) and network-modifiers (non-bridging oxygens).[97] The network connectivity of a glass can dictate various physical properties including its solubility.[98] Silicate network formers with low network connectivity (low molecular mass as well) are potentially bioactive owing to their ease to go into solution and increased solubility.[97] Glass properties have also been determined by substitution of sodium oxide for calcium oxide.[99] The basis of bioactive glass systems should be mole per cent substitutions than weight per cent when considered on a structural level. Weight per cent basis may hide the composition-property relationships of bioactive glass owing to non-calculation of the degree of disruption of the glass network.[99, 100] In order to maintain same numbers of non-bridging oxygen, one mole of NaO should be added if one mole of CaO is removed from a highly disrupted glass network to maintain same network connectivity value. Wallace *et al.*[97] used this concept for designing bioactive glass compositions having controllable physico-chemical and biological properties.

Fabrication

Different methods of fabrication and post heat-treatment have important role on properties of bioactive glass and glass-ceramics subsequently. Many researchers described different fabrication methods including sugar or salt leaching, microsphere emulsification sintering, foam

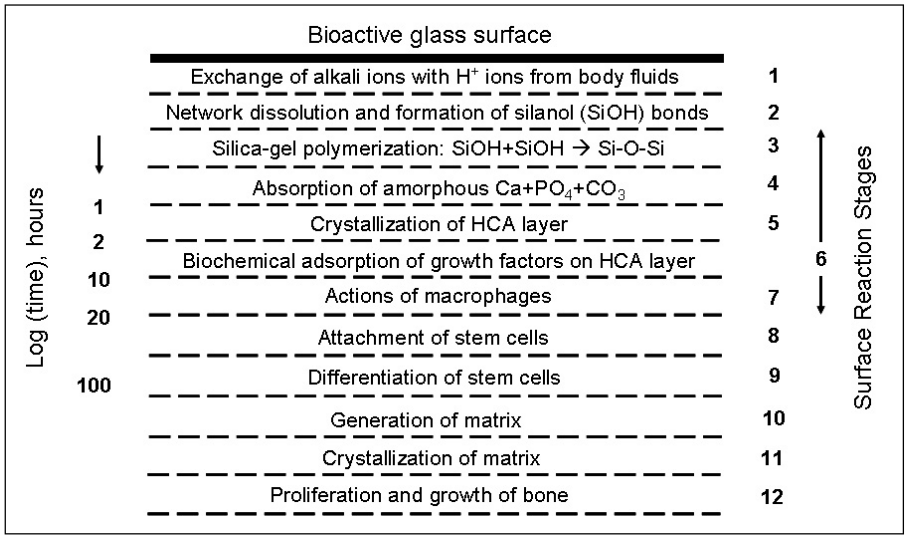

Fig. 2 – Typical reaction kinetics for forming bond between bone and bioactive glass[86, 95]

replication, temperature dependent phase separation, electro-spinning, rapid prototyping, etc after optimizing structure, properties and mechanical integrity of scaffolds,[101, 102] textile and foam coating methods[103–105] and biomimetic approach.[106, 107] Another area of research which is of significance in bone-tissue engineering is mimicking the nanostructure of natural bone by designing and incorporating nano-topographic features on surface.[72, 108–110] Many researchers have also raised the scaffold manufacturing procedure to a height.[68, 70, 85, 105, 111, 112]

Polymeric materials and foaming agents are added to form the pores of bioactive glass and glass-ceramics.[113] Rainer *et al.*[114] used bioactive glass-loaded polyurethane foam (*in situ*) for preparation of scaffolds of bone tissue engineering. This method was found to be very suitable for 3D processing and tailor-made applications in reconstructive surgery. Lin *et al.*[115] reported porous bioactive glass-ceramics up to preclinical trial and used polyethylene glycol ($HO(C_2H_4O)$-nH) with particle sizes ranging between 5 and 500 μm as foaming agent prior to obtaining porous scaffolds. Due to uniform distribution of porous channels (as seen from microstructures), better bony in-growth and bioresorption of implants could be seen. Similar type of porosity can be generated by addition of organic polymers, e.g. dry/wet woods, crops (from food processing and wood finishing)[116] to completely degrade at temperatures above 600°C and make the scaffold porous. Apatite layers formed when bioactive glasses are used *in vitro* / *in vivo*, also closely depend on variations of texture properties (pore size, volume, structure) of biomaterials. For example, owing to higher surface area and pore volume, apatite formation and thus bioactive behaviour were greatly enhanced.[117]

In the SiO_2-Na_2O-CaO-P_2O_5 glass system (like ordinary soda-lime-silica glasses), certain percentages with specific proportions of the compositions show bonding to bone[26, 31, 33, 37, 47, 61, 118–127] (Table I).

Bioactive Glass as Bone Graft Substitute

Bioactive glasses in the form of porous implants, fibers and microspheres and being bioactive (interact with the body) show both osteoconductive and osteoinductive

Table I : Different bioactive glasses

Sl. No.	Name of the bioactive glass	Composition (%)												
		SiO_2	P_2O_5	CaO	$Ca(PO_3)_2$	CaF_2	MgO	MgF_2	Na_2O	K_2O	Al_2O_3	B_2O_3	Ta_2O_5/TiO_2	ZnO
1.	45S5 Bioglass®[31]	45	6	24.5	–	–	–	–	24.5	–	–	–	–	–
2.	45S5.4F Bioglass®[31, 118]	45	6	14.7	–	9.8	–	–	24.5	–	–	–	–	–
3.	45B15S5 Bioglass®[119, 120]	30	6	24.5	–	–	–	–	24.5	–	–	15	–	–
4.	52S4.6 Bioglass®[121]	52	6	21	–	–	–	–	21	–	–	–	–	–
5.	55S4.3 Bioglass®[121]	55	6	19.5	–	–	–	–	19.5	–	–	–	–	–
6.	KGC Ceravital®[26]	46.2	–	20.2	25.5	–	2.9	–	4.8	0.4	–	–	–	–
7.	KGS Ceravital®[26]	46	–	33	16	–	–	–	5	–	–	–	–	–
8.	KGy213 Ceravital®[26]	38	–	31	13.5	–	–	–	4	–	7	–	6.5	–
9.	A/W glass-ceramics[37]	34.2	16.3	44.9	–	0.5	4.6	–	–	–	–	–	–	–
10.	MB glass-ceramics[33]	19-52	4-24	9-3	–	–	5-15	–	3-5	3-5	12-33	–	–	–
11.	S45P7[122]	45	7	22	–	–	–	–	24	–	–	2	–	–
12.	S53P4[123]	53	4	20	–	–	–	–	23	–	–	–	–	–
13.	13-93[124]	53	4	20	–	–	5	–	6	12	–	–	–	–
14.	4-Mar[125]	50.5	1	22.5	–	–	6	–	5	15	–	–	–	–
15.	18-04[125]	54.5	4	20	–	–	4.5	–	15	–	–	2	–	–
16.	23-04[125]	56.25	1	20	–	–	4.5	–	5	11.25	–	2	–	–
17.	H2-02[61]	53	2	22	–	–	4.5	–	6	11	0.5	1	–	–
18.	CEL-2[47]	45	3	26	–	–	7	–	15	4	–	–	–	–
19.	55S[126]	55	4	41	–	–	–	–	–	–	–	–	–	–
20.	H[127]	46.2	2.6	26.9	–	–	–	–	24.3	–	–	–	–	–
21.	HZ5[127]	44.4	2.5	25.9	–	–	–	–	23.4	–	–	–	–	3.8
22.	HZ10[127]	42.5	2.4	4.8	–	–	–	–	22.5	–	–	–	–	7.8
23.	HZ20[127]	38.8	2.2	22.6	–	–	–	–	20.5	–	–	–	–	15.9

properties.[128] Bioactivity is mostly due to the SiO_2 content; presence of 45-52% SiO_2 lift up the bonding of bioglass with bone.[129] The bioactivity and biocompatibility of bioactive glass increase when it is combined with hydroxyapatite[130] and ultimately leads to increased mechanical strength in comparison with calcium phosphate when used alone. The mechanism behind that is a silicate-rich layer is formed in contact with body fluids leading to strong mechanical graft-bone bonding. That triggers formation of hydroxyapatite layer. As a result new bone formation accompanied by protein absorption occurs, which, in turn, attracts mesenchymal stem cells, macrophages and osteoprogenitor cells. Consequently, osteoblasts are produced by dissemination of osteoprogenitor cells into matrix.[129, 131] Owing to sub-optimal mechanical properties of bioactive glass, other ceramic components are occasionally reinforced with the bioactive glass. Alternate way to increase mechanical strength and biological absorbability of SiO_2-CaO bioactive glass is incorporation of Na_2O into bioactive glass by sol-gel process, leading to formation of a hard yet biodegradable crystalline phase when sintered.[132] When calcium concentration (GC5) is increased or P_2O_5 (GP2) is decreased, mechanical properties of potassium fluorrichterite ($KNaCaMg_5Si_8O_{22}F_2$) glass-ceramics are improved. This can be used in development of medical devices anticipated for bone tissue repair.[133, 134] Foaming with rice husks produces a new porous bioactive glass (45S5) with sufficient mechanical support when sintered at 1050^{o}C for 1 h and can maintain bioactivity and biodegrade at later stages.[135]

Greater filler effects of bioactive glass is observed in comparison with autogenous bone in rat cancellous bone defect models.[136] Bioactive glass in conjunction with allogenic demineralized bone matrix triggered bone formation without any adverse cellular reaction.[137–139] The composite scaffolds comprising bioactive glass-collagen alone and in combination with phosphatidylserine showed greater biocompatibility and osteogenesis effects. The said composites fulfilled the criteria to be used in bone tissue engineering and proved itself to have tremendous possibility in bone regeneration.[140, 141] Incorporation of mesenchymal stem cell with hyaluronic acid enhances healing of the bone defect during scaffold preparation.[142] Bone-bonding response is greatly enhanced by micro-roughening of bioactive glass surface.[143] Being biocompatible it shows no inflammatory response in tissues and resorption of glass fiber scaffolds are observed within 6 months.[144] Porous bioactive glass when used experimentally in goat bone defect model, promoted new bone formation that suggests its potential for orthopaedic reconstructive procedures.[145] Apart from its role in bone tissue engineering, it has also beneficial role to enhance neovascularization during soft tissue engineering of larger size.[146] Neovascularization is extremely essential irrespective of hard and soft tissue healing which can be accomplished by delivery of lower amount of bioactive glass in site.[147]

Silica-based bioactive glasses are usually used for dental restoration and bone implants and it also has the ability to deliver drugs to site in conditions like bone infections, defects, fractures (due to osteoporosis) and tumours. Mesoporous silica micro-/nano-particles have potentiality to be used as vehicle which can release anti-cancer drugs within specific malignant cells.[148, 149] Clinically, GTR (guided tissue regeneration) with collagen membrane (CM) merged with autogenous bone, either as graft or combined with bioactive glass, are compared and concluded that autogenous bone can be mixed with bioactive glass where there is less amount of harvested bone. Jebahi *et al.*[150] evaluated the performance of freeze dried bioactive glass containing 17 wt%-chitosan composite (BG-CH) in bone defects of ovariectomized rat and found incorporation of 17 wt% CH with BG matrix to significantly enhance the bioactivity and osteoinductive property. Moreover, it increased Ca and P ion concentrations in the implanted microenvironment.[150, 151] Strontium ranelate has immense importance in the treatment of osteoporosis, hence, incorporation of bioactive strontium into mesoporous bioactive glass scaffold enhances fracture repair process.[152]

Bioactive glass has inherent properties to be used as scaffold materials; borate or borosilicate composition induces new bone formation and doping with Cu, Zn or Sr enhances healthy bone growth. Bioactive glass has important role to enhance neovascularization and neocartilage formation.[153] Osteoconductive and osteointegration properties of borate bioactive glass were evaluated in rabbit model by synchrotron micro-CT, with precise resolution, and resulted in detailed visualization of biomaterial-bone assimilation and detailed microarchitecture of both glass graft and newly formed trabecular bone. Moreover, teicoplanin-loaded borate glass showed osteoconduction.[154]

Bioactive glass in particulate form enhances bone mineralization but may result in inflammation and particle migration. Thus incorporation of chondroitin sulfate-(CS) based bioadhesive improves amalgamation of the bioactive glass as well as prevents particle migration, promotes bone regeneration and provides mechanical stability by encapsulating bone marrow.[155] Modified (as explained earlier) potassium fluorrichterite ($KNaCaMg_5Si_8O_{22}F_2$) glass-ceramics gave direct bone tissue contact *in vivo* through new bone formation and cell proliferation along implant surface into medullary space. But, inclusion of P_2O_5 improves osteoconductivity and mechanical stability to a larger extent.[156] 6 mol% P_2O_5 containing bioactive glasses (SiO_2-P_2O_5-CaO-Na_2O-CaF_2) upon heat treatment, are crystallized to mixed sodium calcium fluoride orthophosphates and fluorapatite which have excellent properties of osteoconduction as well as bone regeneration.[157]

Osteoinductive properties of the glass, on the other hand, results due to dissolution products of glass (mainly, soluble silica and calcium ions) which stimulates osteogenic cells leading to bone matrix.[69] *In vitro* human

osteoblastic cells cultured on bioactive glasses, produce collagenous extracellular matrix (ECM), which eventually forms bone nodules without any supplementation and absence of phosphate in the composition,[158] whereas other bioceramics need osteogenic supplements like dexamethasone and b-glycerophosphate to be incorporated.[159–161] It also increases intracellular calcium levels[162, 163] and upregulate various gene. Calcium ions and soluble silica from bioactive glass also help to stimulate osteoblastic cell division, growth factors production and ECM proteins.[164]

In vitro study shows that MSCs are differentiated into osteoblasts and osteoclasts irrespective of presence or absence of BMP-2 when cultured on bioactive sol-gel coatings with low silica content (40 mol% SiO_2, 54 mol% CaO, 6 mol% P_2O_5),[165] that accelerates osteogenesis and remodelling. Whereas, MSCs differentiate only into osteoblasts when cultured on glass coatings of high silica content (80 mol% SiO_2, 54 mol% CaO, 6 mol% P_2O_5). *In vitro* culture of human adipose stem cells on bioactive glasses show differentiation into osteogenic cells in presence of osteogenic supplements.[166]

Studies with sol-gel derived elestrospun composite fibrous membranes (using $45SiO_2$-24.5CaO-24.5Na_2O_6-P_2O_5 and $43SiO_2$-24.5CaO-24.5Na_2O_6-P_2O_5-2Fe_2O_3 system pre-mixed with polyvinyl alcohol) revealed that the magnetic particles embedded in the scaffolds have a synergistic effect on osteoinductivity with and without external magnetic field[167] where magnetic particles play a key role in providing osteoinductive properties to the composite scaffolds.[168]

Clinical Applications

Bioactive glass coated screw was evaluated clinically for Weber type B ankle fractures in 37 patients without screw loosening within 2 years.[169] Other clinical claim of bioactive glass included vertebroplasty,[170, 171] treatment of unstable distal radius fracture,[172] tympanoplastic reconstruction,[173] as filler in benign tumour surgery,[136] facial bones reconstruction,[174] management of periodontal bone defects,[175, 176] obliteration of frontal sinuses,[177–179] repairing of orbital floor fractures,[180, 181] lumbar fusion,[182] reconstruction of maxillary sinus,[183] cement-less acetabular cups (with metal back-up)[184] and restoration of iliac crest defect post bone graft harvesting.[185] The allergenic mesenchymal stem cells can be delivered from a thermoplastic, viscous carrier with a granular bioactive glass scaffold in a clinically convenient form that was proved to be efficient osteogenic substance during early stages of canine alveolar repair.[186]

Bioactive glasses have also been used for spinal fusion, coatings for orthopaedic metal implants, replacement of bone, in dentistry (like periodontology and endodontology), bone tissue engineered scaffolds, composites and regenerative medicine.[164, 187, 188] In clinical dentistry, bioactive glasses (particles, porous or dense scaffolds) have been used extensively.[164]

The composite product of bioactive glass-ceramics A-W (apatite-wollastonite) and bioactive surface-modified Ti-metal is used clinically as bone substitute (e.g. artificial vertebrae and iliac crest) due to its better bone-bonding ability and superior mechanical strength in contrast to human cortical bone.[189] Good osteoinduction, ectopic bone formation occur in muscle when this porous Ti metal (after strong acid treatment and post heat-treatment) was used.[190, 191] Likewise, heat treated porous Ti metal after subsequent exposure to HCl treatment and NaOH treatment also showed remarkable osteoinducion[192] and osteoconduction.[193–195]

Conclusions

During the past decades, biomedical materials have shown a new vista for effective hard tissue and dental repair as well as in local drug delivery systems. This has enhanced life expectancy as well as meets the social commitments for quality life. A considerable stride towards the exploitation of synthetic biomaterials in bone and dental tissue engineering has been explored. Amid various biomaterials, bioactive glass has shown paramount interest in clinical regenerative medicine due to its inducing capacity as active biomineralization *in vivo*. Initially, it has been thought for its efficacy in bone repair and restoration. Of late, it has eventually become a very striking biomaterial of choice in various clinical settings like in dental, maxillofacial and ear implants, soft tissue regeneration, coating of metallic implants, drug delivery system, septic wound dressing, growth factors carriers, bioactive peptides, etc. In coming days, bioactive glass may be utilized in a more befitting way by the scientists/ researchers/ clinicians for well being of human kind.

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