Editorial

The Era of Endodontic Research…………Root-end Filling Materials

Every now and then, there comes a time when specific areas in the field of dentistry are more researched than others. There were times when the focus was on epidemiological studies of caries and periodontal disease, and now we are in an era where the endodontic research dominates the profession. Some of the recent endodontic developments include Axis (SybronEndo) based on twisted file technology in which the technology allows the TF adaptive file to adjust to intracanal torsional forces depending on the amount of pressure placed on the file. Thus, it allows the dentist to use minimum number of files to clean and shape canals; EndoSequence is the first endodontic system to be fully synchronized from instrumentation through obturation and postplacement; Munce Discovery Burs feature round carbide heads on nonflexible shafts that facilitate positive troughing control for locating separated instruments and uncovering hidden canals; Infinite Flex NiTi files, which are constructed with revolutionary Controlled Memory NiTi technology, exhibit virtually no memory and adapt perfectly to the canal path for precise and conservative removal of tooth structure; HyFlex CM (controlled memory) rotary files are extremely flexible without the shape memory of other NiTi files which make the file follow the canal without creating undesired lateral forces on the canal walls, substantially reducing the risk of file separation and complications, such as ledging, transportation and perforation.

There is a plethora of research going on all over the world, especially in India, with the focus not only on the equipment but also on materials, and the toast of the current scenario is various root-end filling materials.

The success of surgical endodontics is directly proportional to the efficacy of the root-end filling material. This is not only because the material has to provide a hermetic seal and prevents microleakage but also has to be compatible with periapical tissues. Various materials have demonstrated varying degree of success as root-end filling material over a period of time like calcium hydroxide, amalgam, GIC, Teflon, gold foil, screws, super EBA cement and most recently mineral trioxide aggregate (MTA).[1] Calcium hydroxide has been the gold standard for many years because of its clinical and histological excellence of producing tertiary dentin, but poor bonding and microleakage were some of the issues that plagued this material.[2] But, ever since the advent of MTA in 1990s, the changes have been revolutionary as MTA has shown to have excellent bonding strength and shown to form a dentin bridge and has virtually corrected all the problems associated with earlier materials.[3]

However, the mankind always strives for perfection and so do the researchers who have led to the development of some of the new materials like Biodentine, BioAggregate, EndoSequence, polymer nanocomposite and so on. Some of the recent researched materials are as follows:

1. Diaket (3M ESPE GmbH, Seefeld, Bayern, Germany), a polyvinyl resin, has shown good biocompatibility with osseous tissues but generated long-term chronic inflammation.[4]
2. EndoSequence root repair material (ERRM) (Brasseler USA, Savannah, GA, USA) is one of the new promising materials comprising of bioceramic materials used for perforation repair, apical surgery, apical plug and pulp capping.[5] It is a premixed ready-to-use material which is biocompatible, hydrophilic, radiopaque and antibacterial due to a high pH during setting. ERRM is composed of calcium silicates, monobasic calcium phosphate, zirconium oxide, tantalum oxide, proprietary fillers and thickening agents.[6] The material has nanosphere particles with a maximum diameter of 1×10^{-3} µm that allow for the material to enter dentinal tubules, be moistened by dentin liquid and create a mechanical bond upon setting.[7] On comparison of some basic properties of MTA and EndoSequence, it was evaluated that although they had similar strength and biocompatibility levels, but the major advantage of EndoSequence was improved handling characteristics over traditional MTA and the delivery of a consistent product with each application. Damas et al[7] compared the cytotoxic effect of two brands of white MTA (ProRoot MTA and MTA-Angelus), ERRM by using human dermal fibroblasts. They concluded that the ERRM has similar cytotoxicity levels to those of ProRoot MTA and MTA-Angelus. However, one area where EndoSequence lagged behind MTA was microleakage. Hirschberg et al[8] compared the sealing ability of MTA to the sealing ability of ERRM using a bacterial leakage model. They concluded that samples in the ERRM group leaked significantly more than samples in the MTA group.

3. BioAggregate (Innovative BioCeramix Inc) is developed as a fine white hydraulic powder cement mixture which can also be seen as modified MTA. This material is based on nanotechnology that ceramic particles upon reaction with water produce biocompatible and aluminum-free ceramic biomaterials. The composition of BioAggregate is tricalcium silicate, dicalcium silicate, tantalum pentoxide, calcium phosphate monobasic and tantalum pentoxide is used for radiopacity. The BioAggregate powder with the specified composition is mixed with BioA Liquid (deionized water), which leads to the formation of gel-like calcium silicate hydrate intimately mixed with hydroxyapatite bioceramic, which in turn forms a hermetic seal inside the root canal.[9] The various advantages of this material include ease of manipulation; working time is more than 5 minutes and convenient setting time; high strength and minimal microleakage property like MTA. Leal et al[10] compared the ability of ceramicrete, BioAggregate and MTA to prevent glucose leakage through root-end fillings and concluded that both endodontic bioceramic repair cements displayed similar leakage results to white MTA when used as root-end fillings materials. El Sayed and Saeed[11] evaluated and compared sealing ability of BioAggregate versus amalgam, IRM and MTA in which BioAggregate was found to be most superior. This material is highly sought after because it not only has the best properties but also produces no adverse cytotoxic effects on tissues and is highly biocompatible. The cytotoxicity studies of BioAggregate found that it stimulates the differentiation of human PDL fibroblasts as MTA and it is able to induce mineralization-associated gene expression in osteoblast cells.[12,13] It is indicated in repair of root perforation, repair of root resorption, root-end filling, apexification and pulp capping.
4. iRoot BP Plus (Innovative BioCeramix Inc., Vancouver, Canada) is a fully laboratory-synthesized, water-based bioceramic cement which is ready to use white hydraulic premixed formula. Although the material is biocompatible, but its disadvantages include the occurrence of leakage and inadequate strength.[14]
5. NRC (new resin cement) is a powder liquid system wherein the powder has calcium oxide, calcium silicate and triphenylbismuth carbonate, and the liquid is composed of hydroxyethyl methacrylate, benzoyl peroxide, toluidine and toluenesulfinate. The studies evaluating the material exhibit that the calcium reservoir capability of NRC may contribute to mineralization of the tissues but it reported a higher inflammatory reaction.[14]
6. EndoBinder (Binderware, Sao Carlos, SP, Brazil) is a new calcium aluminate-based endodontic cement that has been developed by eliminating disadvantages of MTA like darkening and expansion at the same time keeping its properties like biocompatibility.[14]
7. Generex A (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) is a calcium silicate-based material that has some similarities to ProRoot MTA but is mixed with unique gels instead of water which gives it dough-like consistency thereby improving the handling of material.
8. Polymer nanocomposite (PNC) resins are a new class of composites that have nanoparticles, such as clays, carbon nanotubes and so on dispersed at a nanoscale in PNC resins, such as C18 amine montmorillonite and vinylbenzyl octadecyl dimethyl ammonium chloride.
9. Biodentine (Septodont, Saint Maur des Fosses, France) is new bioactive cement that was recently launched in the dental market as a dentin substitute. Its mode of action is similar to calcium hydroxide and physical/chemical properties are similar to Portland cement derivatives but do not have either drawback. It is supplied in a powder liquid combination with the powder (capsule) composed of tricalcium silicate, calcium carbonate and zirconium oxide as the radiopacifier, and the liquid (pipette) contains calcium chloride as the setting accelerator and water as reducing agent. The setting time of Biodentine is 12 minutes. The biocompatibility of Biodentine is similar to that of MTA and it shows no adverse effects on tissues, whereas it is much superior to that of GIC.[15] Biodentine is stronger mechanically and has high sealability thus preventing microleakage. Pradelle-Plasse et al[16] found that Biodentine causes alkaline corrosion on the hard tissue, which leads to 'mineral interaction zone' and then due to remodelling processes, the sealing of the dentin by Biodentine improves in the course of time. Biodentine can deposit impermeably onto the cavity walls and prevents microleakage. Biodentine was shown to be biocompatible, that is it does not damage pulpal cells *in vitro* or *in vivo*, and is capable of stimulating tertiary dentin regeneration by inducing odontoblast differentiation from pulp progenitor cells. Laurent et al[17] concluded that Biodentine induces reparative dentin synthesis by modulating pulp cells to secrete transforming growth factor-β 1 and stimulate human dental pulp mineralization.[17] Han and Okiji[18] compared calcium and silicon uptake by adjacent root canal dentin in the presence of phosphate buffered saline using Biodentine and MTA and concluded that thickness of the Ca- and Si-rich layer was significantly larger in Biodentine and dentin element uptake was greater for Biodentine as compared with MTA.[18] Another very attractive property of Biodentine is the inhibition of microorganisms and disinfection of surroundings which is accomplished by release of

calcium hydroxide ions during setting phase that increase the pH and cause the basification which inhibits microbial growth. The potential for application for such a material is immense, including crown and root dentin repair treatment, repair of perforation, apexification, restorations, pulp therapy and root-end fillings.[19]

There is plenty of choice of root-end filling materials, be it calcium hydroxide or the universally accepted MTA; however, newer materials, especially EndoSequence, BioAggregate and Biodentine, have given enough evidence to suggest that they are the materials of future as they have shown encouraging strength, minimal leakage and vastly improved biocompatibility.

REFERENCES

1. Glickman GN, Hartwell GR. Endodontic surgery. In: Ingle JI, Bakland LK, Baumgartner JC, editors. Ingle's endodontics. 6th ed. Chapter 33. Hamilton: BC Decker Inc; 2008. p. 1261-1294.
2. Duda S, Dammaschke T. Maßnahmen zur Vitalerhaltung der Pulpa. Gibt es Alternativen zum Kalziumhydroxid bei der direkten Überkappung? Quintessenz 2008;59:1327-1334.
3. Nair PN, Duncan HF, Pitt Ford TR, Luder HU. Histological, ultrastructural and quantitative investigations on the response of healthy human pulps to experimental capping with mineral trioxide aggregate: a randomized controlled trial. Int Endod J 2008 Feb;41(2):128-150.
4. Williams SS, Gutmann JL. Periradicular healing in response to Diaket root-end filling material with and without tricalcium phosphate. Int Endod J 1996 Mar;29:84-92.
5. Ma J, Shen Y, Stojicic S, Haapasalo M. Biocompatibility of two novel root repair materials. J Endod 2011 Jun;37(6): 793-798.
6. Alanezi AZ, Jiang J, Safavi KE, Spangberg LS, Zhu Q. Cytotoxicity evaluation of endosequence root repair material. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010 Mar;109(3):e122-e125.
7. Damas BA, Wheater MA, Bringas JS, Hoen MM. Cytotoxicity comparison of mineral trioxide aggregates and EndoSequence bioceramic root repair materials. J Endod 2011 Mar;37(3):372-375.
8. Hirschberg CS, Patel NS, Patel LM, Kadouri DE, Hartwell GR. Comparison of sealing ability of MTA and EndoSequence Bioceramic root repair material: a bacterial leakage study. Quintessence Int 2013 May;44(5):e157-e162.
9. Grech L, Mallia B, Camilleri J. Characterization of set intermediate restorative material, Biodentine, Bioaggregate and a prototype calcium silicate cement for use as root-end filling materials. Int Endod J 2013 Jul;46(7):632-641.
10. Leal F, De-Deus G, Brandão C, Luna AS, Fidel SR, Souza EM. Comparison of the root-end seal provided by bioceramic repair cements and white MTA. Int Endod J 2011 Jul;44(7):662-668.
11. El Sayed M, Saeed M. In vitro comparative study of sealing ability of Diadent BioAggregate and other root-end filling materials. J Conserv Dent 2012 Jul;15(3):249-252.
12. Yan P, Yuan Z, Jiang H, Peng B, Bian Z. Effect of bioaggregate on differentiation of human periodontal ligament fibroblasts. Int Endod J 2010 Dec;43(12):1116-1121.
13. Yuan Z, Peng B, Jiang H, Bian Z, Yan P. Effect of bioaggregate on mineral-associated gene expression in osteoblast cells. J Endod 2010 Jul;36(7):1145-1148.
14. Saxena P, Gupta S, Newaskar V. Biocompatibility of root-end filling materials: recent update. Restor Dent Endod 2013 Aug;38(3):119-127.
15. Pérard M, Le Clerc J, Meary F, Pérez F, Tricot-Doleux S, Pellen-Mussi P. Spheroid model study comparing the biocompatibility of Biodentine and MTA. J Mater Sci Mater Med 2013 Jun;24(6):1527-1534.
16. Pradelle-Plasse N, Tran XV, Colon P. VI-2-1 Physico-chemical properties. In: Goldberg M, editor. Biocompatibility or cytotoxic effects of dental composites. Coxmoor: Oxford; 2009. p. 184-194.
17. Laurent P, Camps J, De Méo M, Déjou J, About I. Induction of specific cell responses to a Ca_3SiO_5-based posterior restorative material. Dent Mater 2008 Nov;24(11):1486-1494.
18. Han L, Okiji T. Bioactivity evaluation of three calcium silicate-based endodontic materials. Int Endod J 2013 Sep;46(9):808-814.
19. Grech L, Mallia B, Camilleri J. Characterization of set intermediate restorative material, Biodentine, Bioaggregate and a prototype calcium silicate cement for use as root-end filling materials. Int Endod J 2013 Jul;46(7):632-641.

Nikhil Marwah
Editor-in-Chief