Materials Science and Engineering C 76 (2017) 1369–1377

Contents lists available at ScienceDirect

Materials Science and Engineering C

journal homepage: www.elsevier.com/locate/msec

Review

Bioactive glass for dentin remineralization: A systematic review

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A R T I C L E I N F O

Article history:
Received 14 December 2016
Received in revised form 6 March 2017
Accepted 12 March 2017
Available online 14 March 2017

Keywords:
Bioactive glass
Remineralization
Dentin

A B S T R A C T

Background and objectives: Strategies to achieve dentin remineralization is at present an important target of restorative dentistry. Remineralization of dentin by a bioactive material is complete only when the tissue regains its functionality. This is achieved when there is adequate apatite formation which most importantly translates into improved mechanical properties of dentin as a result of intrafibrillar mineralization. Bioactive glass (BAG) is a well-known implant material for bone regeneration and is proven to have excellent ability of apatite formation. Hence, recent studies have proposed BAGs as one of the most desired materials for remineralization of dentin. Therefore the aim of this systematic review was to scope the evidence of bioactive glass to remineralize dentin.
Methods: The following research question was formulated: "Is there strong evidence for bioactive glass to remineralize dentin?" Three databases (Web of science, PubMed and Science direct) were scanned independently following PRISMA guidelines. Inclusion and exclusion criteria were set to identify relevant articles based on title and abstract screening. Finally, potentially relevant articles were downloaded and the full text was scrutinized to select the articles included in this review.
Results: The first phase of search returned 303 articles. A total of 19 papers with full text were scrutinized for inclusion, of which 3 papers were chosen for the final synthesis. All three studies confirm that BAG treatment leads to enhanced apatite formation in dentin. Only 1 of the 3 studies has reported the mechanical properties of dentin after BAG treatment and it revealed that the Young's modulus and flexural bend strength of BAG treated dentin were much lower than natural dentin even though they had similar apatite content.
Conclusions: This review highlights the importance of assessing the mechanical properties of dentin alongside to the newly formed apatite content in order to prove BAGs efficiency to remineralize this tissue. Though studies have confirmed that BAGs stimulate excellent apatite formation in dentin, it should be concluded that there isn't sufficient evidence for bioactive glass to effectively remineralize this tissue as the mechanical properties of the BAG treated dentin haven't been well explored.

Contents

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http://dx.doi.org/10.1016/j.msec.2017.03.083
0928-4931/

1. Introduction

Materials for tissue replacement have progressively evolved overtime. The discovery of bioactive glass (BAG) has played a key role in this evolution. The 1st generation of materials for tissue replacement had the requirement to be bio-inert without triggering any host inflammatory response [1]. In 1969 there was a revolution in tissue engineering when Professor Larry Hench introduced bioactive glass (a sodium calcium phosphor-silicate glass) which was the first material that exhibited bone bonding ability with an excellent bonding capacity [2,3]. Ever since, there was a shift in the paradigm of materials for tissue replacement from being bio-inert to bioactive. A material that could interact beneficially with the host tissue to drive its repair and regeneration became the prime need. From this point there was a growth of bioactive materials (glass, ceramics) including modified bioactive glass, calcium phosphate [4,5], hydroxyapatite [6–8] and calcium silicates [9–11]. In the years following its invention, bioactive glass has been extensively researched and the mechanism behind its high bioactivity has been reported. The two main reasons for its bonding ability are as follows; 1. The ions leached from the glass form carbonated calcium deficient hydroxyl apatite (HCA) that binds with the collagen of the tissue 2. The ions also up regulate genes that encode growth factors and stimulate osteogenic cells to secrete bone matrix [2]. Bioactive glass has therefore been used in many applications such as a putty for bone repair [12, 13], coating on implants (bone and dental) [14,15], scaffolds for bone regeneration [16–18] and also for cartilage repair [19].

Next to bone regeneration, bioactive glass has found its niche in dentistry. The loss of mineral structures of the tooth enamel and dentin due to caries or erosion is a well-known clinical problem in dentistry [20,21]. The leaching of ions from bioactive glass and subsequent HCA formation eventually makes it a valuable candidate to be used for remineralization of these dental tissues. Hence, bioactive glasses are now used in tooth pastes [22,6,23], air polishing procedures [24] and their ability to treat tooth sensitivity and remineralize enamel has been proven [25–27]. Dentin remineralization is more demanding than enamel remineralization due to the difference in their composition. As 96% (weight %) of enamel is composed of mineral apatite, the mechanical properties of this tissue is mainly determined by its mineral content. However, the mineral in dentin accounts to only 70% and the remaining 30% is contributed by organic collagen, non-collagenous proteins and water. Furthermore, the design of dentin is such that it is supported by fibril scaffold-form of the collagen in which the mineral apatite is embedded in an extrafibrillar and intrafibrillar manner (Fig. 1). Therefore, the mechanical properties of this tissue not only depend on the overall mineral content but mainly on the intrafibrillar orientation of minerals in the collagen scaffold [28].

Hence, increased mineral content at the tissue after bioactive glass treatment is not enough to remineralize dentin as it is for enamel remineralization. The review of Bertassoni et al. [28] underlines that the improvement in mechanical properties of dentin through intrafibrillar mineralization is crucial to retain the functionality of this tissue. This emphasizes the need to understand the phenomena of remineralization in the context of the tissue it is interfaced with and sufficient characterizations (physico-chemical and mechanical) are of utmost importance to prove the effective remineralization of dentin. Furthermore, remineralization of dentin by bioactive glass can also be complemented by stimulating the odontoblasts or odontoblast-like cells present in the pulp that can secrete reactionary or reparative dentin. However, the new dentin that could be formed is limited only to the pulp dentin interface and the research in this field is at a very evolutionary stage. Therefore, at present, remineralization of dentin in a non-cellular manner through apatite formation by bioactive glass has gained the spotlight. Thus, there is active ongoing research to use bioactive glass as fillers in tooth restorative materials such as tooth pastes, Glass ionomer cements (GICs) [29] and dental composites [30–32] with the aim to occlude exposed dentinal tubules, improve the bonding at the dentin interface and most importantly to repair the underlying mineral depleted dentin through remineralization and such studies are reporting the efficiency of bioactive glasses for dentin remineralization.

Furthermore, it is well known that the excellent bioactivity of the first developed bioactive glass 45S5 was mainly due to is its finely tuned composition. However, in recent years the glass production methods have become more varied with methods such as sol-gel [33] [34,35], flame spray [36] and spray pyrolysis [37] on offer in addition to the traditional melt-quench route. These methods give additional textural features such as porosity and fine particle size which increases the surface area of these particles. Recent studies suggest that, besides composition, surface textural properties also play a vital role in the bioactivity of these glasses [38–40].

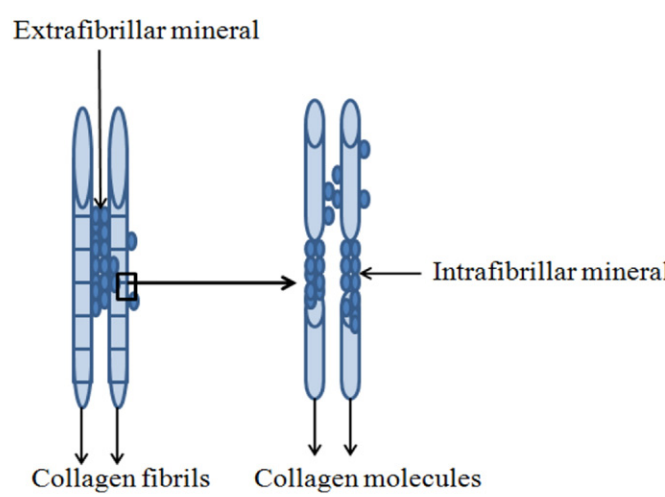

Fig. 1. Representation of extrafibrillar and intrafibrillar mineralization in the collagen structure of dentin.
Adapted from [28].