

Amalgam Alternatives: Myth or Truth?

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Abstract

Objective: To review scientific literature on Amalgam alternative materials, regarding their composition, setting reactions, physical and anti-cariogenic properties, and their clinical use as stated by various studies done on them.

Materials and Methods: A search of English peer-reviewed dental literature from various databases that was conducted.

Keywords: Improved Glass Ionomer Cements; Giomer; Alkasites; Amalgotomer CR; Zirconomer and Zirconomer Improved; Amalgam

Introduction

Dental caries as a multifactorial, oral disease is caused primarily by an imbalance of the oral flora (biofilm) due to the presence of fermentable dietary carbohydrates on the tooth surface over time [1]. It is considered as a component of global disease burden. An ideal restoration should have properties like adequate compressive strength, decreased solubility in oral fluids, no marginal leakage, caries preventing ability etc. But, none of the materials till date have satisfied all this ideal properties [2]. Since the 1890s, dental amalgam that is metallic restorative material widely chosen by dental practitioners for such restorations due to its several advantages such as lower cost, long clinical serviceability and easy manipulation. With the decline in popularity of amalgam in recent years, due to increase in demand of esthetics, its lack of adhesion to tooth surface, and the potential hazard of mercury toxicity considered by Food and Drug Administration (FDA), the pursuit for alternative materials overcoming these shortcomings began [3].

Dentists have long sought after a real alternative to amalgam that are cost-effective, fluoride releasing easy to use without complicated equipment and that offer both strength and good esthetics. The search for a new materials possessing these properties have led to the introduction of a new filling materials offering these characteristics plus other advantages over amalgams. New amalgam alternative formulations like: Giomer, Alkasites, Amalgotomer, and Zirconomer Family are being introduced every day. It is important for practitioners to know their composition, setting reactions, and their properties to facilitate selecting the best restorative material for a particular situation which is the aim of the current work.

Giomer

A new class of hybrid aesthetic restorative material that differs from both resin modified GICs and compomers has been introduced to yet market under the name of gomers. They are produced as Pre-Reacted Glass-ionomer (PRG) filler [4]. PRG fillers are fabricated by reacting fluoroaluminosilicate glass and polyalkenoic acid in the presence of water to form a wet siliceous hydrogel. The product of this

reaction is freeze-dried, desiccated, milled and silanized to form PRG fillers [5]. According to the degree of reaction of the glass ionomer with the acid the produced PRG-fillers are of two types [6] namely 1) surface reaction type (S-PRG fillers) where the reaction is detected in surface layers and 2) full reaction type (F-PRG fillers) where the reaction proceeded throughout. The use of both types of PRG fillers promote rapid fluoride release through a ligand exchange within the prereacted hydrogel [7]. Fluoride release from F-PRG fillers is more than that released from S-PRG fillers because the core of the particles of the 1st is completely reacted unlike of the latter and hence will degrade faster. S-PRG fillers have beneficial properties of releasing five ions (Al, B, Na, Si, Sr ions) other than fluoride (Figure 1) [8,9].

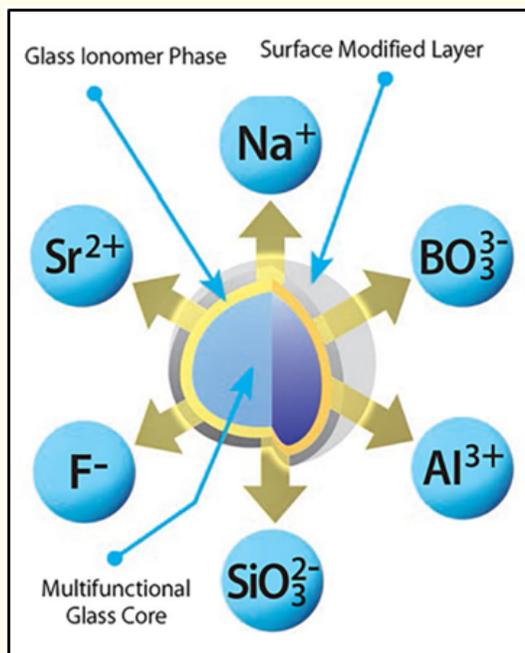


Figure 1: Six ion released from PRG.

Modification of the PRG fillers resulted in the production of modified S-PRG fillers. Each glass filler consists of is a three layers namely the original glass core of multifunctional fluoro-boro-aluminosilicate glass and two-surface layers of reinforced modified layer that covers the surface of pre-reacted glass-ionomer phase. The resulting three layered filler allows fluoride release and recharge to take place (Figure 2) with protection of inner glass core from the damaging effects of moisture ensuring long-term serviceability.

Benefits of ions, other than fluoride, released from S-PRG fillers are: i) Fluoride release and fluoride recharge, ii) formation of acid resistant layer [9] iii) reinforcement of tooth structure [10] iv) antiplaque effect [11] v) remineralization of dentin [8] vi) acid buffering capacity and reduce acid production by acidogenic bacteria [9]. Silicon forms silica gel inducing apatite nucleation on its surface and ends by hydroxyapatite formation. Calcium and phosphorous ions from the surrounding environment interacted with the surface silanol groups of hydrated silica gel generating biologically active apatite on the silica gel surface [12,13]. Another benefit for the released Si is that it helps in condensation of silicic acid to oligomers encouraging dentin mineralization [14]. Boron inhibits bacterial and fungal quorum sensing so used in treatment of periodontitis [14]. Inhibition of Streptococci quorum sensing by boron may be the underlying mechanism of S-PRG actions in inhibiting biofilm formation [15-19]. S-PRG fillers releasing fluoride and other minerals into the underlying dentin leading to perfect occlusion of opened dentinal tubules and consequently eliminated dentin hypersensitivity [20].

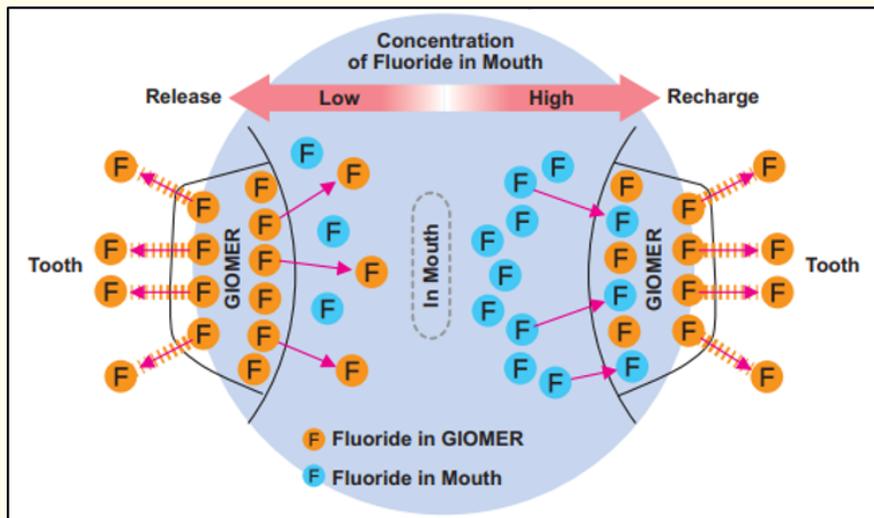


Figure 2: Giomer’s continuous fluoride release and recharge capability contributes to long-term caries inhibition.

In order to determine any new technology quality, like the case with Giomer, its performance should be measured. In a clinical study, 8-year recall patients with Giomer restorations it was found that no secondary caries, no failures, no post-op sensitivity and maintained aesthetics. At 13 years recall these same restorations had a secondary caries rate of only 3% and a retention rate of 61% [21,22].

Giomers are supplied as one paste form that are light cured. Commercial products of Giomers are Reactmer (shofu, japan), beautiful (shofu, japan) and beautiful II (shofu, japan). The later one Beautiful II is a Nano-Hybrid Composite with Fluoride Release and Recharge, and is approved for classes I through V. It has the following advantages: Sustained fluoride release and recharge, ideal handling, easy sculpting without slumping or sticking, exceptional marginal seal, natural fluorescence, high radiopacity (2.3 Al mm), easily polished to attain and retain high luster over time [23]. Giomers absorb water due to the presence of pre-reacted glass polyacid zone that is responsible for generating the osmotic effect which leads to swelling and expansion causing pressure. The resulting pressure may be cause tooth fracture [24].

One study showed that the amount of total and free fluoride release from Giomer was higher than from Compomer and resin composite. The study attributed this to the glass ionomer matrix of glass filler in Giomer play an important role for fluoride releasing and recharging abilities [25]. Giomers and compomers do have the initial fluoride burst effect of the glass ionomer cements was shown in another study [26]. Beautiful showed “smart behaviour” due to its maximum fluoride release both in deionized water and lactic acid and greater fluoride release in lactic acid when compared to water [27].

Material’s ability for fluoride recharge is dependent upon its fluoride retention ability [28] and is controlled by the available sites to retain absorbed fluoride within this material. Consequently, the more the fluoride release, the more sites are available and the more the fluoride recharge [29]. In a study the fluoride release and recharge for Giomer products were found the maximum among fluoride releasing material [30].

The patented filler technology of PRG of Giomers integrates the light transmission, diffusion properties, and fluorescence of natural teeth. Giomers have radiopacity of 3.4 Al mm, which is 70% greater than enamel and 200% greater than dentin. They have high depth of

cure and can reach 5.9 mm [23]. Their mechanical properties are sufficiently high e.g. flexural Strength of 130 Mpa, Shear bond strength of 12.39 Mpa, Vickers Hardness of 62 Hv, Wear Resistance of 0.52 wt% [31]. Their compressive strength when compared to that of Compomer and Composite were found 246 Mpa, 151.943 Mpa and 146.265 Mpa respectively [32].

Alkasites

Alkasites are bioactive filling material for direct restorations, cold or light cured, designed to restore Class I, II or V for deciduous and permanent teeth. Because of their bioactive properties Alkasites release acid neutralizing ions to prevent demineralization of the teeth. Implementing alkaline fillers in a resin matrix of methacrylate resulted a new category of material: Alkasites, commercially available as (Cention-N®) from Ivoclar Vivadent™ company [33]. They are tooth-colored filling materials having high flexural strength that used as full volume (bulk) replacement material. Their liquid are polymers composed of combination of Urethane dimethacrylate (UDMA), Tricyclodecan-dimethanol dimethacrylate, an aromatic-aliphatic-UDMA and Polyethylene glycol 400 dimethacrylate (PEG-400 DMA). These polymers cross-link during polymerization resulting in strong mechanical properties and good long-term stability and lower shrinkage [34]. Their filler is alkaline in nature that increases the release of hydroxide ions to regulate the pH value during the attacks with acid. As a result, the demineralization can be prevented. Furthermore, they released large amounts of fluoride and calcium helping the remineralization of tooth enamel. The initiator system allows for a good chemical self cure [35].

Alkasites do not contain Bis - GMA, HEMA or TEGDMA. UDMA is the main component of their monomers giving them hydrophobic nature with low water absorption. Cention-N® (Ivoclar Vivadent, Schaan, Liechtenstein) is an example for alkasites with aromatic aliphatic UDMA resin matrix that have high viscosity, hydrophobicity, low tendency to discoloration and stiffness [36]. Cention-N® was comparable to regular RBCs and was maintained up to three months in both neutral and acidic conditions suggesting good mechanical stability [37].

A research about alkasite examined the clinical characteristics, features, benefits, composition, clinical applications and present a clinical case explaining the technique step by step and concluded that it is an optimal restorative material in the field of operative dentistry due to its bioactive properties, bulk fill characteristics, aesthetics and time saving application [35]. In an *in vitro* study the compressive strength of Cention N is significantly equal that of high copper amalgam and the conclusions were it can be used in stress-bearing posterior region and recommended long-term clinical studies is needed [38]. In another study it was shown that Alkasites-based material presented excellent marginal adaptation to enamel and dentin whether dentin adhesive was used or not [39].

Amalomer

It is a new ceramic-reinforced glass ionomer (Amalomer CR, Advanced Health Care Ltd, UK) and proposed by the manufacturer to combine the high strength of a metallic restorative and the aesthetics and other advantages of glass ionomers. It is supplied as powder and liquid where powder component comprises of Fluoro-aluminosilicate glass, polyacrylic acid powder, tartaric acid powder, and ceramic reinforcing powder and its liquid component composed of polyacrylic acid and distilled water [40]. It undergoes setting through conventional acid-base reaction like GICs. The set material contains a particulate ceramic component with the intention of increasing its strength, supposedly without sacrificing appearance (although it is opaque white) or other general characteristics of GIC [41]. Zirconia is the major if not the only (crystalline) component of the additive of this product. Under stress zirconia undergoes phase transformation from tetragonal to monoclinic. This transformation is accompanied with 4% expansion causing local compressive stress that offsets crack-opening tension and inhibits crack propagation [42]. Amalomer CR carries inhibitory action may be attributed to the coarse nature of its ceramic particles contributing to fluoride release. DeSchepper, *et al.* observed that the coarse silver alloy particles which are not bound to the cement-matrix in Argion (a metal-reinforced glass ionomer), increased cement microporosity thus increasing the effective surface area available for fluoride elution [43]. Although fluoride forms a major constituent of many GICs but it has no role in setting process [44], on the contrary calcium and aluminum play a basic role in hardening and strengthening during cement setting [45].

Amalgomer is indicated in class I and II cavities, repair of amalgam restored tooth crowns, on root surface for locating overdentures, and long term temporary replacement [46]. The compressive strength, diametric tensile strength, surface hardness, and surface roughness of a ceramic-reinforced glass ionomer in comparison to a high-copper dental amalgam were studied and concluded that the physico-mechanical properties of them were so close and sometimes significantly superior to dental amalgam [40]. The clinical performance of amalgomer CR and Fuji IX restoring small and medium cavities prepared using atraumatic restorative treatment (ART) approach in India concluded that the clinical performances of both materials were satisfactory at the end of 1 year [47]. An *in-vitro* study compared the anticariogenic effect of Amalgomer CR, Fuji VII and Heliomolar Refill concluded that the anticariogenic efficacy of Amalgomer CR was higher than that for Fuji VII, and Heliomolar Refill was the least [48].

An *in-vitro* study compared the antibacterial activity of Amalgomer CR and Fuji VII against *Streptococcus mutans*, *S. salivarius*, *S. parasanguinis*, *Actinomyces viscosus*, and *Lactobacillus casei*. The conclusions were Amalgomer CR have most antibacterial action in inhibiting all bacteria and its most antibacterial effect was against *S. mutans*, followed by *A. viscosus*, *S. salivarius*, *S. parasanguinis*, and *L. casei* [49]. On studying the fluoride release of six different dental restorative materials namely Amalgomer CR, Fuji II, Fuji IX, Beautifil II, Dyract extra, and Coltene Synergy concluded that Amalgomer CR have the highest fluoride releasing capacity among the tested materials. This attributed to its coarse ceramic particles [50]. Another *in-vitro* study evaluated fracture resistance of Amalgomer CR, EQUIA Fort fil and EQUIA fil in class II cavities and concluded that Amalgomer CR appears promising regarding fracture resistance because it recorded the highest mean value among testes materials [51]. An article reviewed scientific literature on Amalgomer CR regarding composition, physical and anti-cariogenic properties, fluoride release, and its clinical use and concluded that Amalgomer CR can be used as an effective restorative material. Authors attributed this to its higher physico-mechanical properties and fluoride releasing capacities but further *in-vivo* studies are needed to justify these results clinically [46].

Zirconomer family

Zirconomer family includes Zirconomer and Zirconomer improved and they are introduced to the market as white amalgam [52,53]. Their filler mainly composed of zirconia. Zirconia (ZrO_2) is a white crystalline oxide of zirconium found in zircon mineral. Zirconia can exist in three phases: the cubic phase which is stable above 2370°C and with moderate mechanical properties, the tetragonal phase which is stable between 1170°C to 2370°C with improved mechanical properties, and the monoclinic phase which is stable at room temperature up to 1170°C, with lower mechanical properties. The addition of 3 mol% yttria can retain tetragonal phase at room temperature to produce Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP). Y-TZP provides cements with superior mechanical properties due to the tetragonal-to-monoclinic phase transformation [54-56]. The mechanism by which tetragonal-to-monoclinic phase transformation produced strengthening is when a defect begins to propagate in a zirconia core, tetragonal phase immediately surrounding the defect transformed to monoclinic with 4% expansion, which effectively hinders crack propagation (Figure 3) [57].

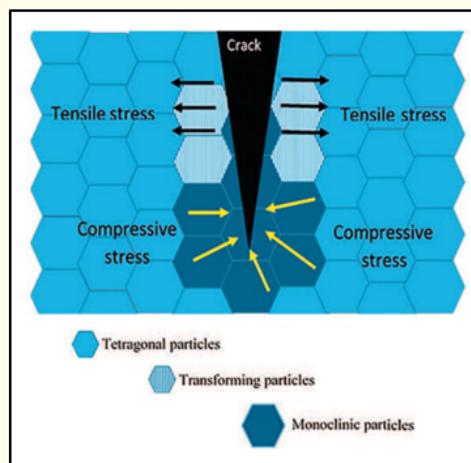


Figure 3: Diagrammatic representation of the transformation toughening process of zirconia.

Zirconomer and zirconomer improved

The inclusion of zirconia fillers in the glass component of Zirconomer family increases the structural integrity of the restoration by imparting superior mechanical properties for restoration of posterior teeth where the conventional restorative of choice is amalgam. In addition to their high strength they have sustained fluoride release making them ideal for permanent posterior restoration in patients with high caries incidence and cases where strong structural cores and bases are required [58].

Zirconomer® and Zirconomer Improved® have several uses in dentistry like restoration for all classes of cavities where radiopacity is a prime requirement especially class I and II cavities, structural base in sandwich restorations, core build-up, root surfaces of overdenture abutments, pediatric and geriatric restorations, and ART techniques. Zirconomer improved® surpass Zirconomer® by having higher translucency for a closer match to natural tooth (Figure 4) [58].

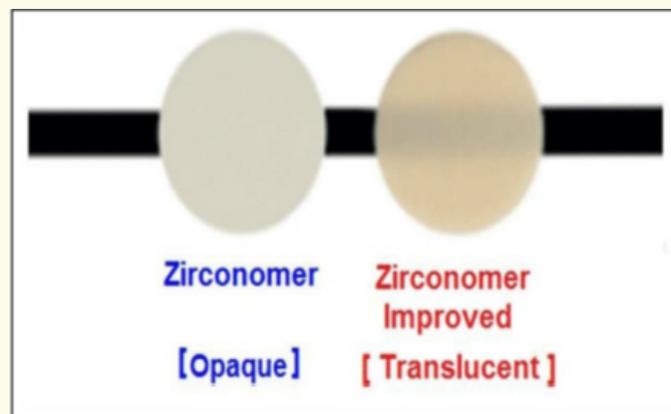


Figure 4: Translucency of Zirconomer family.

Mechanical properties

Zirconia which is the glass component of Zirconomer family is exposed to controlled micronization, giving them optimum particle size and characteristics [59]. It is homogeneously incorporated into their glass to reinforce the material against occlusal loads and durable performance intra orally [60]. An *in-vitro* study showed that the best compressive strength value of Zirconomer was the best followed by Zirconomer Improved and Ketac Molar [61]. Another study tested the mechanical properties of glass ionomer (GI), Zirconomer® and amalgam alloy and concluded that Zirconomer possess outstanding strength properties. Because of its sustained fluoride release, chemical bond with tooth structures, and biocompatibility it is an ideal for permanent posterior restorations in patients with high caries incidence as well as in cases where strong structural cores and bases are required. They added that further *in vivo* studies are mandatory to substantiate our preliminary observations [62].

An *in-vitro* study evaluated the effect of modifying conventional glass-ionomer, Zirconomer, and silver-reinforced glass-ionomer by adding 20 wt% of microhydroxyapatite upon their surface microhardness and revealed that this modification can improve microhardness of Zirconomer [63]. A recent review about Zirconia Reinforced Glass Ionomer Cement concluded that the cement may be considered as a promising material and might be the best alternative to both GICs and its modifications as well as dental amalgam but further *in-vitro* and *in-vivo* research works should be closely followed upon for it to replace other restorative materials used today [64].

Regarding their hardness and abrasion resistance a recent study concluded that The effect upon microhardness of incorporating 5 and 15 wt% of microhydroxyapatite into RMGI and Zirconomer was found to improve the surface microhardness but adverse effects will result if adding more than 15% of HA [65]. This adverse effect is because HA/ZrO₂ particle size is smaller than glass powder that increase the surface area therefore, it might need a greater amount of liquid for interaction [66]. Another reason for surface hardness reduction when HA% is increased might lead to the decrease in the density of set cement containing more calcium ions that will react more than aluminum cations with carboxylate groups in polyacrylic acid in a way that creates fewer cross-links between aluminum and carboxylate and weakens the structure [67].

The microleakage of white amalgam (zirconomer), amalgam, and composite was studied and concluded that zirconomer exhibited the highest micro leakage followed by composite and amalgam (Figure 5). Therefore amalgam still proves to be one of the best materials exhibiting minimal microleakage [68]. An vitro study assessed the microleakage of Zirconomer and compared it with Ketac™ Silver (Conventional GIC, 3M ESPE, Germany), Filtek™ Z500 (Composite, 3M ESPE, Germany), and Dispersalloy® (Amalgam, DENTSPLY, UK) and concluded that: None of the tested materials was free from the microleakage, Cavities filled with Ketac™ Silver exhibited the highest microleakage scores followed by Zirconomer and composite, and Amalgam showed the least microleakage scores. Authors of this work recommend further experiments to be done in order to achieve the maximum enhancement of bonding characteristics of zirconomer family in the long-term [69].

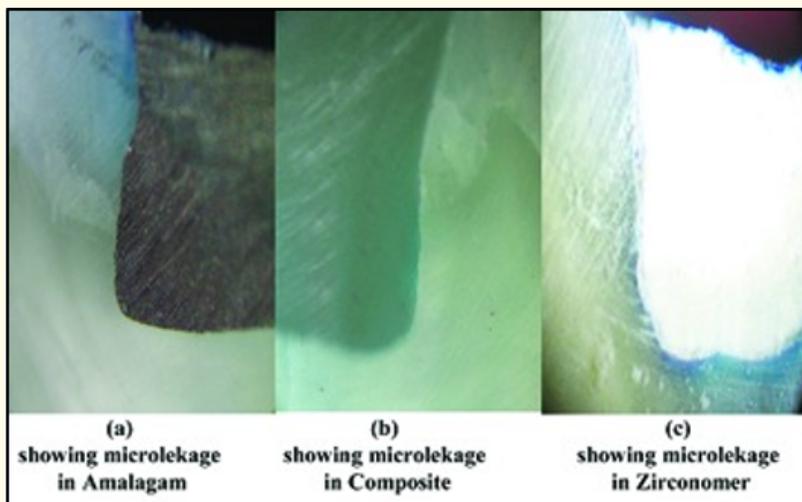


Figure 5: Microleakage of tested materials.

In a study evaluated and compared water sorption and solubility of zirconomer family and silver-reinforced glass ionomer cement concluded that the later absorbs less water and is less soluble than the first [70]. Restorative materials releasing fluoride are preferable because of probable caries inhibitory effect because the released fluoride is a substantial contributor for their antibacterial property [71]. In the literature nothing is written about the antibacterial activity of zirconomer restorations. Only one *in-vitro* research studied antibacterial activity and fluoride release from two conventional glass ionomer cements (GC II and GC IX), compomer (Compoglass) and a zirconia reinforced glass ionomer cement (Zirconomer). The conclusion was Zirconomer had the maximum antibacterial activity and the maximum fluoride release among the tested materials [72]. An *in-vitro* work compared the amount of fluoride released from zirconia reinforced glass ionomer cement (Zirconomer, SHOFU INC, high density glass ionomer cement (Ketac™ Molar, 3MTM ESPETM)

and packable posterior glass ionomer restorative material (GC Fuji IX GP) and concluded that Zirconomer exhibited maximum amount of release of fluoride [73]. The authors attributed rapid elution of fluoride by Zirconomer to the finely controlled micronization of the glass ionomer particles. This identical with the results reported by various studies that smaller glass particles provide a larger surface area, which increase the acid-base reactivity, and hence, have increased capacity to release fluoride from the powder more rapidly thereby increasing the fluoride release of the materials [74-76].

Finally, from the preliminary results of zirconomer and zirconomer improved restorations it can be concluded that they are the best alternative now to both GICs with its other modifications as well as dental amalgam for all teeth whether deciduous or permanent [77].

Conclusion

Within the limit of the reviewed articles, conclusions that can derived are many amalgam alternative materials which are considered promising and might be better alternative to both GICs and their modifications as well as dental amalgam i.e. they are truth. In order to confirm the preliminary good results about them further *in-vitro* and *in-vivo* works are needed.

Conflict of Interest

None declared.

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