Review Article

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

ABSTRACT

The ultimate goal of endodontic treatment is to form a homogenous unit and achieve a fluid-tight seal in the root canal space. 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. The aim of this review article is to provide an overview of the monoblock concept and the different types available along with the drawbacks of this system.

Keywords: Monoblocks, Endodontics , Sealability, Root reinforcement, Retreatment, Methacrylate-based root canal sealers, MTA, Fiber posts

1. INTRODUCTION

The fundamental aim of endodontics is to eliminate the etiology of the pulpal and periapical diseases by thorough disinfection and obturation of the root canal system.[1] Obturation of the radicular space is essential to minimize the risk of coronal leakage and bacterial contamination, in addition, it seals the apex from periapical tissue fluids and confines the residual irritants in the root canal. Innumerable methods and materials have been developed in the past several decades aiming to achieve an optimal root canal filling process. So far, no material or technique can be considered ideal and can provide a void-free homogenous root canal filling.[2]

Even today, one of the most commonly used materials for an endodontic obturation 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] Studies have reported predictable clinical outcomes with the use of gutta percha and endodontic sealers.[2] However, recently an increased interest has been noted in the use of adhesive concepts in endodontics.[6] Moreover, the introduction of endodontic instrumentation systems that simulate the geometry of the master cones makes 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. The word 'monobloc' was introduced into dentistry in 1902 by Dr.Pierre Robin in the field of orthodontics. Franklin R Tay pioneered the concept of monoblock in endodontics which signified a system wherein the root canal space was filled 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. This filling can either be a root canal obturating material or a post and core system.[8]

This concept was first popularized in the year 1996 when epoxy resin-based, carbon fiber reinforced posts were bonded to the root dentin as a mechanically homogenous monoblock.[9] Since the aim of root canal therapy is to achieve a three-dimensional seal of the canal walls, the root dentin, sealer, and obturating material should bond to each other and create a solid, single unit. This is termed as 'monoblock effect'. This concept of monoblocks has become well known in the endodontic literature with the introduction of dentin adhesive technology in the field.

Monoblocks created in root canal spaces are classified as primary monobloc, secondary monobloc, and tertiary monobloc depending on the number of interfaces between the bonding substrate and the bulk core material.[10] This classification can also be applied to the root canal filling materials and post and core systems.

The long-term prognosis of an endodontic treatment depends on factors 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 subsequent leakage - polymerization shrinkage, poor adhesion and wetting, thermal stresses, water sorption, and occlusal loading.[8]The need to achieve a more efficient seal apically and coronally has led to the development of bonded obturation materials. A low viscosity methacrylate resin-based sealer has been introduced with an intention of enhancing the degree of bonding or adhesion of root filling materials. In addition, new root filling materials are now available that claim to adhere to these methacrylate resins.

Four generations of methacrylate resin-based sealers (MBRS) have been introduced so far. The first generation of MBRS included poly [2-hydroxyethyl methacrylate] as the main ingredient, which was marketed as Hydron. Second generation MBRS are hydrophilic that do not require etching to the adjunctive use of a dentin adhesive Eg; ENDOREZ. The third generation sealers involve the use of a self-etching primer and dual-cured resin composite Sealer Eg; RESILON/EPIPHANY. Ultimately, in the fourth generation sealers, the etchant, primer, and sealer were incorporated into an all-in-one self-etching, self-adhesive sealer Eg; 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 in the root canal, thus a good seal 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. As these types of cement have the capacity to bond to the tooth structure, they exhibit lesser microleakage than others. Thus, both the methacrylate resin-based sealers along with resin cement play the main role in achieving a monoblock.

The modulus of elasticity (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 masticatory forces/parafunctional forces repeated over long durations referred to as fatigue stress. Due to the loss of tooth structure, the endodontically treated teeth are more prone to biomechanical failure and to save such teeth the materials used 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. In addition, the adhesive composite resin cements with an elastic modulus in the same range as that of the fibre post, and dentin contribute to the reinforcing potential of the post system.[11]

3. CLASSIFICATION OF ENDODONTIC MONOBLOCKS

Replacement monoblocks that are created 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.

3.1 PRIMARY MONOBLOCK

A primary monoblock presents with only one interface that extends circumferentially between the root canal wall and the core material. In the 1970s, when the scientific principles that explained dentin bonding were being developed and the concept of unidirectional fiber reinforcement of resins was relatively uncommon in dentistry, a 2-hydroxylethyl methacrylate (HEMA) containing root filling material (Hydron; Hydron Technologies, Inc., Pompano Beach, FL) was marketed commercially as en masse filling materials for the root canals.[12] This commercially available Hydron would be injected into root canals to be polymerized in situ[13], often in the presence of residual moisture within the root canals.[14,15] Soft hydrogels that were highly permeable and leachable were produced when HEMA polymerized in the presence of water[16]. However, further literature evaluated the Hydron-filled root canals which revealed extensive leakages.[13] The strength of an endodontically treated tooth depends on the amount of sound tooth structure that is left behind after 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]. Thus it can be concluded that one of the initial monoblocks that came into existence was not stiff enough to strengthen the roots even though it could bond to the canal surfaces.

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] MTA does not bond to dentin, the interaction of the calcium and hydroxyl ions of MTA with a phosphate-containing synthetic body fluid results in the formation of apatite-like interfacial deposits. These deposits fill any gaps induced during the material shrinkage phase and improve the frictional resistance of MTA to the root canal walls. Probably, the formation of these nonbonding, gap-filling apatite deposits also accounts for the seal of MTA 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

Secondary monoblocks have two circumferential interfaces, one between the cement and dentin and another between the cement and the core material. A secondary monoblock is the type of monoblock that is classically perceived in the restorative and endodontic literature. An additional interface is introduced into a monoblock when there is a combined use of a core material along with a cement or a sealer as in contemporary endodontic obturations and fiber post adhesion.

As mentioned in the previous sections for a monoblock to function successfully, it has two primary requirements. First is the ability to bond mutually to the involved surfaces and secondly, the modulus of elasticity of the substrate and the material should be similar. This interaction between these two parameters has been illustrated well in a finite element analysis study of different cements in combination with posts used to restore weakened roots.[21] The availability of a mechanically homogenous monoblock in a root canal space was reported first in 1996 with the bonding of epoxy resin-based and carbon fiber reinforced posts to root dentin. The clinicians then claimed that the modulus of elasticity of the carbon fiber posts was very similar to that of dentin which could achieve a tooth-post-core monoblock as compared to an assembly of heterogeneous materials. This would reduce 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(the late 1980s and early 1990s)

With the advancements in materials, quartz-coated carbon fibers and glass fibers amenable to silane coupling have replaced the carbon fibers in the first-generation fiber posts.[22,23] The epoxy resin embedding matrix in older generations of fiber posts has also been replaced by highly cross-linked, oxygen inhibition layer–free methacrylate resin matrices that have the potential to bond to methacrylate-based resin cement, theoretically. Different modalities of surface treatments of posts are also available to make these newer generations of fiber posts more conducive to bonding to methacrylate-based resins. Although the use of these newer generations of fiber posts has not yet attained the scientific rigor of an ideal monoblock, they are reported to have performed well in vivo. This is probably due to the similarity in the modulus of elasticity between fiber posts and root dentin.

The root canal obturations can also be regarded as secondary monoblocks by definition. However, it has been noted that the conventional root canal sealers do not bond strongly to the dentin and gutta percha and hence do not behave as a mechanically homogenous unit. The year 2004 renewed the interest of researchers in the classic monoblock concept which lead to the advent of bondable root filling materials that can be advocated as alternatives to conventional gutta-percha. Until now, there are three bondable root filling materials available commercially. Of these, Resilon (Resilon Research LLC, Madison, CT) is the only bondable root filling material that may be used for either lateral or warm vertical compaction techniques. As Resilon is applied using a methacrylate-based sealer to the self-etching primer–treated root dentin, it contains two interfaces, one between the sealer and primed dentin and the other between the sealer and Resilon, and hence may be classified as a type of secondary monoblock. The initial studies on resilon were highly favorable. Resilon-filled root canals resisted bacterial leakage better than the conventional gutta-percha–filled canals[24] and also improved the fracture resistance of endodontically treated teeth[25]. Based on these promising qualities, Resilon, together with the Epiphany primer and sealer system (Pentron Clinical Technologies, Wallingford, CT) was referred to as the Resilon monoblock system (RMS), which produced ideal root obturations in terms of coronal sealing and fracture resistance[26].

3.3 TERTIARY MONOBLOCKS

When a third circumferential interface is introduced between the abutment material and the bonding substrate it forms a tertiary monoblock. Fiber posts with an external silicate coating or when unpolymerized resin composite is used for relining wide root canals that cannot take the conventional fibre posts may be considered a tertiary monoblock. In such root canals, the post is adapted to a lubricated post space and photoactivated to partially polymerize the composite. The relined assembly is then removed and optimally polymerized before reinsertion for bonding with the resin cement. In the Anatomic Post system, the resin cement layer was significantly reduced except for the apical portion of the post space in which no relining composite was included. Theoretically, a reduction of the resin cement thickness should result in a reduction of volumetric shrinkage. However, it is uncertain whether polymerization shrinkage stresses along the cavity walls are also reduced due to the reduction in resin layer thickness in a low-compliance environment. Also, the introduction of a tertiary interface is problematic in that gaps were found to be present between the fiber post and the relining composite[27]. These gaps may act as stress raisers eventually resulting in adhesive failure and dislodging of the fiber post from the relining composite.

The two other materials that can be discussed under this category are gutta percha points with coatings that render them bondable to the root canal sealers. Due to this existing tertial interface, a single cone technique or a technique that involves passive placement of the accessory cones without any lateral compaction so as to avoid the disruption of these external coatings is preferred.

In the EndoRez system (Ultradent, South Jordan, UT), conventional gutta-percha cones are coated with a proprietary resin coating[28]. This coating is created by first reacting one of the isocyanate groups of a diisocyanate with the hydroxyl group of hydroxyl-terminated polybutadiene, as the latter is bondable to the hydrophobic polyisoprene component of the gutta-percha cones. This is followed by the grafting of a hydrophilic methacrylate functional group to the other isocyanate group of the diisocyanate, producing a gutta-percha resin coating that is bondable to a hydrophilic, methacrylate-based dual-cured resin sealer[29]. The endodontic seal is dependent on the penetration of the hydrophilic sealer into the dentinal tubules and lateral canals after removal of the smear layer rather than adhesives. Literature suggests that the seal of the EndoRez system is mediocre [30-32], this can be attributed to the polymerization shrinkage of the methacrylate-based sealer and also to the fact that the sealer bonds weakly to the prepolymerized proprietary coating, as it lacks free radicals for bonding because of the removal of the oxygen inhibition layer for packing purposes.[33] It is unrealistic to expect the establishment of a mechanically homogenous unit with the EndoRez system, as the bulk of the material inside the root canal still consists of thermoplastic gutta-percha, an elastomeric polymer that flows when stresses are applied.

ActiV GP (Brasseler USA, Savannah, GA), the root filling system uses conventional gutta-percha cones that are surface coated with glass-ionomer fillers using a proprietary technique[34]. This results in a stiffer gutta-percha cone that transforms it into a gutta-percha core/cone, enabling the latter to function as both the tapered filling cone and as its own carrier core, thus avoiding the need for a separate interior carrier of plastic or metal[35]. The presence of the glass-ionomer filler–coated gutta-percha cone also allows it to be bonded to the root dentin via a glass-ionomer sealer. However, being a single-cone technique, coronal leakage of the ActiV GP system to fluid filtration was worse than that achieved with gutta-percha and AH Plus sealer, which could be due to the increase in the volume of the glass-ionomer cement sealer[36]. It is also unlikely that the use of the ActiV GP system will improve the fracture resistance of an endodontically treated tooth.

4. BONDING AND ASSOCIATED PROBLEMS

Resin materials result in shrinkage on polymerization, this results in separation at the areas of the weakest bond through which micro-organisms enter the root canals[37]. Configuration factor (C factor) is the ratio of bonded to unbonded resin surface area which is supposed to be less than three for effective bonding. However, due to the complex root canal configurations, the ratio was found to be more than 1000 causing debonding at the dentin-sealer interface.[38] The time factor is also considered to be one of the problems associated with bond strength, as it gets deteriorated with time. The hybrid layer has been reported to favor the bond strength rather than resin tag formation and as the radicular dentine contains more intertubular dentine it results in more hybrid layer formation which is favorable for bonding.[39]

5. SEALABILITY and MONOBLOCK INTERFACES

Achieving a fluid-tight seal throughout the root canal system either chemically or micromechanically is necessary for the successful outcome of the endodontic treatment. Poor adhesion, wettability, polymerization shrinkage, thermal stresses, occlusal loading, and water sorption are the possible causes of failure.[40] In order to overcome these instances bonded obturating materials and methacrylate resin-based root canal sealers were developed for improving the sealing ability of root filling materials such as first generation MBRS; Hydron, second generation; ENDOREZ, third generation; RESILON/EPIPHANY the fourth generation; METASEAL.

6. EFFECT OF MEDICAMENTS, IRRIGANTS, AND SMEAR LAYER WITH THE MONOBLOCK

Sodium hypochlorite is considered one of the most important irrigants used in root canal disinfection which possesses a strong antibacterial activity and results in the formation of an oxygen-rich layer on the surfaces of dentin causing weak bond strength with the resin-based sealers. According to past literature, smear layer elimination before obturation has been a controversial aspect. However, the current recommendation is to remove the smear layer before obturation by alternative use of NaOCL, EDTA, MTAD, and citric acid[41] with ultrasonic instruments for better clinical performance.

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 to the periradicular tissues.[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]. Another cytotoxicity evaluation revealed better biocompatibility and a more viable cell count and moderate to severe levels of inflammation when the three monoblocks were tested.

8. MONOBLOCKS AND ANTIBACTERIAL PROPERTIES

The antibacterial and antifungal properties of MTA which is considered a primary monoblock are attributed to its high pH. This high alkalinity has an inhibitory effect on the growth of the microbial flora and causes disinfection of dentin. It is known to be effective against E *faecalis,* S *sanguis,* and C *albicans*.[45] MTA shows no bonding to root dentine, but it releases calcium and hydroxyl ions which interact with a phosphate-containing body fluid, resulting in the formation of apatite-like interfacial deposits. These deposits fill any gaps that are produced during the material shrinkage phase which in turn enhances the frictional resistance of MTA to the root canal walls.

Resilon (Pentron Technologies) is a thermoplastic, synthetic, polymer composite filling material for the root canals. Clinically, this material can be manipulated like gutta-percha however it possesses the potential for bonding with a resin-based sealant or bonding agent. A major advantage that it possesses is the prevention of bacterial microleakage attributed to enhanced sealing. The Resilon core can bond to the resin sealer which, in turn, attaches to the self-etched canal walls. This forms the monoblock, which is highly resistant to bacterial penetration.[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 one of the major reasons why endodontic retreatments are initiated. To eliminate the necrotic tissues/debris and remnant microflora that is responsible for the periapical inflammation it is important to remove as much filling material as possible from the insufficiently prepared and/or filled root canals.[48] The general assumption when it comes to methacrylate resin-based sealers used with Resilon / Gutta percha is that it is more effectively eliminated with lesser remnants than the conventional GP/sealer combinations[49,50], particularly from the apical thirds of the root canal.[51] The middle and coronal thirds of the canal walls exhibited debris irrespective of the removal techniques employed. The difference in the removability of materials could be explained by the adhesion between the core materials and sealers[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 present in the apical thirds. Resilon is soluble in solvents like chloroform[49] whereas Epiphany is insoluble in the solvents that are used commonly in dentistry. Therefore, it is considered challenging to remove the resin sealers from fins, accessory canals, or isthmi.[54]

Mineral trioxide aggregate when used for orthograde obturation as an apexification material, represents a contemporary version of the primary monoblock.[10] MTA once set forms a hard mass, thus making its retrieval tough, this can pose a significant procedural problem in retreatment cases. Studies have shown that the use of ultrasonic instruments for the removal of hard pastes is effective to a certain extent[55] , but it stands a chance of complications such as instrument separation and its usage being limited to straight canals. Boutsioukis et al [56] studied the retrievability of MTA from the root canal by using rotary and ultrasonic instruments and concluded it to be 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, hand instrumentation removed Activ GP more effectively from the root canals than AH plus. Irrespective of the sealer type and retreatment technique, the filling material could not be removed entirely from the root canals, and a significant amount of filling material remained in the apical third. ProTaper Universal retreatment instruments were observed to be as safe and effective as hand instruments in reaching the working length.[60]

10. WHAT'S NEW ???

An in vitro study published in 2018, discussed a novel strategy of sealing and obturating the root canals with tooth-like tissue regeneration. In this study, the authors developed a primary monoblock technique involving a mechanically homogeneous unit with root dentine by using a biomimetic mineralization strategy. This helped them achieve a homogenous and monolithic root canal obturation without leakage between the root canal dentine by forming a thick and compact rod-like fluoridated hydroxyapatite (FHA) deposition as a monoblock that bonds tightly to the canal dentine and in addition seals off all the community of the root canal system from the external environment.[61]

11. CONCLUSION

Monoblocks are a concept of creating mechanically homogenous units with root dentin which sounds excellent theoretically but accomplishing these ideal monoblocks is easier said than done. This term pertains to a scenario wherein the canal space becomes perfectly filled with a gap-free, solid mass that consists of different materials and interfaces, with an aim of simultaneously improving the seal and fracture resistance of the filled root canals.[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 a modulus of elasticity similar to the root dentin and that they do not seal the root canal space completely are significant drawbacks of this system. However, With the application of dentine adhesive technology, the endodontic monoblock filling technique has attracted interest in the field of endodontics. Monoblock units can be created in a root canal system by 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.

CONSENT

It is not applicable.

ETHICAL APPROVAL (WHERE EVER APPLICABLE)

It is not applicable.

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