Review Article

"MONOBLOCK EFFECT" – A review of the concept, types, and sealability

ABSTRACT

The end goal of endodontic treatment is to form a homogenous unit and achieve a fluid-tight seal in the root canals. The adhesion of the sealers to root dentin is important to avoid microleakage. With the introduction of the concept of bonding, the idea of creating a mechanically homogenous 'monoblock' unit has gained momentum. This review article aims to provide a panorama view of the monoblock concept and it's types along with the drawbacks of this system.

Keywords: Endodontics, Root canal obturation , Mineral trioxide aggregate , Dental adhesives, EndoRez, Retreatment

1. INTRODUCTION

The principal goal of endodontics is to eliminate the etiologic factors of pulpal and periapical diseases by thorough disinfection and obturation.[1] It is crucial to obturate the radicular space with appropriate materials. In addition to sealing off the apex from periapical tissue fluids and containing the residual irritants inside the canal, it also helps to reduce the incidence of coronal leakage and bacterial infection. Numerous techniques and materials have been developed over the past several decades to achieve the most efficient root canal filling technique. So far, no available material or technique can be considered ideal that can provide a void-free homogenous root canal filling.[2]

One of the most routinely used materials for endodontic obturation even today is gutta percha.[3] To optimize the sealing process, gutta percha is combined with sealers as they don't bind to the canal walls.[4,5] Endodontic sealants and gutta percha have been employed with predictable treatment outcomes.[2].But recently, there has been a noticeable surge in interest in the application of adhesive principles in endodontics. [6] Moreover, the recent endodontic instrumentation systems that are geometrically similar to the master cones make single cone obturation techniques a fascinating prospect.[7] Discussions on monoblock obturations using a single gutta percha cone and endodontic sealers have thus gained momentum.

‘ Single unit ’ is the literal meaning of the word monobloc. Dr. Pierre Robin coined the term "monobloc" in the discipline of orthodontics in 1902. Franklin R Tay pioneered a concept called monoblock in endodontics which signified a system wherein the root canal space was obturated with a solid mass without any gaps consisting of various materials and their interfaces that simultaneously provided an improved seal and as well as reinforced the filled canals. A post and core system or an obturating material can be employed as this filling. [8]

When carbon fiber-reinforced posts made of epoxy resin were mechanically attached to root dentin as a homogeneous monoblock in 1996, this idea became widely accepted.[9] The root dentin, the canal walls, the sealer, and the obturating substance should all adhere to one another and form a solid, homogeneous unit to establish a three-dimensional seal. This is termed as ‘monoblock effect’. With the development of dentin adhesive technology, this idea of monoblocks has gained widespread recognition in the literature on endodontic therapy.

Based on the number of interfaces between the bonding substrate and the core material, root canal monoblocks may be divided into three categories: primary, secondary, and tertiary.[10] Post and core systems, as well as obturating materials, can also be included under this category.

Endodontic treatment's long-term prognosis depends on variables like the sealability of the filling material to avoid any recontamination of the canals and the ability of the obturating material to reinforce and strengthen the roots which would have been weakened by the cleaning and shaping protocols and restorative interventions. This is where the potential of monoblocks assumes value.[8]

2. SEALABILITY AND REINFORCEMENT OF ROOTS – How do monoblocks work?

The entire concept of obturating the root canal space is to attain a three-dimensional seal that can prevent the entry of microorganisms, tissue fluids, or other molecules and cause microleakage. The following are the possible reasons for micro gaps and resultant leakage - polymerization shrinkage, poor adhesion, thermal stresses, water sorption, and occlusal load.[8]The need to achieve a more efficient seal apically and coronally has led to the development of bonded obturation materials. The introduction of a low viscosity methacrylate resin-based sealer (MBRS) aims to increase the level of bonding between root filling components. Additionally, novel root filling materials that promise to adhere to these methacrylate resins are already available in the market.

The MBRS has so far been introduced in four generations. The first generation's primary component, Poly [2-hydroxyethyl methacrylate], was commercialized under the tradename Hydron. Given that they are hydrophilic, second-generation MBRS do not need to be etched before being used in conjunction with a dentin adhesive. The third generation of sealers uses a dual-cured resin composite sealer and a self-etching primer. The etchant, primer, and sealer were eventually combined into a single self-etching, self-adhesive sealer in the fourth generation sealers as in METASEAL.[8]

Clinical scenarios where there is a significant loss of tooth structure posts and core are indicated. The fibre posts that are very popular these days are retained passively, thus a good seal in the root canal requires the use of an adhesive cement. These types of cement may be divided into three categories – Total etch resin cements, Self – etch resin cements, and self-adhesive resin cements. These cements have substantially less microleakage because they could adhere to the tooth structure. Thus, both the methacrylate resin-based sealers along with resin cement play an important role in achieving a monoblock.

The elastic modulus (MOE) of the materials that are used to replace the lost tooth structure is of a lot of importance, as they have to withstand the physiologic/parafunctional forces repeated over extended durations known as fatigue stress.

Endodontically treated teeth are more susceptible to biomechanical failure due to the loss of tooth structure, hence in order to preserve such teeth, the materials utilised should have a MOE similar to that of dentin (14.0–18.6 GPa). This warrants the current popularity of fibre posts. The irreparable damage to the root is avoided by a positive dissipation of forces that are acting on the tooth. Additionally, dentin and adhesive composite resin cements with an elastic modulus similar to that of fibre posts increase the post system's capacity for reinforcement. [11]

3. CLASSIFICATION OF ENDODONTIC MONOBLOCKS

Replacement monoblocks that are established in the root canals may be classified as primary, secondary, or tertiary depending on the number of interfaces that are present between the bonding substrate and the core bulk material. [10]

3.1 PRIMARY MONOBLOCK

A primary monoblock has a single circumferential contact between the core material and the root canal wall. A 2-hydroxylethyl methacrylate(HEMA)-containing root filling material (Hydron; Hydron Technologies, Inc., Pompano Beach, FL) was commercially marketed as an en masse filling material for the root canals in the 1970s, when the theories underlying dentin bonding were being developed and the idea of unidirectional fibre reinforcement of resins was still relatively uncommon in dentistry.[12] In the root canal, this readily available Hydron would be injected and polymerized[13], oftentimes with residual moisture[14,15]. Highly permeable and leachable, Soft hydrogels were produced when HEMA polymerized in the presence of water[16]. However, additional research on the Hydron-filled root canals showed significant leakages.[13] The strength of an endodontically treated tooth depends on the amount of sound tooth structure that is left behind following the treatment. Furthermore, the potential for tooth fracture increases as more of the tooth structure is lost.[17,18] The modulus of elasticity of the porous hydrogel-like hydron ranges between 180 to 250 MPa which is nowhere near that of the root dentin (i.e. 14,000 MPa)[19]. Therefore, it can be said that even if one of the first monoblocks to exist could bond to the canal surfaces, it was not rigid enough to strengthen the roots.

Mineral trioxide aggregate (MTA; ProRoot MTA, Dentsply Tulsa Dental, Tulsa, OK) is another material that can be considered a primary monoblock when used in the root canals as an orthograde filling material such as in cases of apexification. The composition is very similar to that of Portland cement and in addition, it contains bismuth trioxide for radiopacity.[20] Apatite-like interfacial deposits are created when the calcium and hydroxyl ions of MTA interact with a synthetic bodily fluid that contains phosphate. These deposits strengthen the frictional resistance of the root canal walls by filling up any gaps caused by material shrinkage. These most likely also explain how MTA seals in orthograde obturation and perforation repair. However, it does not contribute to root strengthening which can be attributed to the lack of bonding and low tensional stress.

3.2 SECONDARY MONOBLOCK

Two circumferential interfaces between the cement and the dentin and the cement and the core material are present in secondary monoblocks. This variety of monoblock is usually accepted in both endodontic and restorative literature. When a core material is used in conjunction with cement or a sealer, as is the case with modern endodontic obturations and fiber post adhesion, an extra interface is created into a monoblock.

As mentioned in the previous sections for a functionally successful monoblock, there are two primary requirements. First is the ability of mutual bond formation with the involved surfaces and secondly, the MOE of the substrate and the material should be in a similar range. A finite element analysis research using various cements and posts to repair weak roots has demonstrated the relationship between these factors.[21] The bonding of posts made of carbon fibre reinforced and epoxy resin-based posts to root dentin was the first to demonstrate the existence of a mechanically homogeneous monoblock in a root canal area. This was initially reported in 1996. When compared to a variety of heterogeneous materials, the clinicians reported that the carbon fiber posts' elasticity modulus was comparable to that of dentin. This enabled the development of a tooth-post-core monoblock. This aided in reducing the functional stresses and distribute the masticatory loads evenly. However, this concept even though extremely appealing, was way too advanced for its times looking at the material availability(1980 -1990)

The carbon fibers in the first-generation fiber posts have been replaced with glass fibers susceptible to silane coupling and carbon fibers covered with quartz as a result of technological developments.[22,23] A strongly cross-linked, oxygen inhibition layer-free methacrylate resin matrix has also been used to replace the epoxy resin embedding matrix in prior generations of fiber posts. Theoretically, this matrix might bond to methacrylate-based resin cement. These more recent generations of fiber posts can be surface-treated in a variety of ways to improve their ability to adhere to methacrylate-based resins. They are thought to have performed well in vivo, which is likely because they have a comparable modulus of elasticity, even if the utilization of these more recent generations of fiber posts has not yet reached the scientific rigor of an ideal monoblock.

The obturations of radicular space can also be regarded as secondary monoblocks by definitionThe standard endodontic sealers, it has been found, do not adhere well to the dentin or gutta percha, failing to create a mechanically homogeneous unit. The year 2004 renewed the interest of researchers in the classic monoblock concept which lead to the advent of potential alternatives to gutta percha , the bondable root filling materials. There are now three bondable root filling products on the market. The only one of these that can be utilised for lateral or warm vertical compaction procedures is Resilon (Resilon Research LLC, Madison, CT). Resilon may be categorised as a type of secondary monoblock because it has two interfaces—one between the sealer and primed dentin and the other between the sealer and Resilon—and is applied to the self-etching primer-treated root dentin using a methacrylate-based sealer. In addition to improving the fracture resistance of the teeth that had endodontic treatment, resilon-filled canals outperformed conventional gutta-percha-filled canals at resisting bacterial leakage[24,25]. The Resilon monoblock system (RMS), which combined these promising Resilon properties with the Epiphany primer and sealer system (Pentron Clinical Technologies, Wallingford, CT), produced optimal root obturations in terms of coronal seal and fracture resistance. [26].

3.3 TERTIARY MONOBLOCKS

A tertiary monoblock is created when a third circumferential interface is added between the abutment material and the bonding substrate. Tertiary monoblocks are fiber posts with a silicate coating or unpolymerized resin composite used to line broad canal gaps that cannot sustain conventional fiber posts. The relined assembly is then taken out and properly polymerized so that it may be reinserted in order for it to adhere to the resin cement. The resin cement layer was greatly decreased in the Anatomic Post system, with the exception of the apical part of the post space, which did not include any relining composite. Theoretically, volumetric shrinkage should be decreased if the resin cement thickness is decreased. It is unclear, nevertheless, if the decreased resin layer thickness in a low-compliance environment also results in decreased polymerization shrinkage stresses along the cavity walls. A tertiary interface is also challenging since gaps were discovered between the fiber post and the relining composite.[27] The fiber post may get detached from the relining composite and the adhesive may fail as a result of these gaps operating as stress raisers.

Gutta percha points with coatings that make them bondable to endodontic sealers are also another material that belongs in with this category. A single cone approach or a technique that passively places the accessory cones without any lateral compaction is chosen because of the preexisting tertial interface in order to prevent the disruption of these surface coatings.

In the EndoRez system (Ultradent, South Jordan, UT), a proprietary resin coating is seen on the conventional gutta-percha cones [28]. In order to make this coating, one of the isocyanate groups of a diisocyanate must first be reacted with the hydroxyl group of a polybutadiene with a hydroxyl terminal so that the latter may attach to the hydrophobic polyisoprene component of the gutta-percha cones. The second isocyanate group of the diisocyanate is then grafted with a hydrophilic methacrylate functional group, creating a resin coating that may be adhered to a hydrophilic, methacrylate-based dual-cured resin sealer[29]. After the smear layer has been removed, the hydrophilic sealer is able to penetrate into the dentinal tubules and lateral canals, potentiating the endodontic seal rather than the adhesives. The polymerization shrinkage of the methacrylate-based sealer and the fact that the sealer forms a weak bond with the prepolymerized proprietary coating because it lacks free radicals for bonding because the oxygen inhibition layer has been removed for packing purposes are the reasons given in the literature as to why the EndoRez system produces a mediocre seal [30–33]. Expecting the EndoRez system to create a mechanically homogeneous unit is not feasible because the majority of the material inside the root canals still consists of thermoplastic gutta-percha, an elastic polymer that flows when under stress. ActiV GP (Brasseler USA, Savannah, GA) employs traditional gutta-percha cones with glass-ionomer fillers coated on their surfaces [34]. This causes the gutta-percha cone to become stiffer, converting it into a gutta-percha core/cone that may serve as both the tapering filling cone and its own carrier core [35]. The glass-ionomer filler coating's presence enables the cone to be sealed to the root dentin using a glass-ionomer. Despite using a single-cone method, the ActiV GP system's coronal leakage was worse than what was accomplished with gutta-percha and AH Plus sealer; this might be because the amount of the glass-ionomer cement sealer was increased [36]. Additionally, there are no instances of the ActiV GP system improving the fracture resistance of a tooth that has had endodontic treatment.

4. BONDING AND ASSOCIATED PROBLEMS

When resin materials are polymerized, they shrink, which causes voids to appear at the points of the weakest bonds, allowing microorganisms to recolonize the root canals.[37]. For a successful bond, the configuration factor (C factor), which is the ratio of bonded to unbonded resin surface area, should be less than three. However, because of the intricate canal configurations, it was discovered that the ratio was over1000, which caused debonding at the dentin-sealer contact.[38] Time is another issue with connection strength since it deteriorates with time. An increased fraction of intertubular dentine in the radicular dentine causes greater hybrid layer production, which is advantageous for bonding and has been observed to favor bond strength as opposed to resin tag formation.[39]

5. MONOBLOCK INTERFACES and SEALABILITY

A fluid-tight seal must be achieved throughout the root canal system, either chemically or micromechanically, for an endodontic therapy to be successful. Poor adhesion, wettability, polymerization shrinkage among others are the possible causes of failure.[40] In order to avoid these situations, bonded obturating materials and methacrylate resin-based root canal sealers were created to enhance the root filling materials' ability to seal, including the first generation of MBRS; Hydron, the second generation of ENDOREZ, the third generation of RESILON/EPIPHANY and the fourth generation of METASEAL.

6. MEDICATIONS, IRRIGANTS, AND SMEAR LAYER'S IMPACT ON THE MONOBLOCK

One of the most significant irrigants used in root canal disinfection is sodium hypochlorite, which has a potent antibacterial effect and causes the creation of an oxygen-rich layer on the surfaces of the dentin, weakening the binding strength between the dentin and the resin-based sealants. According to earlier research, removing the smear layer before obturation has been a contentious issue. However, for better clinical outcomes, it is currently advised to remove the smear layer prior to obturation by various means, including NaOCL, EDTA, MTAD, and citric acid [41].

7. BIOCOMPATIBILITY

The ideal properties of a material used for obturation to create a monoblock would be that it should be non-mutagenic, non-carcinogenic, non-irritating, and biocompatible.[42] An in vivo study was conducted on guinea pigs to evaluate the biocompatibility of primary monoblock (MTA)[43], secondary monoblock (resilon)[44], and tertiary monoblock (Endorez)[43]. When the three monoblocks were evaluated, a second cytotoxicity analysis showed improved biocompatibility, a higher viable cell count, and moderate to severe levels of inflammation.

8. MONOBLOCKS AND ANTIBACTERIAL PROPERTIES

The high pH of MTA, which is regarded as a primary monoblock, is what gives it its antibacterial and antifungal characteristicsThe dentin is disinfected as a consequence of the high alkalinity which has a detrimental impact on the growth of the microbial flora.[45] MTA does not bond to root dentine, but it does release calcium and hydroxyl ions, which when they contact with a bodily fluid that contains phosphate, generate interfacial deposits that resemble apatite.

Resilon (Pentron Technologies) is a thermoplastic, synthetic, polymer composite filling material for the root canals. Clinically, this substance is comparable to gutta-percha in terms of manipulation, but it has the ability to bind with a resin-based sealant or bonding agent. Its potential to prevent bacterial microleakage due to improved sealing is a significant benefit. The resin sealer and the self-etched canal walls are attached by the Resilon core, which can bond to the resin, forming a monoblock that is extremely impenetrable to bacteria.[46]

The assessment of the antibacterial properties of Endorez which forms a tertiary monoblock revealed that it has no potent antibacterial properties. An in vitro study compared the antibacterial efficacy of Endorez with five other sealers using an agar diffusion test to reveal that it is not a potent bacterial growth inhibitor.[47]

9. RETREATMENT/RETRIEVABILITY OF MONOBLOCKS

Leakage is an important reason why endodontic retreatments are initiated. It's critical to remove as much of the prior obturating material as possible from the inadequately prepared and/or filled root canals in order to eliminate the necrotic tissues/debris and residual microorganisms that are causing the periapical inflammation.[48] When methacrylate resin-based sealers are combined with Resilon/gutta-percha, it is generally believed that they are more efficiently eradicated with fewer remnants than traditional GP/sealer combinations[49,50], particularly from the apical thirds of the root canal.[51] Regardless of the methods used for its cleaning, debris were visible on the middle and coronal thirds of the canal walls. [52,53]. Secondly, easier removal and lesser remnants implied that the methacrylate-based resins did not bond very well to sclerotic dentin which is usually prevalent in the apical thirds. Resilon is soluble in solvents like chloroform[49] whereas Epiphany is insoluble in the typical solvents used in dentistry. Therefore, it is considered challenging to remove the resin sealers from complex anatomies and difficult to reach areas of the root canal.[54]

Mineral trioxide aggregate when used for orthograde obturation, portrays a contemporary version of the primary monoblock.[10] MTA, once set, hardens into a mass that is difficult to remove; this might be a serious procedural challenge in retreatment instances. Studies have indicated that using ultrasonic tools to remove tough pastes may be partially successful [55] , but it stands a chance of complications such as instrument separation and its usage being limited to straight canals. By employing rotary and ultrasonic tools to study the retrievability of MTA from the root canal, Boutsioukis et al.[56] came to the conclusion that it was irretrievable. However, It has been noted that an acidic pH weakens and alters the microstructure of tricalcium silicate materials[57]. An in-vitro study utilized 2 % acetic acid and 2 % carbonic acid to check their effect on the microstructure of set MTA and the results showed that both these acids were effective in altering the microstructure of the set mass with 2 % acetic acid having a significantly greater effect. [58]

The ActivGP system is an example of a tertiary monoblock wherein the Activ GP sealer bonds to the dentine.[59] Based on gross radiographic criteria, manual instrumentation was more successful at removing AH plus than Activ GP from the root canals. In order to attain the working length, ProTaper Universal retreatment tools were found to be just as secure and efficient as hand instruments.[60]

10. WHAT’S NEW ???

Using tooth-like tissue regeneration to seal and obturate the root canals was the subject of an in vitro study that was published in 2018. By utilising a biomimetic mineralization method, the authors of this study developed a primary monoblock procedure including a mechanically homogenous unit with root dentine. By forming a thick, compact rod-like fluoridated hydroxyapatite (FHA) deposition as a monoblock that tightly bonds to the canal dentine in order to prevent any leakage and additionally seal off the entire community of the root canal system from the outside environment, they were able to achieve a homogenous and monolithic root canal obturation.[61]

11. CONCLUSION

Although the notion of generating mechanically homogeneous units with root dentin sounds excellent in theory, it is more difficult to put these perfect monoblocks into practice. This phrase describes a scenario in which the canal space is completely filled by a gap-free, solid mass made up of various materials and interfaces, with the goal of concurrently enhancing the root canals' ability to close and resist fracture.[54,48] This topic is however controversial and has paved the way for several discussions. The fact that the currently available materials cannot reinforce the roots as they do not have an elastic modulus similar to the dentin and that they do not seal the root canal space completely are significant drawbacks of this system. However, the endodontic monoblock filling approach has gained popularity in the field of endodontics with the use of dentine adhesive technology. Units of monoblock can be built in the root canal space using adhesive root canal sealers, resin cement, or bondable coating filling materials/post.[10,62] It is safe to say that these current endodontic practices around adhesives and bonded materials are here to stay. Nevertheless, further evaluations are required to draw a parallel as to whether these materials work better than the conventional materials.

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