Mineral trioxide aggregate (MTA) was developed for use as a dental root repair material by Dr. Mahmoud Torabinejad, it is based on portland cement combined with bismuth dioxide powder for radiopacity. MTA is used for creating an apical plug during apexification, repairing root perforations during root canal therapy and treating internal root resorption and can be used as both a root-end filling material and pulp-capping material. Originally, MTA was dark gray in color, but white versions have been on the market since 2002.

MTA is composed of 1. tricalcium silicate, 2. dicalcium silicate, 3. tricalcium aluminate, 4. tetracalcium aluminoferrite, 5. calcium sulfate and 6. bismuth oxide. The later 4 phases vary among the commercial products available.

Newly developed fast set MTAs were developed by Pozzolan Cement or Zeolite Cement. These were used by pozzolanic reaction. Pozzolan Cement is a mineral aggregate with watery calcium silicate hydration.

Components (phases) in MTA

Tricalcium silicate $(CaO)_3.SiO_2$

Dicalcium silicate $(CaO)_2.SiO_2$

Tricalcium aluminate $(CaO)_3.Al_2O_3$

Tetracalcium aluminoferrite $(CaO)_4.Al_2O_3.Fe_2O_3$

Gypsum $CaSO_4 \cdot 2\ H_2O$

Bismuth oxide Bi_2O_3

Characteristics Biocompatible with periradicular tissues

1. Non cytotoxic to cells, but antimicrobial to bacteria
2. Non-resorbable
3. Minimal leakage around the margins.
4. Very basic AKA alkaline (high pH when mixed with water).
5. As a root-end filling material MTA shows less leakage than other root-end filling materials, which means bacterial migration to the apex is diminished.
6. Treated area needs to be infection free when applying MTA, because an acidic environment will prevent MTA from setting.
7. Compressive strength develops over a period of 28 days, similar to Portland cement. Strengths of more than 50 MPa are achieved when mixed in a powder-to-liquid ratio of more than 3 to 1
8. Originally, MTA products required a few hours for the initial and final setting, which is uncommon in dental materials. Newer materials are available that set more quickly and have added characteristics.

MTA Plus is washout resistant.

In root canal therapy where an apical infection is persistent, an apicoectomy may be required. Flap[is raised over the tooth and the root tip is resected and a cavity created (3–4 mm) in the root tip removed. Retrograde application of MTA to the root tip cavity is completed.

MTA was originally developed for root-end filling. There were several different materials such as amalgam, reinforced zinc oxide eugenol cements (interim restorative material - IRM), super ethoxy benzonic acid [EBA], glass ionomer cement and composite resin for root-end filling after apicoectomy. MTA, a refined "Portland cement" - calcium alumino-silicate cement-, was found to have less cytotoxic and better results in biocompatibility and micro-leakage sealing ability, giving it more success over root-end filling materials. But MTA is not acceptable as "ideal root-end filling material" because MTA has some drawbacks of toxic heavy metal presence, discoloration, difficult handling, short working time, long setting time, washout before setting and washout after set (calcium carbonate based MTA has solvent of carbonic acid).

For ideal Root-end filling, there are many new materials or improved materials developed.

1. Glass ionomer cement: It is based on alumino-silicate based bioceramic material. Most cytotoxicity is caused by polyacrylic acid. So current GIC as root-end filling material is reducing the cytotoxic acclerator's concentration. - calcium alumino-silicate - MTA (calcium alumino-silicate) + GIC (alumino-silicate), calcium reinforced glass ionomer cement is developed. It's a promising material.

2. Calcium phosphate cement (hydroxyapatite) bioceramic material: CPC has been studied since 1985 in the US. Bone grafting material, artificial bioceramic CPC is developed for Root-end filling or pilot material in root-end filling and root repair material.

3. Calcium silicate based material - bioceramic material: It was known as bioceramic sealers. But actual bioceramic aggregates are composed of pure medical graded calcium silicate based material.

4. Calcium aluminate bioceramic material - (alumina cement in minerals, calcium aluminate cements in bioceramics) Alumina is an initial fast setting element and high compressive strength. It has been used as dental products as luting agent. Calcium aluminate cement (bioceramic) has been developed for dental products and root-end filling material.

These newly developed root-end filling materials are based on bioceramic, chemically bonded ceramic, not by mineral (ceramic in nature) like MTA. Even if mineral shows higher biocompatibility, minerals have potential toxic heavy metals in material. Bioceramic or bioMaterial is used for medical and dental products. BioMaterials can reduce the issues on discoloration and toxic heavy metals' presence initially.

Indications:

Direct pulp capping

Repair of perforations (at the bottom of endodontic cavity, perforations of root, filling of widely open apex)

Management of resosptions

Apexification - in non vital teeth (plug od MTA placed apically)

Filling material in endodontic surgery.

The powder is mixed with sterile water to initiate the setting reaction.

Examples of practical applications:

Internal & external root resorption & obturation

In internal resorption: ¨

RCT is performed, putty mixture of MTA is inserted in the canal using pluggers to the level of the defect. Gutta percha and root canal sealer are placed above the defect to complete the root canal treatment. In direct cases, the canal may be completely obturated with MTA. The MTA will provide structure and strength to the tooth by replacing the resorbed tooth structure. In external resorption: fter root canal therapy is performed. Flap is raised over the tooth and the defect removed from the root surface with a round bur. Retrograde application of MTA to the root surface is then completed.

Lateral or furcation perforation

Lateral perforation occurs when an instrument has perforated the root during cleaning & shaping of the canal by the dentist. If it happens, one should finish cleaning & shaping of the canal, irrigate the canal with sodium hypochlorite to disinfect it and dry it with a paper point. The perforation can be sealed with a thick mixture of an MTA-type product, preventing bacterial ingress. Make sure that you can locate the canal while the MTA has not set and remove the excess material from the area.

MTA is also indicated for perforation repairs that are below the crest of the bone. It will not work for perforations that are exposed to the oral cavity. That is because MTA does not bond to tooth structure, and takes about 7 hours to set, so it can be easily washed out. Glass-ionomer based materials are better for these cases. The material can also be dislodged even after it has set. That's why after a perforation repair has been made, it's best to leave the filling alone, and just place the build up material over it, without disturbing the MTA.

Apexification (Necrotic pulp)

When the root is incompletely formed in adolescents and an infection occurs, apexification can be performed to maintain the tooth in position as the roots develop. In case of non-vital pulp: 1. Isolate the tooth with a rubber dam 2. perform root canal treatment. 3. Mix MTA and insert it to the apex of the tooth, creating a 3 mm thickness of plug. 5. Fill the canal with sealer and gutta percha. Alternatively, revascularization techniques are being used where an

antibiotic is locally administered. Later a blood clot is formed in the canal and a coronal plug of MTA is placed.

Apexogenesis (Vital pulp)

The process of maintaining pulp vitality during pulpal treatment to allow continued development of the entire root (apical closure occurs approximately 3 years after eruption). 1. Isolate the tooth with a rubber dam 2. Perform a pulpotomy procedure. 3. Place the MTA material over the pulp and close the tooth with temporary cement until the apex is completely formed.

MTA can be used in a one step or a two step approach. It can be used as a powder or a Wet Mix. However a study found that all these approaches have shown to be equally effective.

Pulp capping[edit]

In case of mechanical exposure that occurs during cavity preparation and not a pathological exposure due to caries. Proper isolation should be completed using a rubber dam and cotton pellet. Disinfection of the cavity with sodium hypochlorite. then application of MTA over the exposure area. restoration of the cavity with amalgam or composite is done. MTA provides a higher incidence and faster rate of reparative dentin formation without the pulpal inflammation.

MTA Plus material is also indicated for base and liner in vital pulp therapy. In root-end filling after apicoectomy, the anti-washout agent (chitosan or gelatin) is useful to prevent from MTA washout. But in vital pulp therapy, anti-washout gel doesn't increase bioactivity or bacterial tight sealing ability of MTA. Instead, hydraulic (100% pure water) MTA shows the higher success rate than anti-washout gel or resin medium. Resin Modified MTA or Calcium Silicate Cement was marketed already. TheraCal LC is HEMA-free resin modified calcium silicate cement (MTA-like, Portland cement Type III) light-curable for base and liner in vital pulp therapy.

Literature review:

Mineral Trioxide Aggregate Review
Download a 200 page review HERE

MTA is nothing but in fact only portland cement that is available in your hardware shop, can we use it in our cases ? CLick on the link to read more and download papers on this topic. Use of Portland cement instead of MTA

Comparison of the root-end seal provided by bioceramic repair cements and White MTA, IEJ 44, 662–668, 2011
Leal et al. – Aim To compare the ability of Ceramicrete, BioAggregate and white ProRoot MTA (mineral trioxide aggregate) to prevent glucose leakage through root-end ?llings. There was a signi?cant difference between the three materials (anova, $P < 0.05$). Ceramicrete had signi?cantly lower glucose penetration than BioAggregate (Tukey, $P < 0.05$). There was no difference between the two bioceramic cements and white MTA ($P > 0.05$). On the basis of

the present laboratory study, it was possible to observe that bioceramic based endodontic repair cements Ceramicrete and BioAggregate had a similar ability to white ProRoot MTA in preventing glucose leakage as root-end fillings and that Ceramicrete provided signficant better results than BioAggregate. FULL PAPER

A histological study of pulp reaction to various water/powder ratios of white mineral trioxide aggregate as pulp-capping material in human teeth: a double-blinded, randomized controlled trial. IEJ,44: no. doi: 10.1111/j.1365-2591.2011.01916.x
Shahravan A et al. – There were no significant differences in the diameter, morphology and continuity of the calcified bridges, intensity and type of inflammation or presence of necrosis in the pulps covered by mineral trioxide aggregate (MTA) with various water/powder ratios. Two teeth failed to display a calcified bridge, and one had a pulp necrosis. Water–to–powder ratios of MTA had no significant influence on the histological outcome of direct pulp capping on healthy pulps.

Treatment of Tooth Discoloration after the Use of White Mineral Trioxide Aggregate:(J Endod 2011;37:1017–1020)
A partial pulpotomy was performed with the use of WMTA after a complicated crown fracture of the upper right central incisor. Seventeen months later, the WMTA was removed because of tooth discoloration, and internal bleaching was performed. Results:Upon access, the WMTA was completely discolored.After it was removed, a signi?cant color change was observed in the tooth crown, which was further improved with internal bleaching. The tooth remained vital, and a dentin bridge was con?rmed clinically and radiographically. Conclusions: The recommendation to use WMTA for vital pulp therapy in the esthetic zone may need to be reconsidered. Should discoloration occur with the use of WMTA, the technique described may be used to improve the esthetics.

Surgical repair of root perforation caused by an orthodontic miniscrew implant, AJODO Pages 407-411, March 2011
Root damage is a significant complication of orthodontic miniscrew implant placement. Although root damage is rare, its proper management should be clearly understood by practitioners. This article reports the iatrogenic root perforation of a mandibular lateral incisor caused by the placement of a miniscrew. Despite a large radiolucent area caused by chronic apical periodontitis, the perforation was successfully repaired by using a recently developed material, mineral trioxide aggregate. The treatment, clinical implications, and clinical guidelines for preventing root damage during miniscrew placement in orthodontic practice are discussed. Read full Paper

Portland cement: A Building of Evidence for Clinical Use Int J of DC Jan.2011
Mineral trioxide aggregate (MTA), has been successfully used in difficult endodontic situations such as immature pulp less teeth and vital pulp therapy. Portland cement (PC), which forms the bulk of MTA, has been reported to exhibit similar properties. The physical properties and biocompatibility of PC has been researched in vitro and on animals, with a few studies on humans as well. This article reviews the potential for clinical use of PC along with the existing drawbacks and concerns with the material. Read full Paper

Physical and chemical properties of new-generation endodontic materials., Volume 36, Issue 3 , Pages 524-528, March 2010

INTRODUCTION: Mineral trioxide aggregate (MTA), white and gray, has many uses in endodontic therapy but is limited by its difficult handling characteristics. This study compared the physical and chemical properties of white MTA (WMTA) with three experimental root-end filling materials: Capasio (Primus Consulting, Bradenton, FL), Ceramicrete-D (Tulsa Dental Specialties/Argonne National Laboratory, Argonne, IL), and Generex-A (Dentsply Tulsa Dental Specialties, Tulsa, OK).

METHODS: The setting time and radiopacity were tested using International Organization for Standardization (ISO) 6876 methods. Compressive strength was measured following the ISO 9917 method. The pH of the materials was measured after mixing. A novel test was developed for washout resistance of the materials immediately after placement. Data were compared by analysis of variance and Sidak post hoc analysis ($p<0.05$) for compressive strength and washout resistance.

RESULTS: The setting time of Generex-A was half that of WMTA. All materials met the ISO 6876 requirements for radiopacity. The compressive strengths after 7 days decreased in this order: Generex-A>Capasio>WMTA>Ceramicrete-D. The initial pH of Capasio and Generex-A were alkaline, similar to WMTA, whereas that of Ceramicrete-D was acidic. Significantly, alternative materials remained in situ after the washout test, whereas WMTA was displaced from the retropreparations.

CONCLUSIONS: The clinical handling and washout resistance of the alternative materials were far superior to WMTA. The radiopacity, compressive strength, and washout resistance make Generex-A and Capasio materials suitable for further study. Ceramicrete-D was weaker, less radiopaque, and initially acidic.

Repair of Furcal Iatrogenic Perforation with Mineral Trioxide Aggregate: Two Years Follow-up of Two Cases, Gul Celik Unal et al, Eur J Dent 2010;4:475-481

Furcal perforation is usually an undesired complication that can occur during preparation of endodontic access cavities or exploring canal orifice of multirooted teeth. Inadequacy of the repair materials has been a contributing factor to the poor outcome of repair procedures. On the basis of the recent physical and biologic property studies of the relatively new introduced mineral trioxide aggregate, this material may be suitable for closing the communication between the pulp chamber and the underlying periodontal tissues. There are few reports on repair of furcal perforation with MTA in molar teeth. The purpose of this case report was to describe the treatment of two furcal perforation using MTA in molar teeth. The perforations were cleaned with NaOCl and saline solu- tion and sealed with MTA without internal matrix. Finally, the teeth were endodontically treated and coronally restored with composite resin and ceramic veneer crown and bridge. After 2 years, the absence of periradicular radiolucent lesions, pain, and swelling along with functional tooth stability indicated a successful outcome of sealing perforations in two cases. Read full Paper

PULPOTOMIES WITH PORTLAND CEMENT IN HUMAN PRIMARY MOLARS, J Appl Oral Sci. 2009;17(1):66-9

Two clinical cases in which Portland cement (PC) was applied as a medicament after

pulpotomy of mandibular primary molars in children are presented. Pulpotomy using PC was carried out in two mandibular first molars and one mandibular second molar,which were further followed-up. At the 3, 6 and 12-month follow-up appointments, clinical and radiographic examinations of the pulpotomized teeth and their periradicular area revealed that the treatments were successful in maintaining the teeth asymptomatic and preserving pulpal vitality. Additionally, the formation of a dentin bridge immediately below the PC could be observed in the three molars treated. PC may be considered as an effective alternative for primary molar pulpotomies, at least in a short-term period. Randomized clinical trials with human teeth are required in order to determine the suitability of PC before unlimited clinical use can be recommended. Read full Paper

Evaluation of two mineral trioxide aggregate compounds as pulp-capping agents in human teeth, IEJ Jan 2009

Aim The present randomized, controlled prospective study evaluated the histomorphological response of human dental pulps capped with two grey mineral trioxide aggregate (MTA) compounds. Methodology Pulp exposures were performed on the occlusal floor of 40 human permanent pre-molars. The pulp was capped either with ProRoot (Dentsply) or MTA-Angelus (Angelus) and restored with zinc oxide eugenol cement. After 30 and 60 days, teeth were extracted and processed for histological examination and the effects on the pulp were scored. The data were subjected to Kruskal–Wallis and Conover tests (a = 0.05). Results In five out of the 40 teeth bacteria were present in pulp tissue. No significant difference was observed between the two materials ($P > 0.05$) in terms of overall histological features (hard tissue bridge, inflammatory response, giant cells and particles of capping materials). Overall, 94% and 88% of the specimens capped with MTA-Angelus and ProRoot, respectively, showed either total or partial hard tissue bridge formation ($P > 0.05$). Conclusions Both commercial materials ProRoot (Dentsply) and MTA-Angelus (Angelus) produced similar responses in the pulp when used for pulp capping in intact, caries-free teeth..

Mineral trioxide aggregate for obturation of maxillary central incisors with necrotic pulp and open apices

Authors: Pinar Erdem, Arzu; Sepet, Elif

Dental Traumatology, Volume 24, Number 5, October 2008 , pp. e38-e41(1)

There are few reports on treatment of necrotic pulps with mineral trioxide aggregate (MTA) for apexification. Five immature teeth with necrotic pulps were treated with the use of an apical plug of MTA for apexification. All teeth were central incisors that had premature interruption of root development caused by a previous trauma. According to the treatment protocol, the root canals were rinsed with 5% NaOCl; then calcium hydroxide paste was placed in the canals for 1-6 weeks. The apical portion of the canals were filled with MTA. The rest of the canals were obturated with lateral condensation of the gutta-percha applied with a canal sealer. At 6 months, 1 year and 2 year follow-up periods the clinical and radiographic appearance of the teeth showed the resolution of the periapical lesions and continued root end development in all except in the one case in which the MTA was extruded out the apex. MTA can be considered a very effective option for apexification with the advantage of reduced treatment time, good sealing ability and high biocompatibility.

Direct Pulp Capping With Mineral Trioxide Aggregate

JADA Feb 2008 An Observational Study

George Bogen, DDS, Jay S. Kim, PhD and Leif K. Bakland, DDS

Background. Pulp capping in carious teeth has been considered unpredictable and therefore contraindicated. A recently developed material, mineral trioxide aggregate (MTA), resists bacterial leakage and may provide protection for the pulp, allowing repair and continued pulp vitality in teeth when used in combination with a sealed restoration. **Methods.** Forty patients aged 7 to 45 years accepted pulp-capping treatment when they received a diagnosis no more severe than reversible pulpitis after undergoing cold testing and radiographic examination. The primary author removed caries using a caries detector dye and sodium hypochlorite solution for hemostasis and placed MTA over the exposures and all surrounding dentin. The operator then restored the teeth provisionally with unbonded Clearfil Photocore (Kuraray Medical, Okayama, Japan). During a second visit, the operator restored the teeth with bonded composite after sensibility testing and confirmed MTA curing. At recall appointments, patients were evaluated for reparative dentin formation, pulpal calcification, continued normal root development and evidence of pathosis. **Results.** Over an observation period of nine years, the authors followed 49 of 53 teeth and found that 97.96 percent had favorable outcomes on the basis of radiographic appearance, subjective symptoms and cold testing. All teeth in younger patients (15/15) that initially had had open apexes showed completed root formation (apexogenesis). **Conclusions.** MTA can be a reliable pulp-capping material on direct carious exposures in permanent teeth when a two-visit treatment protocol is observed.

1. Witherspoon, D.E. and K. Ham, *One-visit apexification: technique for inducing root-end barrier formation in apical closures.* Pract Proced Aesthet Dent, 2001. 13(6): p. 455-60; quiz 462.

Numerous procedures and materials have been utilized to induce root-end barrier formation. Mineral trioxide aggregate (MTA) was introduced to dentistry as a root-end filling material. It has been advocated for filling root canals, repairing perforations, pulp capping, and root-end induction. Mineral trioxide aggregate reacts with tissue fluids to form a hard tissue apical barrier. As a result, MTA shows promise as a valuable material for use in one-visit apexification treatment, primarily for treating immature teeth with necrotic pulps.

2. Schmitt, D., J. Lee, and G. Bogen, *Multifaceted use of ProRoot MTA root canal repair material.* Pediatr Dent, 2001. 23(4): p. 326-30.

Mineral Trioxide Aggregate (MTA) is a new material recently approved by the FDA for use in pulpal therapy. MTA has been reported to have superior biocompatibility and sealing ability and is less cytotoxic than other materials currently used in pulpal therapy. This report is a review of MTA's physical and biological properties and the clinical techniques of direct pulp capping, apexification, and repair of failed calcium hydroxide therapy.

3. Roda, R.S., *Root perforation repair: surgical and nonsurgical management.* Pract Proced Aesthet Dent, 2001. 13(6): p.467-72; quiz 474.

Root perforation repair has historically been an unpredictable treatment modality with an unacceptably high rate of clinical failure. Recent developments in the techniques and

materials utilized in root perforation repair have dramatically enhanced the prognosis of both surgical and nonsurgical procedures. This article presents a review of the literature pertaining to root perforation repair and illustrates, through clinical case presentations, the principles of extraradicular surgical repair and non-surgical internal repair of root perforation using mineral trioxide aggregate (MTA).

4. O'Sullivan, S.M. and G.R. Hartwell, *Obturation of a retained primary mandibular second molar using mineral trioxide aggregate: a case report.* J Endod, 2001. 27(11): p. 703-5.

This case report demonstrates Mineral Trioxide Aggregate obturation of the root canal system of a retained primary mandibular second molar where no succedaneous permanent tooth was present. The technique seemed to provide a biocompatible seal of the root canal system in this case. It is not recommended for obturation of primary teeth that are expected to exfoliate since it is anticipated that Mineral Trioxide Aggregate would be absorbed slowly, if at all.

5. Koh, E.T., *et al., Prophylactic treatment of dens evaginatus using mineral trioxide aggregate.* J Endod, 2001. 27(8): p. 540-2.

Two case reports with dens evaginatus are presented. Each patient had one tooth affected. There was a prominent tubercle on the occlusal surface of the mandibular second premolar. Under local anesthesia and rubber dam isolation a partial pulpotomy was conducted and mineral trioxide aggregate was placed. After 6 months the teeth were removed as part of planned orthodontic treatment. Histological examination of these teeth showed an apparent continuous dentin bridge formation in both teeth, and the pulps were free of inflammation. These cases show that mineral trioxide aggregate can be used as an alternative to existing materials in the proplylactic treatment of dens evaginatus.

6.Holland, R., *et al., Mineral trioxide aggregate repair of lateral root perforations.* J Endod, 2001. 27(4): p. 281-4.

This study was conducted to observe the healing process of intentional lateral root perforation repaired with mineral trioxide aggregate (MTA). Forty-eight root canals of dogs' teeth were instrumented and filled. After partial removal of the filling, an intentional perforation was made with a bur in the lateral area of the root. The perforations were repaired with MTA or Sealapex (control group). Histological analysis occurred 30 and 180 days after treatment. Results showed no inflammation and deposition of cementum over MTA in the majority of the specimens. In the 180-day period, Sealapex exhibited chronic inflammation in all the specimens and slight deposition of cementum over the material in only three cases. In conclusion, MTA exhibited better results than the control group.

7. Koh, E.T., *Mineral trioxide aggregate (MTA) as a root end filling material in apical surgery--a case report.* Singapore Dent J, 2000. 23(1 Suppl): p. 72-8.

Many root end filling materials for apical surgeries have been identified either for scientific evaluation or clinical usage but none meets the requirements of an ideal root end filling material. Recently a new cement, Mineral Trioxide Aggregate (MTA) was researched as a potential root end filling material and showed promising results. This paper reports the significant findings of research done on MTA as a root end filling material and presents a clinical case where apical surgery was performed using MTA as retrograde filling.

8. Schwartz, R.S., *et al.*, *Mineral trioxide aggregate: a new material for endodontics.* J Am Dent Assoc, 1999. 130(7): p. 967-75.

BACKGROUND: Mineral trioxide aggregate, or MTA, is a new material developed for endodontics that appears to be a significant improvement over other materials for procedures in bone. It is the first restorative material that consistently allows for the overgrowth of cementum, and it may facilitate the regeneration of the periodontal ligament.
CASE DESCRIPTION: The authors present five cases in which MTA was used to manage clinical problems. These included vertical root fracture, apexification, perforation repair and repair of a resorptive defect. In each case, MTA allowed bone healing and elimination of clinical symptoms.
CLINICAL IMPLICATIONS: Materials such as zinc oxide-eugenol cement and resin composite have been used in the past to repair root defects, but their use resulted in the formation of fibrous connective tissue adjacent to the bone. Because it allows the overgrowth of cementum and periodontal ligament, MTA may be an ideal material for certain endodontic procedures.

9. Torabinejad, M. and N. Chivian, *Clinical applications of mineral trioxide aggregate.* J Endod, 1999. 25(3): p. 197-205.

An experimental material, mineral trioxide aggregate (MTA), has recently been investigated as a potential alternative restorative material to the presently used materials in endodontics. Several in vitro and in vivo studies have shown that MTA prevents microleakage, is biocompatible, and promotes regeneration of the original tissues when it is placed in contact with the dental pulp or periradicular tissues. This article describes the clinical procedures for application of MTA in capping of pulps with reversible pulpitis, apexification, repair of root perforations nonsurgically and surgically, as well as its use as a root-end filling material.

10. Behnia, A., H.E. Strassler, and R. Campbell, *Repairing iatrogenic root perforations.* J Am Dent Assoc, 2000. 131(2): p. 196-201.

BACKGROUND: Post preparation is an integral part of restoring endodontically treated teeth in indicated cases. Iatrogenic perforation of the root can result from preparing post space and can severely compromise the prognosis of the tooth.
CASE DESCRIPTION: Two years after a patient's maxillary lateral incisor was restored with a post-retained composite resin, he went to a dental school emergency clinic with a chief complaint of soft-tissue swelling adjacent to the tooth. The authors took a periapical radiograph that revealed evidence of a circumscribed radiolucent lesion associated with the distal midroot area and a periapical radiolucency. Based on the radiograph, the authors suspected that the canal preparation for the post and the post placement had perforated the root at the base of the post.
CLINICAL IMPLICATIONS: The authors used a combined surgical and orthograde approach with a biocompatible restorative material and a clear, plastic light-transmitting post to repair the iatrogenic perforation.

11. Blackler, S.M., *Space maintenance--a review of treatment options to repair the iatrogenic perforation.* Ann R Australas Coll Dent Surg, 2000. 15: p. 252-3.

Management of intra-canal and furcation perforations can pose a significant clinical challenge. In such cases a biological matrix can provide the framework for healing of injured

periodontal tissues and will facilitate placement of the perforation repair material. As a consequence the long-term prognosis for treatment of the iatrogenic perforation can be significantly improved and the need for surgical intervention can often be eliminated.

12. Germain, L.P., *Mineral trioxide aggregate: a new material for the new millennium.* Dent Today, 1999. 18(1): p. 66-7, 70-1.

A midroot strip perforation can be a difficult problem to treat. Surgical treatment is arduous and has a poor prognosis. Variable success has been seen with the classic repair materials for nonsurgical treatment. Mineral trioxide aggregate seems to have incredible promise for sealing these defects with a good long-term prognosis.

13.Bruder, G.A., 3rd, *et al., Perforation repairs.* N Y State Dent J, 1999. 65(5): p. 26-7.

Management of instrument perforations in the periodontal ligament space during endodontic or restorative procedures is an ongoing problem in dentistry. The introduction of microscopes, new instruments and materials has resulted in more controllable and predictable surgical and nonsurgical outcomes. This paper discusses some of the newer techniques and materials used to manage perforations effectively.

14.Arens, D.E. and M. Torabinejad, *Repair of furcal perforations with mineral trioxide aggregate: two case reports.* Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 1996. 82(1): p. 84-8.

Furcal perforation is an unfortunate incident that can occur during root canal therapy or post preparation of multirooted teeth. Studies have shown that the materials currently used to repair these iatrogenic accidents are inadequate. The poor prognosis of furcation perforations is probably due to bacterial leakage or lack of biocompatibility of repair materials. On the basis of the recent physical and biologic property studies of the newly introduced mineral trioxide aggregate, this material may be suitable for closing the communication between the pulp chamber and the underlying periodontal tissues. These case reports support this hypothesis.

15. Valavanis, D.K. and G.N. Spyropoulos, *[Perforation during endodontic treatment].* Hell Stomatol Chron, 1989. 33(1): p. 57-65.

Perforations of the pulp chamber wall and area of root may occur during access opening of the pulp chamber and during root canal instrumentation. The authors in this paper describe in details the factors that can lead to perforations of pulp chamber or area of the root, the treatment and factors that affecting the repair and the prognosis of the perforations.

16.Ford, T.R., *et al., Use of mineral trioxide aggregate for repair of furcal perforations.* Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 1995. 79(6): p. 756-63.

The histologic response to intentional perforation in the furcations of 28 mandibular premolars in seven dogs was investigated. In half the teeth, the perforations were repaired immediately with either amalgam or mineral trioxide aggregate; in the rest the perforations were left open to salivary contamination before repair. All repaired perforations were left for 4 months before histologic examination of vertical sections through the site. In the immediately repaired group, all the amalgam specimens were associated with inflammation,

whereas only one of six with mineral trioxide aggregate was; further, the five noninflamed mineral trioxide aggregate specimens had some cementum over the repair material. In the delayed group, all the amalgam specimens were associated with inflammation; in contrast only four of seven filled with the aggregate were inflamed. On the basis of these results, it appears that mineral trioxide aggregate is a far more suitable material than amalgam for perforation repair, particularly when used immediately after perforation.