Novel dental materials for root-end applications: a review

Abstract

Achieving a good apical seal is crucial for ensuring successful endodontics; especially in cases that involve a wide apex (e. g. immature apices, apical resorption, and fracture involving the tooth apex). An efficient root-end material is an absolute requisite towards achieving this goal. The recent years have witnessed a decent outflow of new products for root-end applications. However, their merits, and claims of superiority over MTA, have to be ascertained via sustained research.

Keywords: Apical seal, bioactive, MTA, novel root-end materials, review.

Introduction

The quest for an ideal material for root-end applications has produced a plethora of products that are based on different compositions and exhibit varied setting reactions. Though many of them have been proven to be effective, none of them can be described as ideal yet, thus generating scope for further development.

MTA as the gold standard

Since its introduction by Torabinejad in 1993, MTA has been extensively studied and used. Over the years, it has emerged as the time-tested and attested material. MTA is essentially Portland cement (Sio_2, CaO, Al_2O_3, MgO, and Fe_2O_3), to which a radioopacifier (Bi_2O_3), and dehydrated(anhydrous) calcium sulphate have been added. MTA is biocompatible and osteogenic. It is bioactive: i. e. MTA is capable of interacting with living tissues and allows deposition of apatite crystals in the

MTA-tissue interface. This material is capable of inducting hard tissue formation. [1] Apart from exhibiting excellent sealing properties, it also has the capacity to set and also remain steady in the presence of moisture. Hence, a recent review has described it as ‘ hydraulic silicate cement’. [2]

However, this material is not devoid of disadvantages. Re-entering MTA-treated teeth is difficult. High acidity and alkalinity (beyond a pH of 8. 4) can unfavorably influence the surface hardness of set MTA. MTA is shown to expand uncontrollably. [3] Grey MTA has been found to discolor tooth and the neighboring gingival tissues. Both grey and white MTA contain toxic substances and impurities. The material is fairly difficult to manipulate owing to its sandy consistency; though the small particle size of white MTA may aid in producing a thicker mix; hence, better workability. [4] MTA exhibits low washout resistance during initial set especially when a setting accelerator is not incorporated into the MTA mixture. Its initial solubility is undesirable when used as a root-end filling material. [5]

In lieu of MTA’s potential drawbacks, the search for superior materials has resulted in the emergence of newer materials in the market; the majority of which, bear resemblance to MTA with minor alterations in their composition.

Bioaggregate

This novel water-based, hydraulic cement, consists of tricalcium silicate as its primary component. Tantalum oxide imparts radioopacity; hydroxyapatite and amorphous silicon oxide have been added to reduce the level of formation of the weak phase- calcium hydroxide. [6] Purity is ensured via elimination of aluminum. Though the manufacturer states that trace amounts of naturally occurring contaminants may be detected during chemical analysis, the lack of detection of heavy metal contamination is noteworthy. The material is bioactive. [7] Sayeed et al. suggested that Bioaggregate be considered as an alternative to MTA owing to the former's better sealing ability. The authors attributed the hermetic seal associated with bioaggregate to: (1) Its nano-sized particles that exhibit excellent adhesion to the dentinal walls of the root canal, (2) Its hydrophilicity. The presence of a gel-like calcium silicate hydrate as the main component, resulted in improved strength, hardness, and sealing characteristics to the set material. [8] Bioaggregate also exhibited excellent biocompatibility and induced periodontal regeneration. [9]

Biodentin

Biodentine, marketed by Septodont is available as a powder and liquid formulation. Tricalcium silicate and dicalcium silicate form the core materials of the powder. Purity of calcium silicate is enhanced by eliminating the contaminants namely aluminates. Calcium carbonate and calcium oxide, and zirconium oxide have been added as the fillers and as the radioofacifier respectively. Liquid comprises of calcium chloride as the accelerator. Hydrosoluble polymer and water reducing agents are also present. Biodentine can be used as a root repair material but is not indicated for root amputation and hemisection. The working time is over 1 minute and the setting time ranges between 9 and 12 minutes. The final hardness of Biodentine approximates that of the dentin, thus rendering retreatment difficult if not impossible. [10] On performing cytotoxicity assay and cell growth on set materials, human gingival fibroblasts responded similarly to Biodentine and MTA extracts. [11]

EndoSequence Root Repair Material

EndoSequence Root Repair Material (Brasseler USA) is based on bioceramic technology and is essentially composed of nanoparticles of tricalcium silicate, dicalcium silicate, calcium phosphate monobasic, amorphous silicon dioxide, and tantalum pentoxide. [12] It differs from white MTA mainly in that it is aluminium free and contains calcium phosphate monobasic and tantalum pentoxide (radioopacifier). [13] It is marketed as a pre-mixed formulation in two different consistencies: syringeable paste, and condensable putty. `The former has bendable tips to facilitate intra-canal material placement. [14] According to the manufacturer, the material exhibits superior handling properties owing to its pre-mixed formulations, short setting time (~2 hours), and high resistance to washout. The material is radiopaque, hydrophilic, and highly alkaline (+12 pH), thus bactericidal. Its setting reaction is initiated by dentinal moisture. [15] Endo sequence is bioactive. [16] Hirschberg et al. compared the sealing ability of ERRM with MTA, and concluded that leakage was greater in samples restored with ERRM when compared to that of MTA-restored samples. [17]

In simulated root resorption defects, intracanal placement of white MTA resulted in greater and sustained release of hydroxyl ions, and thus a higher pH when compared to EndoSequence. This, the authors attributed to the quicker set of ES as compared with MTA. But, few MTA samples exhibited discoloration, while none of the ES samples did. This may be esthetically relevant. [18]

Top of Form

Bottom of Form

iRoot BP Plus

These bioceramic materials are primarily composed of calcium silicate, and require the presence of moisture to set and harden. They also contain zirconium oxide, tantalum pentoxide, calcium phosphate monobasic, and filler agents They are available in three forms: (1) iRoot® BP Plus putty root canal filling andrepair material- white hydraulic premixed puttyintended to be used for root canal repair and restorative applications, (2) iRoot® BP Injectable Root Canal RepairFilling Material- white hydraulic premixed injectable paste intended to be used for root canal repair and restorative applications, and (3) iRoot® SP Injectable Root Canal Sealer- injectable white hydraulic cement paste intended to be used for permanentroot canal filling and sealing applications. [19]

According to the manufacturer, these materials are insoluble, radiopaque, aluminum-free, possess excellent physical properties, and do not contract on setting. [20] iRoot ® BP Plus was biocompatible and did not elicit critical cytotoxic effect. However, its long-term performance was inferior as compared to White MTA. [21] Another study observed that both materials i. e. iRoot BP Plus and iRoot FS exhibited negligible cytotoxicity. Under simulated clinical conditions, iRoot FS was able to completely solidify within an hour, whereas iRoot BP Plus set only after seven days. [22]

Ceramicrete

Developed at Argonne National laboratory, Ceramicrete is essentially a chemically bonded phosphate ceramic (CBPC), which was developed to function as a binder for waste management. The material was inducted into dentistry owing to its inherent strength, biocompatibility, and bioactivity. Radioopacity is achieved by incorporation of radio opacifiers (bismuth oxide, cerium oxide).

Wagh and Primus found Ceramicrete to be a strong material exhibiting lower porosity and permeability due to the formation of potassium-magnesium phosphate hexahydrate ceramic matrix phase. The decreased porosity also contributes to Ceramicrete’s superior sealing capacity. [23] The use of an acid conditioner prior to application of ceramicrete may result in better adaption due to removal of smear layer, thus improving the seal. Incorporation of calcium silicate whiskers resulted in the formation of a brushite phase, which improves mechanical properties.

Though, initially, the material tends to be acidic, set Ceremicrete-D is alkaline (pH of 11 after 72 hours). However, the acidic pH (2. 2) of a fresh mix may exacerbate the acidic condition of an already inflamed tissue. [24] The low pH may be the reason why ceramicrete D caused initial death of primary osteoblasts and failed to support further cell growth, since low pH is shown to inhibit osteoblast activity. [25]

The radioopacity of ceremicrete was substantially less (3. 2mm of aluminium) than white MTA (8. 5mm of aluminium). Handling properties and resistance to washout were superior. According to porter et al, Ceremicrete-D retained a weak chalk like consistency even after seven days of setting. They suggested the original formula be modified to effect increase in the strength of the material. [26]

Capasio

Capasio (Primus Consulting, Bradenton, FL) is an experimental calcium-phospho-aluminosilicate–based cement that is mixed with a water based gel. Bismuth oxide has been added as a radiopacifier. [27] When mixed, Capasio develops dough like consistency and can be rolled into a rope which enables better handling. Ceremicrete-D and Generex A also demonstrate this desirable property. Capasio displays good washout resistance, and improved physical characteristics such as setting time (9 minutes), compressive strength, and washout resistance. [26] It exhibited slightly less basic pH (10. 9) when compared with white MTA. [28] The radiopacity of Capasio was significantly less as compared to MTA but marginally greater than

Ceremicrete-D.[26] Capasio is also bioactive. It has the ability to precipitate apatite crystals on its surface.

The smaller particle size of Capasio (a mean particle size of 5. 3µm as compared to 10µm of MTA) may be perceived as an advantage. Materials that demonstrate the capability of penetrating dentinal tubules exhibit improved marginal adaptation, retention, and also entomb the residual bacteria. The material was shown to penetrate dentinal tubules up to a depth of 18-26 µm; much greater than that of MTA.[29] Penetration of an endodontic material into the dentinal tubules results in improved marginal adaptation, increase mechanical retention, entombs residual bacteria and improved antibacterial effects owing to closer proximity of the material to the bacteria.[30]

Quick-set

Capasio (Primus Consulting, Bradenton, FL) has been further developed and has been renamed as Quick-Set (Primus Consulting). The refinement has been performed via removal of the cationic surfactant from the liquid gel component, which was thought to affect its biocompatibility. Using murine dental papilla-derived odontoblast-like cell line (MDPC-23), Wei et al. observed that the in vitro cytotoxicity of Quick-Set was similar to that of WMTA.[31] Ashraf et al. concluded that the in vitro osteogenic/dentinogenic differentiation potential of Quick-Set was favorable.[32]

Generex A and B

Generex A (Dentsply Tulsa Dental Specialities, Tulsa, Usa) and B are calcium-silicate-based materials with novel setting reactions. Generex A contains tricalcium silicate, dicalcium silicate, and tricalcium alumunate. Its composition is similar to that of MTA but for the fact that the powder is finer, and unique gels are used for mixing instead of water as is the case with MTA. [25] Usage of the gel results in: improved handling characteristics and reduced setting time. [26]

Among the materials evaluated for their osteogenic potential (Generex A, Capasio, Ceramicrete, and MTA), only Generex A and MTA allowed primary osteoblast growth. [25] In a study conducted by Porter et al, Generex A exhibited the shortest setting time (1. 25 hrs) as compared to Capasio and Ceramicrete, which set in 2. 5 hours. Generex A also emerged as the strongest among the other materials tested. [26]

Endobinder

Endobinder differs from MTA in that, MgO and CaO (cause undesirable expansion of the material), and Fe_2O_3 (causes tooth darkening) are eliminated from its composition. Al_2O_3 and $CaCO_3$ are calcined at temperatures between 1315deg C and 1425d C, and are ground following which, Bismuth oxide is added to obtain radioopacity. Purity is ensured by eliminating traces of MgO, CaO, and Fe_2O_3. [32, 33]

Endobinder assisted early differentiation of a higher osteoblastic cell population in comparison to MTA. this, the authors attributed to the lower calcium hydroxide release from endobinder when compared with MTA. [34] While slightly higher concentration of extracellular calcium can stimulate osteoblast cell viability, proliferation, differentiation, and function, an overload can be cytotoxic. [35] According toOliveiraet al., Endobinder exhibited better fluidity, improved handling properties, higher mechanical strength, and reduced porosity (with lower pore size) when compared with MTA. [36] The material was biocompatible when tested in subcutaneous tissue of rats. [37]

Conclusion

The past few years have witnessed the development of novel materials with a purpose of overcoming the disadvantages of MTA. Some are primarily composed of calcium silicate (Endobinder, Endosequence, Generex A and B, and iRoot BP Plus), some are primarily tricalciumsilicate-based (Bioaggregate, and Biodentine) or calcium-alumino-silicate based (Capasio and quickset), and one is a chemically bonded phosphate ceramic (Ceramicrete). The focus behind developing these materials has mainly been- improved physical and biological properties over the present gold standard i. e. MTA. While some of these novel materials have exhibited improved characteristics, more research in the form of in vivo and in vitro studies are required in this direction, in order to ascertain the same. Also, newer materials with a composition differing from that of MTA, may bring a fresh approach with regard to this application.

1