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Review Article

Zirconomer and Zirconomer Improved (White Amalgams): Restorative Materials for the Future. Review

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Abstract

Dental caries has been considered as a historically important component of the global oral disease burden. Thus, the quest for an ideal restorative material with optimum physical properties and durability exists. There was a lack of availability and development in the field of restorative materials. Though amalgam has many drawbacks, such as postoperative tooth sensitivity, susceptibility to fracture of the restored teeth, microleakage, mercury environmental pollution, and high incidence of development of secondary caries, it has been used for more than a century as a successful restorative material. Many tooth-colored materials have evolved to replace amalgam in the recent past. The popularity of resin based composite restoration has increased because of its excellent esthetic and other favorable characteristics. However, failure is also seen in composite restoration in posterior dentition as excessive wear, polymerization shrinkage, open inter proximal contacts, tooth sensitivity, secondary caries, irreversible pulpitis, and restoration fracture.

The unique properties of glass ionomer cement (GIC), such as adhesion to moist teeth, anti-carcinogenic character, lack of exothermic polymerization, excellent adhesion to dentin, close thermal expansion to tooth, satisfactory biocompatibility, make it an important material in dental applications. One of the major drawbacks is its weak mechanical properties like brittleness, low strength, and toughness. Hence GICs were mostly used for the restoration of anterior teeth and in areas without any load due to their poor mechanical strength. Several modifications have been introduced with the purpose of enhancing their mechanical properties. The introduction of resin-modified GICs with superior mechanical strength was used in the posterior restorations. Several strategies are followed to enhance the mechanical properties, such as addition of zirconia, hydroxyapatite, N-vinyl pyrrolidone, fluoroapatite, and HA/ZrO_2 is a well-known method to enhance the mechanical properties of GIC.

New GIC formulations called as Zirconomer® and zirconomer improved® (white amalgams) are novel materials, composed of ceramic and zirconia reinforced glass ionomer cements that could overcome the drawbacks of previously used amalgam as well as other tooth-colored restorative materials. They exhibit the strength of amalgam and at the same time maintain the fluoride releasing capacity of GICs. The aim of the current review was to present the new zirconomer family regarding their composition, properties, mechanism of zirconia toughening, previous researches about them. This is to ensure the right choice of the material for clinical purposes.

Keywords: *Amalgam; Amalgomer CR; Conventional Glass Ionomer; Reinforced Glass Ionomer Cements; White Amalgams (Zirconomer, and Zirconomer Improved)*

Introduction

Dental caries has been considered as a historically important component of the global oral disease burden. Thus, the quest for an ideal restorative material with optimum physical properties and durability exists. Since the 1890s, amalgam - a metallic restorative material-was widely chosen for such restorations by dental practitioners because of its high compressive strength (CS) (380 - 540 MPa) and tensile strength (57 Mpa), durability, longevity, and marginal integrity of the material; moreover, there was lack of availability and development in the field of restorative materials. However, 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 fulfilling these shortcomings began [1]. Though amalgam has many drawbacks, such as postoperative tooth sensitivity, susceptibility to fracture of the restored teeth, microleakage, and high incidence of development of secondary caries, it has been used for more than a century as a successful restorative material. Many tooth-colored materials have evolved to replace amalgam in the recent past [2,3].

The popularity of resin based composite restoration has increased because of its excellent esthetic and other favorable characteristics. However, failure is also seen in composite restoration in posterior dentition as excessive wear, polymerization shrinkage, open inter proximal contacts, tooth sensitivity, secondary caries, irreversible pulpitis, and restoration fracture [4,5]. The unique properties of glass ionomer cement (GIC), such as adhesion to moist teeth, anticarcinogenic character, lack of exothermic polymerization, excellent adhesion to dentin, close thermal expansion to tooth, satisfactory biocompatibility, make it an important material in dental applications [6]. One of the major drawbacks is its weak mechanical properties like brittleness, low strength, and toughness [7]. Hence GICs were mostly used for the restoration of anterior teeth and in areas without any load due to their poor mechanical strength [8]. With the decline in popularity of amalgam in recent years, there is a need Glass ionomer (GI) cements were introduced by Wilson and Kent in 1972 [9]. Since then, several modifications have been introduced with the purpose of enhancing their mechanical properties [10]. The introduction of resin-modified GICs with superior mechanical strength was used in the posterior restorations [11]. The newer generation of GI retained the most desirable qualities of conventional versions, namely fluoride release, ion exchange adhesion to conditioned enamel, and dentin, and low interfacial shrinkage stress [12]. Several strategies are followed to enhance the mechanical properties, such as addition of zirconia, hydroxyapatite, N-vinyl pyrrolidone, fluoroapatite, and HA/ZrO_2 is a well-known method to enhance the mechanical properties of GIC [13].

Glass ionomer cements are esthetically more pleasing than metallic restorations, on the contrary, their use in dentistry as a restorative material in stress-bearing areas is limited due to poor mechanical properties, such as low fracture strength, toughness, and wear resistance. The addition of metal powders or fibers to glass ionomer cements can improve its strength. Simmons suggested mixing amalgam alloy powders into the cements and developed this system clinically under the name "Miracle Mix". This alloy is used for core building and for the treatment of mouths with high caries incidence. However, their esthetics are poor and they do not take burnish [14]. A high-strength restorative material, which has been reinforced with zirconia fillers known as zirconomer (white amalgam), has been a recent substitute to glass ionomer cement in dentistry. Zirconia (ZrO2) is a white crystalline oxide of zirconium. It is a polycrystalline ceramic without a glassy phase and exists in several forms. The name "zirconium" comes from the Arabic word "Zargon" which means "golden in color" [15].

New GIC formulations are being introduced every day and it is important to know the physical and mechanical properties of each product when selecting GICs as restorative mater. Zirconomer® and zirconomer improved® are novel materials, composed of ceramic and zirconia reinforced glass ionomer cements that could overcome the drawbacks of previously used amalgam as well as tooth-colored restorative materials. They exhibit the strength of amalgam and at the same time maintain the fluoride releasing capacity of GICs [16].

Aim of the current review was to present the new zirconomer family (called the white amalgam) regarding their composition, properties, mechanism of zirconia toughening, previous researches about them. This is to ensure the right choice of the material for clinical purposes.

Zirconomer family

Zirconomer® is developed to exhibit the strength, i.e., consistent with amalgam, through a rigorous manufacturing technique. The glass component of this high-strength GI undergoes finely controlled micronization to achieve optimum particle size and characteristics. The homogeneous incorporation of zirconia particles in the glass component further reinforces the material for lasting durability and high tolerance to occlusal load. The polyalkenoic acid and the glass components have been specially processed to impart superior mechanical and handling qualities to this high-strength GI [17]. It contains zirconium oxide, glass powder, tartaric acid (1 - 10%), polyacrylic acid (20 - 50%), and deionized water as its liquid. Zirconium oxide, the main powder component of Zirconomer, results from Baddeleyite ($ZrO2$) that contains high levels of zirconia ranging from 96.5 to 98.5% [18].

Zirconomer Improved developed as a reliable and durable self-adhesive tooth coloured zirconia reinforced posterior bulk fill restorative comprises of nano-sized zirconia fillers to enhance aesthetic properties and superior handling characteristics [12]. The success of any material is assessed by its longevity and biocompatibility in oral environment [19].

What is zirconia?

Zirconia, a high-strength ceramic, was introduced for dental use as a core material in conventional and resin bonded FPDs and crowns [20]. Zirconia is highly rated in terms of esthetics and has several other advantages, including biocompatibility as it is metal-free and has a low degree of bacterial adhesion, high flexural strength, and acceptable optical properties, such as adaptation to the basic shades [21,22].

In the early 1990s, zirconia was popularized into dentistry as endodontic posts [23], later on as implant abutments [24], and hard framework cores for crowns and fixed partial dentures [25]. The accessible zirconia powders have different grain sizes and different additives, such as yttrium oxide and alumina, which can be distributed homogeneously throughout the whole material or higher concentration at grain borders [26]. The grain-size variety affects the resulting porosity as well as the translucency of the material. The glass component of Zirconomer is subjected to controlled micronization, to acquire optimum particle size and characteristics [18]. The grain size has an effect on an exclusive characteristic of zirconia called transformation toughening (Figure 1), which gives it higher strength, toughness, high hardness, and corrosion resistance; thus, when it is homogeneously incorporated in the glass component, it further reinforces the material for lasting durability and high tolerance to occlusal load [18]. Hence, this biomaterial promises to show outstanding strength, durability, and sustained fluoride protection, thus combining and retaining the benefits of both popularly used restorative materials amalgam and conventional GI.

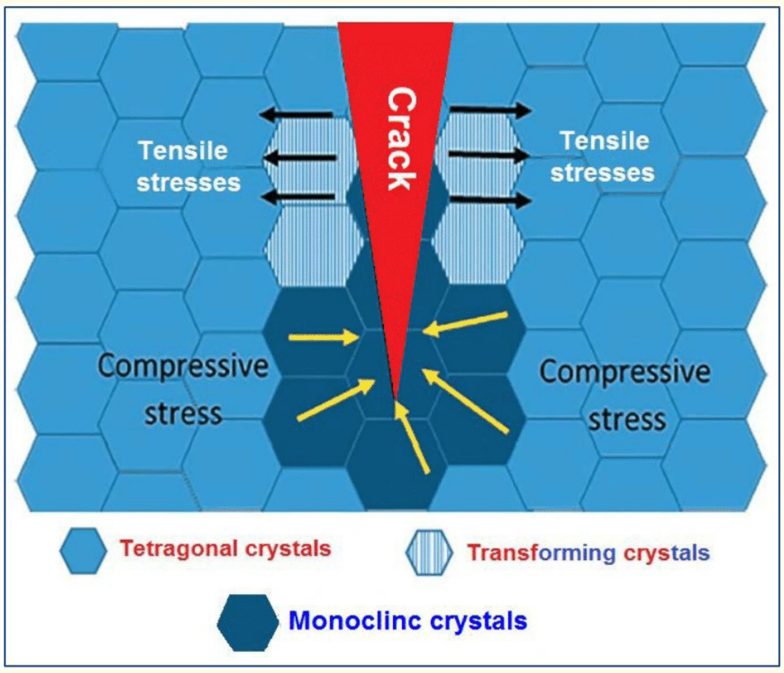

Figure 1: *Diagrammatic representation of the transformation toughening process of zirconia.*

Mechanism of Transformation toughening [Figure 1]

In a study compared the compressive strength of zirconia-reinforced glass ionomer cements (white amalgam) with other restorative materials and concluded that zirconia-reinforced glass ionomer cement has the highest compressive strength (160.91 MPa) among all the groups tested; silver-reinforced glass ionomer cement has the second highest value, and the least value of compressive strength is seen with glass ionomer cement type IX-Extra. Authors of this study attributed this to the homogeneous incorporation of microsized zirconia particles in the glass component, which further reinforces the material with high strength, lasting durability, and high tolerance to occlusal load [27]. Other authors attributed this to the property of transformational toughening (Figure 1), which is the ability to stop the growth of cracks, and it gives zirconia its unique mechanical properties [17,28]. The addition of alumina to Yttria Stabilized Zirconia (YTZP) provides a material with a higher elastic modulus and finer microstructure, often with greater toughness. The increase in fracture toughness (KIC) from pure zirconia to composites, for example containing 4% vol. Al_2O_3, is a process based on the toughness of the zirconia grain due to the presence of impurities of alumina at the edges and, consequently, provides an increase in transgranular fracture mode [29]. In the case of the tetragonal phase, zirconia remains metastable at environmental conditions, meaning that it is theoretically unstable and may persist indefinitely. Thus, the stress field in front of a crack causes these particles to transform into a stable tetragonal monoclinic phase. Following this transformation, there is a slight increase in the volume of the particle and the result is that compressive stresses are set on the surface of the cracks in regions close to their terminus, which tend to throttle and close the cracks, thus preventing their growth. The result is an increase in the toughness of zirconia in the face of this transformation, preventing the propagation of cracks and improving the mechanical behavior of ceramics in the face of tension stresses [30].

Another toughening mechanism that happens in ceramic materials is crack deflection, which occurs when a crack changes its propagation direction after encountering a particle of the second phase, pore or grain boundaries. In zirconia, the pattern of crack propagation is usually transgranular. An increase of crystalline content present in the fully sintered zirconia equals an increase in the mechanical properties. However, in crystalline materials with the same content, the difference in strength and fracture toughness is related to porosity and effectiveness of each toughening mechanism [31].

Zirconomer® and Zirconomer Improved® [16]

Zirconomer® is an deal for Restoration of: a) Class I and II cavities, Structural base in sandwich restorations, b) All classes of cavities where radiopacity is a prime requirement, c) Core build-up under indirect restorations, d) Root surfaces where overdentures rest, e) Pediatric and Geriatric restorations, f) Long-term temporary replacement for fractured cusps, and g) Fractured amalgam restoration, Suitable for ART techniques.

Zirconomer improved® is an ideal restoration for: a) Class I and II cavities in deciduous teeth, b) Class I and II restoration in selected permanent teeth, c) Repair of amalgam restored teeth when either tooth o restoration has fractured, d) In all classes of cavities where radiopacity is a prime requirement, e) Core build-up, and f) Repair of crown margins.

Features of Zirconomer® and Zirconomer Improved®: a) Superior Mechanical Properties with remarkable edge strength, excellent marginal adaptation, and Excellent resistance to abrasion and erosion, b) Self-adhesive with tooth-like co-efficient of thermal expansion, c) Sustained fluoride protection, especially in cases with high caries risk, c) Excellent mixing and handling qualities, d) Higher translucency for a closer match to natural tooth especially the Zirconomer Improved, and e) Durability like silver amalgam without the hazard of mercury.

Aesthetic properties of zirconomer family: Zirconomer Improved® is formulated with zirconia nano fillers that impart a higher level of translucency than Zirconomer® (Figure 2) for a closer match to natural tooth colour (Figure 3), ideal even for cores requiring coverage with high end all-ceramic restoration [16].

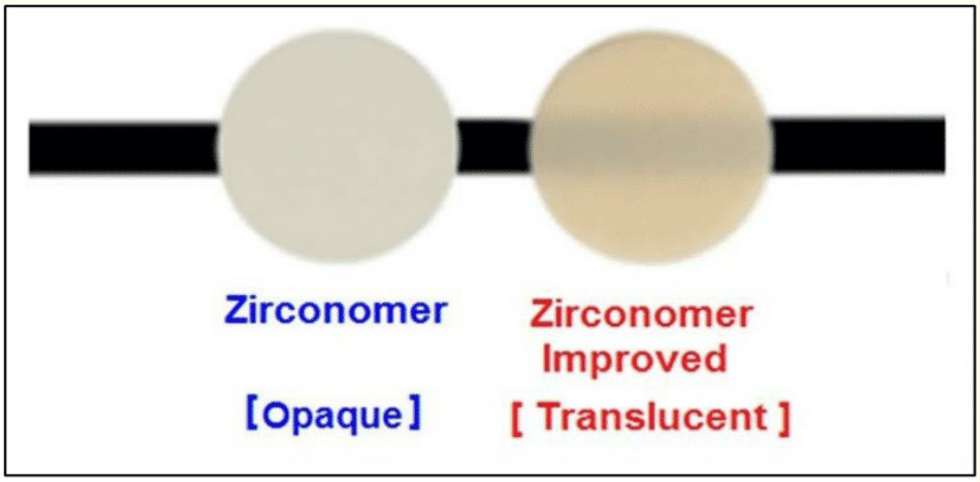

Figure 2: *Translucency of Zirconomer family.*

Figure 3: *A) Tooth # 46 restored with Zirconomer® and B) tooth # 14 restored with Zirconomer Imroved®.*

Researches done about Zirconomer family properties

Mechanical properties

The use of any restorative material is to substitute the biological, functional, and esthetic harmony of the lost tooth structures [32]. Evolution of restorative materials is imperative for better delivery of treatment. Thus the newer materials should exhibit significantly better properties than its predecessors [33].

The compressive strength of a material is any important factor to be considered in relation to masticatory forces. This property is the resistance exhibited by a restorative material against intraoral compressive and tensile forces which are produced both in function and parafunction. It is the amount of stress required to distort the material in an arbitrary amount [1]. Hence it is essential for a material to exhibit good compressive strength. Glass ionomer cements have been commercially available since nearly 25 years, with continuous advancements setting new standards one such material being Ketac molar which is widely used [34]. The introduction of newer materials was initially due to the diminution of the large popularity of amalgam which has been attributed to its mercury content. These newly introduced materials such as Zirconomer as per manufacturer's claims are strong and safe replacements imbibing the strength of amalgam and the various advantages of glass ionomer. The structural integrity has been attributed to the inclusion of zirconia fillers in the glass component thereby imparting better strength [35-37]. Zirconomer Improved developed as a reliable and durable self-adhesive tooth coloured zirconia reinforced posterior bulk fill restorative comprises of nano-sized zirconia fillers to enhance aesthetic properties and superior handling characteristics [37]. The success of any material is assessed by its longevity and biocompatibility in oral environment [19].

Compressive strength testing is commonly used as a measure by which clinicians and researchers predict the performance of a restorative material in oral environment. The increase in compressive strength in Ketac Molar when compared to conventional glass ionomer cements has been attributed to the introduction of high concentration of glass fillers [21,23-25]. In a study compared the compressive strength of Zirconomer, Zirconomer Improved, and Ketac Molar showed that best compressive strength value was exhibited by Zirconomer followed by Zirconomer Improved and Ketac Molar [38]. Zirconomer which exhibited the highest compressive strength value in this study contains zirconium oxide, glass powder, tartaric acid, polyacrylic acid with deionized water as the liquid. The superior mechanical property is ascribed to the inclusion of zirconia fillers. The glass component in Zirconomer is subjected to finely controlled micronization to achieve optimum homogenous particle size and further leading to enhanced mechanical property such as higher strength. Homogeneity of the glass particles further reinforces the durability of the material and the strength to withstand occlusal load [21,39]. Zirconomer Improved which exhibited better compressive strength than Ketac Molar as per manufacturer's claims has the durability of amalgam. The material reinforced with nano-zirconia fillers is responsible for imparting enhanced mechanical properties especially making it suitable for posterior load bearing areas as per various studies [21,39]. In a study evaluated and compared the compressive strength of restorative materials Ketac Molar, Zirconomer, and Zirconomer Improved it was found that Zirconomer and Zirconomer Improved both exhibited compressive strength values of over 300 MPa after 24 hours as per the limit set by ISO for materials to be used as posterior restoratives. According to the results obtained in this study, best compressive strength value was exhibited by Zirconomer followed by Zirconomer Improved and Ketac Molar [38].

A study tested the mechanical properties of GI, Zirconomer®, and amalgam alloy in order to compare the properties, such as CS and DTS. Both CS and DTS and found that it was higher for amalgam and zirconia-reinforced GI. In this study it was found that the addition of zirconia as filler particle in the glass component of Zirconomer® improved the mechanical properties of the restoration. This was attributed to the reinforcing structural integrity of the restoration by the addition of zirconia. In this study it was concluded that combination of outstanding strength, durability, and sustained fluoride protection deemed with chemical bonding makes it ideal for permanent posterior restorations in patients with high caries incidence as well as in cases where strong structural cores and bases are required. However, further *in vivo* studies are mandatory to substantiate our preliminary observations [40].

In another study evaluated the compressive strength of restorative materials Ketac Molar, Zirconomer, and Zirconomer Improved. All the tested restorative materials exhibited sufficient compressive strengths with Zirconomer exhibiting significantly higher compressive strength [33]. In another study demonstrated different levels of sorption, solubility, and compressive strength and found that zirconia-reinforced glass ionomer cement has the highest compressive strength among all the groups tested; silver-reinforced glass ionomer cement has the second highest value, and the least value of compressive strength is seen with glass ionomer cement type IX-Extra, and the differences are statistically significant. Silver-reinforced glass ionomer cement absorbed less water and is less soluble than other cements followed by zirconia-reinforced glass ionomer cement, and the highest sorption and solubility rates in artificial saliva were seen with glass ionomer cement type IX-Extra. There were significant differences among the tested materials. Zirconia-reinforced glass ionomer cement is a promising dental material and can be used as a restoration in stress-bearing areas due to its high strength and low solubility and sorption rates. It may be a substitute for silver-reinforced glass ionomer cement due to the added advantage of esthetics [27].

Other studies found that compressive strength of Miracle Mix (151.47 MPa) was much greater than conventional glass ionomer cement as silver particles increased gelation of the cement, but was less than zirconomer due to the fact that simple mixtures of metal powders failed at the metal and poly-acrylate matrix interface and this was the weak link [41]. The results of this study are in accordance with many previous studies [42-45].

Hardness and abrasion resistance

Glass-ionomer cements (GICs) are used in clinical dentistry as commercial materials since the early 1970s [46,47]. The success of these cements is attributed to their unique properties such as direct bonding to tooth structure, anti-cariogenic action due to release of fluoride and biocompatibility with pulp tissue [47,48]. Incorporation of various fillers like silver, gold, titanium, palladium, zirconia, stainless steel powder and SiC whiskers into glass-ionomers has been investigated in order to improve their mechanical properties, but poor aesthetic and low abrasion resistance are their important limitations [49,50].

Zirconia fillers have often been applied in dental procedures like implants due to their chemical and good mechanical strength and toughness [46,51]. Zirconia is one of the tooth-colored materials with good dimensional stability and excellent strength and toughness, coupled with a Young's modulus in the same order of magnitude of stainless steel alloy and is the origin of the interest in using ZrO_2 as a filler [46,51]. Zirconia has higher strength than GIC and HA particles and does not dissolve in distilled water [46].

Recent study concluded that incorporation of 5 and 15 wt% of microhydroxyapatite into RMGI and Zirconomer improved the surface microhardness but adding more than 15% of HA resulted in adverse effects. In addition, incorporation of 25% microhydroxyapatite into Zirconomer and RMGI decreased hardness values less than the groups without HA In the present study, it might have been the larger glass particles sizes and less voids and cracks of RMGI that resulted in higher microhardness values. Due to resin cross-linking and rapid setting, it seems that RMGI was more resistance to being dissolved in water after a day of water storage but Zirconomer is self-curing and therefore chemically similar to glass-ionomers, resulting in more dissolution in water [52]. Since HA/ZrO2 particle size is smaller than glass powder, the surface area is much larger compared to glass; therefore, it might need a greater amount of liquid for interaction [46]. However, in the current study, the same ratio as the manufacturer's instruction was used; therefore, it seems that an inadequate amount of liquid in the mixture can alter the mechanical properties. Another reason for the reduction in surface hardness when HA is added to RMGI and Zirconomer might be the decrease in the density of set cement consisting of HA, which contains calcium ions. These ions seem to react more than aluminum cations to carboxylate groups in polyacrylic acid in a way that creates fewer cross-links between aluminum and carboxylate and weakens the structure [53].

Microleakage

Marginal microleakage is commonly observed with various restorative materials which can lead to marginal staining and secondary caries and if not treated in time, it can cause pulpal pathology. These factors have been cited as the main reasons for restoration replacement. Controlling microleakage has always been an important goal of operative dentistry [54].

Dental amalgam has been used by dentists for more than a century. It has many advantages as a restorative material, because it has high strength, durable and easy to use. However, amalgam fillings have a number of drawbacks, such as, corrosion; they do not fulfill aesthetic demand; making undercuts for mechanical retention necessary, mercury toxicity and lack of adhesion to tooth structures [55]. Recently popularity of resin-based composite restoration has increased than amalgam restoration because of its excellent aesthetic and other favourable characteristics. However, failure is also seen in composite restoration in posterior dentition as excessive wear, polymerization shrinkage, open inter proximal contacts, tooth sensitivity, secondary caries, irreversible pulpitis and restoration fracture [55]. To overcome drawbacks of above materials a high strength restorative material which has been reinforced with ceramic and zirconia fillers known as zirconomer (white amalgam) has been recently introduced in dentistry [16].

The success of any material is assessed by its longevity and biocompatibility in oral environment. Thus clinical testing of new material is more in determining the effectivity and biocompatibility of newer material than *in vitro* screening [34]. There is a constant search for the material and technique that ensures adhesion to the tooth structure in order to minimize the leakage potential. Microleakage is used as a measure by which clinicians and researchers can predict the performance of a restorative material. A study was designed to evaluate the sealing properties of amalgam, composite and white amalgam (zirconomer). They concluded that even though composite and amalgam are being marketed aggressively and new material like zirconomer are on origin, amalgam still proves to be one of the best materials when you consider micro leakage as a factor. Despite of the newer material, zirconomer had highest microleakage as compared to composite and amalgam. According to the results, in this study zirconomer exhibited the highest micro leakage as compared to composite and amalgam but composite having higher micro leakage as compared to amalgam and lower micro leakage compared to zirconomer [17].

Another study conducted *in vivo* and *in vitro* studies and concluded that coating the cavity walls with cavity varnish could have no effect on decreasing marginal leakage in amalgam restorations and they also concluded resin composite restorations revealed higher microleakage scores than amalgam restorations [54]. Class-I amalgam restoration had lower microleakage than bonded composite [56]. Many studies were done on microleakage of amalgam and composite but this is the pioneer study showing the microleakage of the new innovative dental restorative material that is zirconomer (white amalgam). Microleakage is defined as the passage of bacterial fluids, molecules and ions between the cavity walls and the restorative materials, which is not clinically detectable and is one of the most important reasons for recurrent caries and pulpitis [57]. Marginal micro leakage should be considered in the evaluation of a restorative material, because it has been directly related to the success or failure of the restorations [54]. Highest marginal quality should be pursued in order to increase success rates and to decrease postoperative sensitivity, marginal discoloration, and potential secondary caries [58].

When an Amalgam is initially placed, a micro space exists between the amalgam restoration and tooth structure. The mechanism for the resolution of this problem is considered to be the sealing of the margins by corrosion products and possibly organic aggregates [59]. Now-a-days patients are more concerned regarding the aesthetic hence, composite is commonly used as a restorative material in dentistry. One of the main drawbacks associated with composite restoration or the posterior restorative material is its shrinkage during polymerization which creates stress on the network and its bonding system. This leads to marginal staining, poor marginal seal and recurrent caries, which affects the longevity of the restoration [55]. With the decline in popularity of amalgam in recent years and drawback of composite there is a need for an equally strong & bondable material ease of replacement. Zirconomer, a new class of glass ionomer restorative material, exhibiting strength and durability of amalgam, along with bondable and fluoride releasing property of glass ionomer cement at the same time it eliminates the hazardous property of amalgam because of mercury [16]. Addition of zirconia as filler particle in the glass component of Zirconomer improves mechanical properties of the restoration by reinforcing structural integrity of the restoration in load bearing areas where amalgam is material of choice. Combination of outstanding strength, durability and sustained fluoride protection deems with chemical bonding, it is ideal for permanent posterior restorations in patients with high caries incidence as well as cases where strong structural cores and bases are required [16].

In a study compared Microleakage, Surface Roughness and Hardness of Three Glass Ionomer Cements - Zirconomer, Fujii IX Extra GC, and Ketac Molar and found that: a-microleakage of Zirconomer with was more than that of Fujii IX Extra GC and Ketac Molar. One explanation to this is that large size of the filler particle in Zirconomer prevents proper adaptation of this material to the tooth surface. b-Zirconomer did not match with the shade of the tooth at the cervical region. c- Another disadvantage of Zirconomer is that it's poor working consistency, longer setting time, and rough surface texture. Zirconomer showed least polish ability. This may be due to large filler particle incorporated in the cement [60]. Increase in surface roughness results in alterations in light reflection and material surface turn opaque [61]. Studies showed that material with large particle size possess high surface roughness [62].

Sealing property of Zirconomer is lower than that of Ketac Molar and Fujii IX Extra GC. No material was able to completely eliminate microleakage at cervical margin. Ketac Molar showed best surface finish before and after polishing. Fujii IX Extra GC showed high hardness and excellent shade matching at buccal surface of the cervical third of the tooth [60]. Minimal microleakage as a result of low coefficient of thermal expansion similar to the tooth structure is one of the important advantages of glass-ionomers [13,63].

Over the past 50 years, many changes have occurred in restorative materials in development and on availability [64]. Restorative dentistry, in its infancy, was dominated by the simple principle of "Extension for Prevention," laid down by GV Black and which was partially dictated by the restorative material available at that time [65]. Restoration in primary teeth differs from the permanent teeth because of limited lifespan of teeth, different morphology of primary molar teeth, and their susceptibility to caries, lower biting force in children [66]. The ideal requisites for restorative material are that it should have a good color stability, have a coefficient of thermal expansion, have biocompatibility similar to that of natural tooth structure, excellent marginal seal, and the ability to adhere chemically to enamel and dentin [67]. Glass ionomer cement (GIC) seems to meet most of these requirements along with particular advantage. But, there were certain drawbacks in conventional GIC for use in primary molar due to its low physical properties and poor long-term performance. These findings contradict the choice of materials made by clinicians worldwide [68]. To overcome these drawbacks, a high strength restorative material which has been reinforced with ceramic and zirconia filler known as zirconomer (white amalgam) has been introduced in dentistry [17]. The most recent ceramic-reinforced glass ionomer, amalgomer CR (Advanced Health Care Ltd., Kent, England), is used in children. It has been proven that amalgomer CR exhibited higher shear bond strength than that of miracle mix [66].

Microleakage is identified as one of the significant problems because of interfacial gap formation, which can result in recurrent caries, possible pulp involvement, tooth discoloration, and restoration replacement [69]. Controlling microleakage has always been an important goal of operative dentistry [17]. The clinical success of this new restorative material depends on a good adhesion with the dentinal surface, which should resist various dislodging forces acting on them; hence, the present study was undertaken to evaluate the microleakage of three restorative cements [70].

Microleakage is defined as the clinically detectable passage of bacteria, molecules, fluids, or ions between a cavity wall and the restorative materials applied to it, and is a major challenge in clinical dentistry [71-73]. This may occur because of changes in dimensional temperature and mechanical stress or lack of adaptation of the restorative material, resulting in a gap at the tooth material junction [33,74]. There are various methods to detect the microleakage, which include chemical tracers, the use of dyes, radioactive tracers, scanning electron microscopy, electrochemical method neutron activation analysis, air pressure, and fluid filtration. The most common were those with stained solutions like aniline blue, eosin, erythrosine, fluorescein, methylene blue, and Indian ink [67]. Out of the various studies, methylene blue has been proved to be a useful aid in endodontics. In the present study also, methylene blue (0.5%) was used. Methylene blue is a superior tracer of microspaces. It is a more sensitive indicator of leakage than the three radioisotopes tested [75,76]. Due to lack of studies on recent modified GICs on primary teeth, the *in vitro* study was conducted to compare the coronary microleakage of following restorative cements: Conventional GICs, zirconomer, and amalgomer CR. In this study, Fuji Type II showed least microleakage than zirconomer and amalgomer CR. They added that, zirconomer exhibited the highest microleakage as compared with amalgomer CR and Fuji II GC, but amalgomer CR has more microleakage compared with Fuji II. Within the limitations of this study, none of the material was free from microleakage. Although the new materials have certain advantage of strength, they lack microleakage. Despite the newer material, zirconomer had the highest microleakage compared with amalgomer CR and conventional glass ionomer type II [77]. There is research supporting this study as they found that GC Fuji IX Extra has much lower microleakage than zirconomer [17].

In a study evaluated the sealing properties of composite {Group I}, white amalgam (zirconomer) {Group II}, GIC/composite {Group III}, and zirconomer/composite {Group IV} in sandwich technique by using dye penetration method. They concluded from the results of the present study that all materials showed some microleakage at the cervical margin of restoration. However, Group III exhibited lowest microleakage followed by Group IV, II and I. But for clinical relevance further *in-vitro* studies and with a larger sample size are required. They added that successful placement of a proximal restoration requires a predictable outcome that offers protection from further caries at the cavo margins. The RMGIC family of materials should be recommended for use in the open-sandwich technique when cervical margins are placed in dentine [78].

Amalgam is the most commonly used restorative material in dentistry over the last 150 years. However, hazards of mercury from amalgam restorations on human health and environment have impelled the development of new restorative materials [79]. Also, secondary caries has been quoted as one of the most common cause of restoration failures [80]. Microleakage can lead to accumulation of bacteria underneath the restoration [81], *Streptococcus mutans* is primarily associated bacterium in dental caries [82]. Therefore Zirconomer family restorations (white amalgams) are the best alternative to amalgam.

Sorption and solubility

In a study the authors concluded that silver-reinforced glass ionomer cement absorbed less water and is less soluble than other cements followed by zirconia-reinforced glass ionomer cement, and the highest sorption and solubility rates in artificial saliva were seen with glass ionomer cement type IX-Extra. Miracle Mix-GC has the lowest sorption and solubility values in artificial saliva, i.e. 55.73 and 10.7 ug/mm^3 respectively, with respect to Fuji type IX-Extra and zirconomer. The addition of silver had the advantage of increasing radiopacity of the cements and forming strong bonds with the matrix, which is responsible for lower sorption and solubility of the material [83].

Floride release and anticariogenecity

Restoring carious teeth is one of the major treatment needs of young children [8]. Also, secondary caries has been quoted as one of the most common cause of restoration failures [80]. The ability of dental restorative materials to inhibit recurrent caries is an important clinical property [84]. The cariostatic property of glass ionomer cement (GIC) stems from its ability to release fluoride into the oral environment. Fluoride release from restorative materials is important because of probable caries inhibitory effect [85].

There are several fluoride containing dental restorative materials available in the market including glass ionomer cements, resin modified glass ionomers, polyacid modified resins (compomers), giomers and resin composites. Recently, zirconia reinforced GIC has been launched which promises the protective benefits of glass ionomer while completely eliminating the hazard of mercury [86]. Release of fluoride from various reformations of GICs is a substantial contributor for their antibacterial property. In literature search no study on fluoride release and antibacterial properties of Zirconomer. The present research is the first of its kind on Zirconomer where an *in vitro* 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) was performed. The antibacterial activity of the cement specimens was evaluated against *Streptococcus mutans* using the agar inhibition test. Zone of inhibition on Mueller-Hinton agar plates was measured after 48 hours. The fluoride release from the cement specimens in ppm were measured at day 1, 7, 14 and 21 using a fluoride ion selective electrode. Statistically significant largest zone of inhibition was observed with Zirconomer. Also, significant differences were seen in fluoride release of different materials. At all the time intervals maximum fluoride release was observed with Zirconomer and minimum with Compoglass. This *in vitro* investigation has revealed that zirconia reinforced GIC (Zirconomer) had maximum antibacterial activity against *S. mutans* and fluoride release. There was limitation of this study. This because it was conducted in laboratory conditions (*in vitro* study). Oral environment is dynamic and different from *in vitro* conditions. Further *in vivo* studies with more parameters are recommended to evaluate Zirconomer in real environmental circumstances [87].

Amount of fluoride released from zirconia reinforced glass ionomer is not well documented in the literature, thus it is imperative to know the amount of fluoride released when compared to other glass ionomer materials already adopted in clinical practice as amount of fluoride release is of paramount importance to achieve the cariostatic and antibacterial effects [88]. Any modifications employed in the material to improve physical and/or mechanical properties must not compromise the fluoride releasing properties. Fluoride released from fluoride containing restorative materials effectively protect the tooth tissues from demineralization in the area adjacent to the restorative materials [89,90]. Initial release of fluoride reduces the number of viable bacteria and induces remineralization of enamel and dentin [91]. Fluoride release from the material brought about by diffusion is affected by the concentration of the particles and the material matrix. Diffusion of fluoride from the matrix exposed on the surface of the material is rapid. This phenomenon of "burst effect" is usually seen during the first two days [92-95].

Recently a study compared the amount of fluoride released from zirconia reinforced glass ionomer cement (Zirconomer, SHOFU INC, high density glass ionomer cement (KetacTM Molar, 3MTM ESPETM) and packable posterior glass ionomer restorative material (GC Fuji IX GP). In this study artificial saliva was used to measure fluoride release to better simulate the oral environment and more clinically relevant than deionized water, buffers and organic acids. Maximum amount of fluoride release was observed by Ketac molar at 24 hrs, 1.584 ppm. Zirconomer exhibited maximum amount of release of fluoride at 7 hrs, 1.026 ppm followed Fuji IX at 48 hrs, 1.088 ppm. Fluoride release by Zirconomer was constant from 14 hrs up to 10 day with a decline thereafter [88]. The pattern of rapid elution of fluoride by Zirconomer may be attributed to the finely controlled micronization of the glass ionomer particles as claimed by the manufacturers. It is in conjunction with 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 [93,96,97].

Conclusion

Zirconomer family restorations are the best alternative now to both GICs with its other modifications as well as dental amalgam for all teeth whether deciduous or permanent. Further *in-vitr*o and *in-vivo* works are needed to confirm the preliminary good results about them.

Conflict of Interest

None.

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