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RECENT ADVANCES IN DENTAL RESIN CEMENTS

Dentistry

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ABSTRACT

Resin cements are the material of choice amongst all the contemporary cements due to their superior physical and mechanical properties compared to other cements. There are various types of resin cement based on their curing methods. Though each resin cement has its own purpose, but dual-cure resin cement is preferred by clinicians due to its high degree of conversion and reduced polymerization shrinkage which ultimately leads to strong, durable and long lasting cement. Self-adhesive resin cement is the latest of them all with ease of manipulation and easy to handle and place as it doesn't need tooth preparation and it can be used in areas where moisture control is a big challenge.

KEYWORDS

Dental resin cements, advances in resin cements, luting cements, adhesive cements.

INTRODUCTION

Zinc phosphate cement (ZPC) was initially used for cementing the prosthesis to the teeth for over r a century and hence it is the gold standard for comparing other dental cements [4] (Edward E. Hill DDS, MS, 2007). Later polycarboxylate cement (PC) was introduced in late 1960 followed by glass ionomer cement (GIC) in 1970. Resin cements, though invented in 1950, have recently gained popularity and are the contemporary luting cements of choice. They have undergone various improvements and now are the material of choice due to their excellent aesthetic appearance and better mechanical properties than other luting cements.

Dental luting cements are the adhesive cements used in cementation of restoration to the tooth surface. They are used in cementation of indirect restorations such as inlays, only, post & core and in core build up. An ideal luting cement must qualities such as biocompatibility, good adhesion with the tooth surface, should be insoluble, able to withstand thermal and chemical insults, durable and long lasting, must be antibacterial, aesthetically acceptable, easy to handle with good mechanical properties to resist stresses and wear at tooth surface-restoration interface, provide adequate working and setting time and be economical [1][2]. Though luting cements have undergone tremendous evolution and changes and this has transformed dentistry and has brought in confidence in the dental clinicians in treating the patients, but no luting cement possesses all the qualities of ideal cement. There are 3 different ways of interaction with the tooth surface; they are non-adhesive, chemically adhesion by micromechanical bonding. Table 1 gives their details [3][4].

Table 1- Properties of Different Dental Cements

Method of interaction	Cement	Film thickness (μm)	Tensile strength (MPa)
Non-adhesive cements	Zinc phosphate	25	3.1-4.5
Chemically adhesive	Polycarboxylate	25	3.6-12
	Glass ionomer	11-35	42-53
	Resin-modified glass ionomer	24	13-25
	Phosphate-modified resin (self-adhesive)	16	34
Micromechanical bonding	Self-cure resin	24-50	62
	Light-cure resin	5-10	77
	Dual-cure resin	16.4	40-56

A strong bond is essential to hold the restoration attached to the teeth and to prevent microleakage [2][5][6]. Contemporary luting cements is based on either chemical or micromechanical bonding between the tooth and restoration [7].

Resin cements are low viscosity materials and they are the material of choice for low strength ceramic, lab manufactured composite and in area where extra retention is needed. Initially, resin cements adhesion to the tooth structure was limited until Buonocore developed the idea of acid etching technique of enamel using phosphoric acid in 1955 [8] but still they did not adhere well to the tooth, underwent polymerization shrinkage, had a high coefficient of thermal expansion, underwent microleakage, and excess removal was difficult. Later in 1963, Masuhara and Kojima proposed that methyl methacrylate (MMA) polymerized with the initiator tributylborane (TBB) bonded well to wet elephant tusk ivory and teeth without acid etch technique [9]. Further improvements were done by Masuhara's team in 1978 and 4-methacryloxyethyl trimellitate anhydride (4-META)/MMA-TBB-based auto polymerizing resin cement was developed as adhesive resin cement that adhered not only to enamel but also to dentin [10]. In 2002, Hecht and Ludstech developed a new group of self-adhesive resin cement based on composite resins (resin cements) for use in ceramic restorations [11]. Self-adhesive cements have methacrylate monomers with phosphoric acid groups enabling self-adhesive reaction between resin cement and tooth structure.

Depending on their curing mode, they have been divided into three types as per the ISO specification "ISO 4049-2019", they are Class 1 being self-cure, class 2 is light cure and class 3 is dual cure resins [10]. They basically consist of an organic resin matrix and inorganic filler content bonded together by a coupling agent. General composition of resin cements and their role is mentioned in table 2.

Table 2: Composition of Resin Cements

Organic matrix	Inorganic contents
BisGMA (it is highly viscous hence reduces degree of conversion of monomer[12] , reduces polymerization shrinkage of ressin matrix) UDMA (used as a replacement of BisGMA, have greater polymerization rate and degree of conversion than BisGMA based resin cements [13]) TEGDMA (used as diluent, reduces viscosity of matrix and makes it flexible) HEMA (reduces viscosity, prevents collagen collapse and restores collapsed collagen network, improves the wettability of acid-etched dentin and increases bond strength [14,15,16] Silane coupling agent (bonds resin matrix with filler particles) Camphoroquinone (photo-initiator)	Various filler particles have been used such as amorphous silica, strontium glass, zirconium silicate, barium borosilicate glass, fluoro-aluminosilicate glass, sodium persulfate cupric acetate, and ytterbium fluoride [17].

One of the earliest developed resin cement introduced in 1980s was self-cure resin cement and it was developed to combine the benefits of chemical properties, such as adhesion and fluoride release of glass ionomer cement and mechanical properties of resin cements. It contains mainly self-curing polymethyl methacrylate as resin matrix and quartz particles as fillers. According to ISO specification 4049 (2009), based on curing mode, they are classified as Class 1 [34]. Its composition is similar to other resin cements but contains Benzoyl peroxide as self-cure activator in the catalyst paste [34]. It relies on chemical reaction for curing. They are available in 2 forms, hand mixed as powder-liquid and automixed as in two paste system (base and catalyst). Composition of two paste system is presented in table 3 [35].

Table 3: Composition of Self-cure Resin Cement

Base paste	Catalyst paste
Acidic mononers with phosphoric acid group Dimethacrylate resin Initiators for self-cure reactions	fluoroaluminosilicate, silanated barium glasses, or both Silanated silica (70% by mass of 50% by volume) Initiators Methacrylate monomers

Degree of conversion of self-cure resin cements is low (5%-20%) [56] compared to dual-cured and light-cured resin cement. They do not require any pre-treatment of the tooth surface with etchant or primer or adhesive materials as they contain acidic monomers like carboxylic or phosphoric acid groups which demineralize the tooth surface and aid in micromechanical and extra chemical retention [36][37][38]. Some of its properties are presented in table 4.

Table 4: Properties of Self-cure Resin Cements

Properties	Value	Reference
Compressive strength	52-224 MPa	[41]
Flexural strength	50-100MPa	[35]
Shear bond strength	3-15 MPa	[35]
Elastic Modulus	1.2-10.7 GPa	[41]
Degree of conversion	5%-20%	[56]

In early 1970s, the first photo curing unit was introduced in dentistry. It emitted UV light whose wavelength was around 350 nm and it used quartz rod under high pressure mercury source [35]. Soon after this in 1976, Dr. Mohammed Bassouiny first used visible light for curing [39]. It used camphorquinone (CQ) as photoinitiator and a tertiary amine co-initiator for successful curing [40]. It uses blue light which is within blue light spectrum in the specific range between 400nm-540nm, with an average of 468nm, as the photoinitiator and it in turn initiates polymerization of resin cements [40]. Various light sources are used such as quartz-tungsten halogen light (QTH), plasma-arch lights, argon-ion lasers, High intensity QTH lights, light-emiting diodes (LED) [42]. Currently LED light cure is most used light source. A major advantage of light-cure resin cement over self-cure resin cement is the control and flexibility in the setting process and the extended working time since polymerization in light-cure resin cement is initiated upon exposure to the light source [43]. When the resin is exposed to the blue light polymerization is initiated by activation of CQ by photons. The amount of CQ should be optimal else it compromises aesthetics; biocompatibility and the resin cements are susceptible to early wear [44]. The overall properties of light-cured resin cement are superior to self-cured resin cement.

In early 2000, a new approach was attempted by combining both self-cure and light-cure curing system and a dual-cure curing system was introduced. The rationale behind it was to have material with extended working time and achieve high degree of conversion, with or without light source [45]. The setting takes place by redox reaction of benzoyl peroxide with aromatic tertiary amines, which are represented by catalyst and base paste, respectively [46]. When catalyst and base paste are mixed and before it is exposed to light, the working time is controlled by the ratio of inhibitors to benzoyl peroxide and aromatic tertiary amines. These cements are superior to their predecessors and have properties of both the systems. While light activation allows initial fast setting, chemical activation facilitates adequate curing in the areas inaccessible by the light [47][48][49]. Though redox initiators increase degree of conversion in inaccessible area, but they reduce working time and increase discoloration and to overcome this primers and adhesives are applied to the substrates prior to cementation to improve chemical-activated polymerization [48][50][51]. Studies indicate that delaying light activation reduces polymerization stresses by allowing the conversion to take place under diffusional limitations [52][53]. Another method of reducing the polymerization stresses is by adding chain transfer agents like thiourethane in methacrylate but it reduces the working time [54]. Some of its properties are mentioned in table 5 [55].

Table 5: Properties of Dual-cure Resin Cement

Properties	Value
Degree of conversion	50%-73% (self-cure mode) 67%-85% (light-cure mode)
Compressive strength	180-300 MPa
Flexural strength	80-100 MPa
Elastic modulus	4-10 GPa
Film thickness	13-20 µm
Polymerization shrinkage	2%-5%
Shear bond strength	12-18MPa

The latest and advanced type of resin cement is self-adhesive resin cement (SARC), developed in 2002 and was first introduced commercially by 3M ESPE (RelyX Unicem) and since then it has gained great attraction and popularity. The uniqueness of SARC compared to other cements is its ease of manipulation and cementation technique due to acidic monomers incorporated into it thus eliminating the need for etching and priming resulting in lower technique sensitivity and postoperative sensitivity [57][58] as the smear layer is not removed from the tooth surface. There is no need for tooth preparation, the cement is mixed and directly placed over the tooth surface similar to water-based cements. Unlike other resin cements SARC is moisture tolerant enabling its placement in subgingival area and the areas where moisture control is very difficult [59].

There is a lot of potential and need to further investigate and understand various aspects of resin cement in order to prepare a resin cement which is superior to the one's existing and is as close to the ideal qualities as possible.

Methods

Extensive search was conducted and a number of articles were referred from pub med, Google scholar, science direct, research gate, MDPI journals searching for dental resin cements, advances in resin cements, luting cements, adhesive cements. Data relevant to these topics was included and the information related to other dental cements was excluded.

DISCUSSION

Since the inception of resin cements in dentistry a lot of investigation and study has been conducted on it to overcome its shortcomings and also to enhance its properties in improving its performance. Last couple of decades has seen some major breakthroughs in adhesive dentistry, especially resin cements and has attracted the attention of researchers and clinicians to expand their knowledge onto further horizons.

Dental caries is the most common disease globally and secondary caries is the foremost reason for the failure of restorations. The gap at tooth-restoration interface resulting due to polymerization shrinkage of resin cement results in disintegration of hybrid layer and formation of biofilm in the gap leading to micro-leakage and eventually caries [11][18][19]. Dental caries is predominantly caused by S.mutans bacteria amongst other bacteria hence a new approach was adopted to overcome this challenge by addition of nanoparticles that possess antibacterial properties [20]. Chen et al. concluded a review study wherein the necessity of blending new anticaries materials and nanoparticles was established [21]. Some of the nanoparticles, such as copper [22], titanium dioxide (TiO_2) [23], zinc oxide [24], silver [25], diamond [26], gold [29] has been used in composite resins, resin cements, GIC etc. and have been found to be effective in management of caries. Compounds like riboflavin [27] and curcumin [28] have also been found to be effective when included in resin cements.

Fluoride is effective and potent in preventing caries development in teeth. For a long time only silicate and GIC were the cements that released fluoride to prevent secondary caries and it was one of the major shortcomings of resin cements, especially because of caries development in tooth-restoration interface due to polymerization shrinkage. K Yoshida, M Atsuta incorporated fluoroaluminosilicate glass in the resin cement and studied fluoride release [30]. Fluoride composites also release fluoride in vitro, but much smaller amounts compared with glass ionomer cements. Despite the relatively low-level fluoride release, a positive effect of fluoride-releasing composites on secondary caries has been reported both in vitro [31] and in vivo [32][33]. Fluoride-containing fillers such as flour potassium silicate or ytterbium trifluoride (YbF_3) incorporated into these composites also release fluoride.

Self-cure resin cement, light-cure resin cement, dual-cure resin cement and self-adhesive resin cement are all used as there is no single resin cement that can be used in all the conditions. Amongst all of these, mechanical properties of self-cure resin cement are inferior and that of dual-cure resin cement is superior.

There are several additions made to the resin cements to achieve goals such as enamel and dentin remineralisation by resin cement, pulp healing resin cement, resin cement with colour indicator, self-sealing resin fixator in dentistry, resin cement with anti-fungal properties, bioactive resin cement etc. and there is still needed to further investigate them for their impact and success.

CONCLUSION

Resin cements have proven to be the material of choice by clinicians and it is the material which has attracted the interest of researchers. Tremendous efforts have been put and significant improvement has been achieved over time in developing the resin cements but still it is far from being an ideal material hence more study is needed.

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