# Comparison of Apexification With Mineral Trioxide Aggregate and Calcium Hydroxide

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## Abstract

**Purpose:** The aim of this study was to compare mineral trioxide aggregate (MTA) with calcium hydroxide [Ca(OH)2] clinically and radiographically as materials used to induce root-end closure in necrotic permanent teeth with immature apices (apexification).
**Methods:** Fifteen children, each with at least 2 necrotic permanent teeth requiring root-end closure (apexification), were selected for this study. All selected teeth were evenly divided into 2 test groups. In group 1, the conventional calcium hydroxide apexification (control) was performed, whereas in group 2, the MTA apexification (experimental) was done. The children were recalled for clinical and radiographic evaluations after 3, 6, and 12 months.
**Results:** The follow-up evaluations revealed failure due to persistent periradicular inflammation and tenderness to percussion detected at 6 and 12 months postoperative evaluation in only 2 teeth treated with Ca(OH)2. The remaining 13 teeth appeared to be clinically and radiographically successful 12 months postoperatively. None of the MTA-treated teeth showed any clinical or radiographic pathology.
**Conclusions:** Mineral trioxide aggregate showed clinical and radiographic success as a material used to induce root-end closure and is a suitable replacement for calcium hydroxide for the apexification procedure. (Pediatr Dent 2006;28:248-253)


**KEYWORDS:** MINERAL TRIOXIDE AGGREGATE, CALCIUM HYDROXIDE, APEXIFICATION

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Root-end closure, also known as apexification, is defined as the process of creating an environment within the root canal and periapical tissues after pulp death that allows a calcific barrier to form across the open apex. This barrier has been characterized as dentin, cementum, bone, and osteodentin. The result is blunting of the root end and very little, if any, increase in root length.[1]

Numerous procedures and materials have been recommended to induce root-end closure in teeth with immature apices. These procedures include:

1. no treatment[2];
2. infection control[3];
3. induction of a blood clot in the periradicular tissue[4];
4. antibiotic pastes[5]; and
5. calcium hydroxide mixed with various materials.[6]

Calcium hydroxide [$Ca(OH)_2$] has become the material of choice for apexification; it is bactericidal with an alkaline pH that may be responsible for stimulating apical calcification.[7]

Despite its popularity for the apexification procedure, $Ca(OH)_2$ therapy has some inherent disadvantages, including variability of treatment time, unpredictability of apical closure, difficulty in patient follow-up, and delayed treatment.[8] Also, it has some tissue altering and dissolving effects.[9] Therefore, the search continues for procedures and materials that may allow for more natural continued apical closure in teeth with immature apices.

The US Food and Drug Administration approved mineral trioxide aggregate (MTA) in 1998 as a therapeutic endodontic material for humans.[10-12] MTA has been shown to have superior sealing ability to amalgam, zinc oxide eugenol (ZOE), intermediate restorative material (IRM), and super-ethoxybenzoic acid (EBA).[13-16] MTA has also been shown to have superior characteristics as a direct pulp capping agent when compared to $Ca(OH)_2$ in animals and humans.[17-19]

The biocompatibility of MTA has been found to be equal or superior to amalgam, IRM, and ZOE.[17,20,21,22] In a histologic study of perforation repair using MTA in the canine model, cementum was shown to grow over the MTA with minimal inflammation present, even when the material

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is extruded beyond the perforation site.[23]

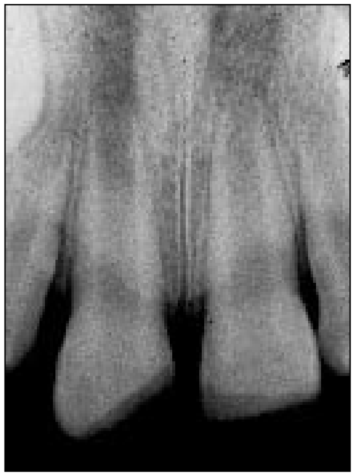

Figure 1. Preoperative periapical radiograph showing traumatized maxillary central incisors with open apices.

Human osteoblasts were studied in vitro, and it was found that MTA stimulated the release of cytokines and the production of interleukin.[24] The material has also been shown to have antimicrobial properties similar to that of amalgam, ZOE, and super EBA.[25,26] MTA has been found to have low cytotoxicity when compared with IRM and super EBA.[27,28]

MTA has been demonstrated to have diverse applications for all fields of dentistry. These indications include direct pulp capping, repair of internal resorption, root end filling, apexification, repair of root perforations, and pulpotomy.[29,30] In all cases, MTA allowed bone healing and elimination of clinical symptoms. It was also found that MTA induced hard tissue formation more often than did $Ca(OH)_2$.[31] MTA showed very high clinical and radiographic success rates as a root end filling material in immature permanent teeth.[32-34] The authors suggest that MTA may be a suitable replacement for $Ca(OH)_2$ for apexification in immature roots.

MTA is marketed as ProRoot (Dentsply Tulsa Dental, Tulsa, Okla), which comes in a box of 1-gram packets with a carrier at a cost of approximately $300. According to Tulsa Dental, each packet is intended for one-time use only. If a treatment procedure requires only a small amount of MTA to be utilized, however, it is recommended that the unused portion can be stored for future use in sterilized empty film canisters, preventing hydration. The manufacturer's guidelines recommend that MTA should be mixed with the ProRoot liquid microampules (sterile water) included with the MTA packets. The material can be placed in the tooth with the Tulsa carrier, an amalgam carrier, Messing gun, or a hand instrument.[29]

More recently, white ProRoot (white MTA) root canal repair material was introduced as an esthetic improvement over the original material (gray MTA) for placement in anterior teeth. The major components of white MTA are tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium sulfate dehydrate, and bismuth oxide.[35] The cement's setting time is 3 to 4 hours, and its compressive strength after setting is 70 MPa—comparable to that of IRM.[17]

The objective of this study was to compare mineral trioxide aggregate with calcium hydroxide clinically and radiographically as a root-end barrier in necrotic permanent teeth with immature apices.

## Methods

This study was carried out on 30 traumatized or carious necrotic immature permanent teeth of 15 children ranging from 6 to 12 years old (24 maxillary central incisors and 6 maxillary lateral incisors equally distributed in the 2 groups). Each child had at least 2 qualifying necrotic teeth, and none of the teeth had received previous treatment for necrosis. These children were selected from the Pediatric Dental Clinic at the Faculty of Dentistry, Alexandria University, Alexandria, Egypt, and they were invited for treatment over a period of 12 months. The children were healthy and cooperative. Prior to treatment, an appropriate informed consent was obtained from the parents. This study was conducted in compliance with all policies of appropriate patient care at Alexandria University.

The apexification criteria were those of Walton and Torabinejad[1]:

1. immature teeth with pulp necrosis;
2. teeth must be ultimately restorable;
3. no vertical or horizontal root fractures;
4. no radiographic evidence of replacement resorption (ankylosis);
5. root length must be approximately half or more established; and
6. teeth were selected only in subjects free from any systemic diseases.

The sample included 24 necrotic teeth as a result of previous trauma (concussion or subluxation with or without crown fracture) and 6 necrotic teeth as a result of caries. Both etiologies were not present in any of the teeth. Preoperatively, there were no signs of pathological resorption or purulent exudate associated with the teeth. The teeth "felt different" or were somewhat sensitive to percussion. Additional diagnostic procedures to confirm necrosis included assessments of color, mobility, thermal pulp tests, and preoperative radiographs. Necrosis was confirmed finally after entering the teeth for treatment.

Figure 2. Three-month postoperative periapical radiograph of the same teeth shown in Figure 1. The maxillary right central incisor was treated with MTA and the maxillary left central incisor was treated with calcium hydroxide. The teeth are showing no signs of failure.

Preoperative periapical radiographs of the teeth considered for treatment in the study were made using the XCP (Dentsply Rinn, Elgin, Ill) extension cone paralleling technique.[36] The selected teeth were randomly assigned and divided into 2 test groups according to the material used for root-end closure. Group 1 included 15 teeth treated with

$Ca(OH)_2$ (control group). Group 2 included 15 teeth treated with MTA (experimental group).

The treatments were distributed randomly to each of 2 teeth so that each child would receive 2 different treatments. For both groups, the following technique was followed[1]:

1. After isolation, a large access was made to allow removal of all necrotic tissue.
2. The remaining necrotic pulp tissue was then removed by inserting, rotating, and withdrawing a large barbed broach or a large Hedstrom file.
3. Working length was determined slightly short of the radiographic apex.
4. Instrumentation was performed with a gentle circumferential filing motion, beginning with a relatively large file and progressing up through the file sizes. The aim was to maximize cleansing, aided by copious irrigation with sodium hypochlorite and to minimize dentin removal. Instrumentation beyond the apices was avoided.
5. Large sterile paper points or cotton rolled on a broach were used to dry the canal.

For group I, $Ca(OH)_2$ powder was mixed with saline to form a stiff paste. The paste was then placed into the canal with an amalgam carrier. The canal was filled to the working length with the paste. The $Ca(OH)_2$ placement was radiographically examined. The seal was completed with a layer of fortified zinc oxide eugenol cement (IRM).

For group 2, to disinfect the root canal, a $Ca(OH)_2$ paste was placed in the root canal for 1 week, as recommended by Giuliani et al.[32] After rinsing $Ca(OH)_2$ from the canal, a mixture of MTA powder with sterile water was carried into the canal with an amalgam carrier. The mix was condensed to the apical extent using pluggers. The MTA placement was radiographically examined. A moist cotton pellet was then placed over the material, and the access cavity was closed with fortified zinc oxide-eugenol cement (IRM). After a week, the IRM and the cotton pellet were removed to confirm the set of the MTA. The teeth were resealed with IRM. The same operator provided these treatments to all 15 patients in this study.

The children were recalled for clinical and radiographic evaluations after 3, 6, and 12 months. Two examiners, who were blinded to treatment type, evaluated the teeth clinically and radiographically. The examiners were faculty colleagues from the Department of Pediatric Dentistry and Public Health, Alexandria University.

Clinically, the treatment was considered successful for both groups if there were no of signs or symptoms of periapical disease. Radiographically, the treatment was considered successful for group 1 [$Ca(OH)_2$] if there was evidence of calcific barriers across the root apices. If there was no apparent radiographic change but a positive stop was found in the apical area of each tooth during endodontic re-entry, the tooth was scored as a radiographic success. For group 2 (MTA), the treatment was considered successful if there was radio-graphic evidence of calcific barriers across the root apices. The clinical and radiographic data for the 2 groups were statistically analyzed using the chi-square test.

Figure 3. Six-month postoperative periapical radiograph of the same 2 teeth considered to be successful.

## Results

All 30 teeth were available for examination at each of the 3-, 6-, and 12-month evaluations. The results of this work are divided into clinical and radiographic findings.

### Clinical findings

Table 1 presents the clinical findings of the 2 groups at each follow-up period. After 3 months, no clinical signs or symptoms of failure were observed in any of the 2 groups. After 6 months, 2 teeth in group 1 [$Ca(OH)_2$] complained of tenderness to percussion, while no signs of failure were observed in group 2 (MTA). After 12 months, tenderness to percussion persisted in the same 2 teeth of group 1, even though they had been retreated after their 6-month evaluations. All other group 1 teeth remained free of adverse signs or symptoms. All group 2 teeth also remained free of any clinical signs and symptoms at the 12-month evaluation visits. At the end of the study, 2 cases in group 1 were considered to be clinical failures.

**Table 1. Clinical Findings of the 15 Teeth in Each Group**

| Post-treatment interval (mos) | Clinical findings* | | | | | |
|---|---|---|---|---|---|---|
| | No pain | | No tenderness to percussion | | No swelling or fistula | |
| | Group 1 | Group 2 | Group 1 | Group 2 | Group 1 | Group 2 |
| 3 | 15 | 15 | 15 | 15 | 15 | 15 |
| 6 | 15 | 15 | 13 | 15 | 15 | 15 |
| 12 | 15 | 15 | 13† | 15 | 15 | 15 |

*Group 1=calcium hydroxide apexification; group 2=mineral trioxide aggregate apexification.
†The same 2 teeth failed the 6-month evaluation.

### Radiographic findings

Table 2 records the radiographic findings of the 2 groups during the follow-up periods. After 3 months, no significant radiographic findings were observed in any teeth from the 2 groups. After 6 months, 2 teeth in group 1 showed widening of lamina dura and periapical radiolucencies and the teeth were retreated (same 2 teeth mentioned as failures in the clinical findings aforementioned). No signs of failure were observed in group 2 after 6 months. After 12 months, persistent periapical abnormalities were evident in the same 2 teeth of group 1 that were observed after 6 months. All group 2 teeth showed normal periapical conditions. At the end of the study, 2 teeth in group 1 were considered to be radiographic failures.

Figure 4. Twelve-month postoperative periapical radiograph of the same 2 teeth—both of which were considered successful.

Eight successfully treated teeth in group 1 required re-entry to verify an apical stop at the end of the study, while 5 treated teeth in the same group were considered successful by the visible evidence of a calcific barrier across each root apex, as observed on the radiographs. Four group 1 teeth were found to be slightly overfilled with $Ca(OH)_2$, but no other adverse effects occurred in these teeth. Each tooth scored as a success in group 1 also had a positive apical stop to facilitate the final endodontic treatment.

### Clinical and radiographic success rates

The clinical and radiographic success rates for the $Ca(OH)_2$ and MTA groups were 87% and 100%, respectively. Figures 1 through 4 show radiographs of one successfully treated tooth for each of the 2 groups (the patient's right side is on the reader's left). Interestingly, the 2 examiners (blinded) reported identical findings both clinically and radiographically. There was no statistically significant difference between the 2 groups, clinically or radiographically, using the chi-square test (chi-square=2.14; $P$=.16).

## Discussion

This study compared the results of 15 MTA-treated teeth with 15 $Ca(OH)_2$-treated teeth, clinically and radiographically, for the apexification procedure during a postoperative period of 12 months. Although the study was carried out on a relatively small sample of immature and necrotic teeth (30) for a relatively short follow-up period (12 months), the results are remarkably consistent at all 3 observation periods. The selected teeth were randomly assigned and divided into 2 groups, according to the material used for apexification. Group 1 included 15 teeth treated with $Ca(OH)_2$ (control group). Group 2 included 15 teeth treated with MTA (experimental group).The children were recalled for clinical and radiographic evaluation after 3, 6, and 12 months.

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.[14,15,17]

$Ca(OH)_2$ was selected as the control apexification dressing because it is still considered by many to be the standard therapeutic material for apexification procedures. Several studies have demonstrated that $Ca(OH)_2$ has a high rate of success for treating necrotic immature permanent teeth.[37-39]

In the present study, the immature permanent teeth treated with MTA showed no adverse clinical or radiographic changes after 12 months. The immature permanent teeth treated with $Ca(OH)_2$ included 2 failures at 6 and 12 months (same 2 teeth). Maroto et al have reported successful apexification with MTA in a tooth that did not respond favorably after 3 years of therapy with $Ca(OH)_2$.[33]

A significant and important problem in the classic apexification technique with $Ca(OH)_2$ is the duration of the therapy, which is from 3 to 21 months.[38] The duration may depend on factors such as size of the apical opening, the traumatic displacement of the tooth, and the repositioning methods used. $Ca(OH)_2$ creates an environment conducive to the formation of an apical barrier formed by osteocementum tissue at the end of the root canal of immature teeth.[40] During the long apexification procedure, the root canal is susceptible to reinfection if the coronal seal fails. In addition, the canal is susceptible to fracture during treatment.[32] A more efficient permanent treatment is preferable to reduce the risk of reinfection that could cause apical periodontitis and inhibit canal closure. The importance of the coronal seal was shown by Tronstad et al.[41] They found the highest success rate in teeth diagnosed with good endodontics and good coronal restorations. The rate decreased by 10% in

**Table 2. Radiographic Findings of the 15 Teeth in Each Group**

| | Radiographic findings* | | | | | |
|---|---|---|---|---|---|---|
| | Normal PDL | | No periapical radiolucency | | No external root resorption | |
| Post-treatment interval (mos) | Group 1 | Group 2 | Group 1 | Group 2 | Group 1 | Group 2 |
| 3 | 15 | 15 | 15 | 15 | 15 | 15 |
| 6 | 13 | 15 | 13 | 15 | 15 | 15 |
| 12 | 13† | 15 | 13† | 15 | 15 | 15 |

*Group 1=calcium hydroxide apexification; group 2=mineral trioide aggregate apexification.
†The same 2 teeth failed the 6-month evaluation.

teeth with good endodontics and poor restorations. In teeth with poor endodontics and good restorations, the success rate dropped even further.

With the MTA apexification technique, a 1-step obturation after short canal disinfection with $Ca(OH)_2$ may be performed. MTA stimulates the formation of a calcific barrier across the root apex. This study's results are similar to other reported studies in which MTA appeared to show good sealing ability, good marginal adaptation, a high degree of biocompatibility, and a reasonable setting time (about 4 hours).[15,16,22,42] As observed in the radiographs from this study, all teeth treated with MTA seemed to show effective filling and sealing of the root canals. When compared with $Ca(OH)_2$, however, MTA is much more expensive and also somewhat more difficult to work with during placement in a root canal. The challenge of working with MTA is primarily due to its naturally sandy consistency when hydrated.[43]

Both clinical and radiographic follow-ups of the teeth treated with MTA showed the absence of clinical symptoms and the formation of new hard tissue in the apical area. These results with MTA seem to be similar to those reported by Torabinejad and Chivian.[17] MTA appeared to be a valid option for apexification and offers the added advantages of durable and complete root canal obliteration during the initial placement of the material. Further studies of apexification with a larger sample size and longer follow-up periods, both clinically and radiographically, would be beneficial and are recommended.

## Conclusions

Based on this study's results, the following conclusions can be made:

1. Mineral trioxide aggregate showed clinical and radiographic success as a material used to induce root-end closure in necrotic immature permanent teeth.
2. MTA is a suitable replacement for calcium hydroxide for the apexification procedure.

## Acknowledgements

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## References

1. Walton RE, Torabinejad M. Management of incompletely formed roots. In: *Principles and Practice of Endodontics*. 3rd ed. Philadelphia, Pa: WB Saunders; 2002:388-404.
2. Lieberman J, Trowbridge H. Apical closure of nonvital permanent incisor teeth where no treatment was performed: Case report. J Endod 1983;9:257-260.
3. Das S. Apexification in a nonvital tooth by control of infection. J Am Dent Assoc 1980;100:880-881.
4. Ham J, et al. Induced apical closure of immature pulpless teeth in monkeys. J Oral Surg 1972;33:438-448.
5. Ball JS. Apical root formation in a non-vital immature permanent incisor. Br Dent J 1964;116:116-117.
6. Frank A. Therapy for the divergent pulpless tooth by continued apical formation. J Am Dent Assoc 1966;72:87-93.
7. Binnie WH, Mitchell DF. Induced calcification in the subdermal tissues of the rat. J Dent Res 1973;52:1087.
8. Shabahang S, Torabinejad M, Boyne PP, Abedi H, McMillan P. A comparative study of root-end induction using osteogenic protein-1, calcium hydroxide, and mineral trioxide aggregate in dogs. J Endod 1999;25:1-5.
9. Andersen M. In vitro solubility of human pulp tissue in calcium hydroxide and sodium hypochlorite. Endod Dent Traumatol 1992;8:104.
10. Dentsply Endodontics. *Materials Safety Data Sheet (MSDS): ProRoot MTA (Mineral Trioxide Aggregate) Root Canal Repair Material*. Tulsa, Okla: Dentsply Endodontics; 2001.
11. Schwartz RS, Mauger M, Clement DJ, Walker WA III. Mineral trioxide aggregate: A new material for endodontics. J Am Dent Assoc. 1999;130:967-975.
12. Torabinejad M, Hong CU, McDonald F, Pitt Ford TR. Physical and chemical properties of a new root-end filling material. J Endod 1995;21:349-353.
13. Torabinejad M, Hong C, Pitt Ford T, Kettering J. Cytotoxicity of four root-end filling materials. J Endod 1995;21:489-492.
14. Pitt Ford T, Torabinejad M, Abedi H, Kariyawasam S. Using mineral trioxide aggregate as a pulp-capping material. J Am Dent Assoc 1996;127:1491-1494.
15. Sluyk S, Moon P, Hartwell G. Evaluation of setting properties and retention characteristics of MTA when used as a furcation perforation repair material. J Endod 1998;24:768-771.
16. Tang HM, Torabinejad M, Kettering J. Leakage evaluation of root-end filling materials using endotoxin. J Endod 2002;28:5-7.
17. Torabinejad M, Chivian N. Clinical applications of mineral trioxide aggregate. J Endod 1999;25:197-205.
18. Faraco Jr IM, Holland R. Response of the pulp of dogs to capping with mineral trioxide aggregate or a calcium hydroxide cement. Dent Traumatol 2001; 17:163-167.
19. Aeinehchi M, Eslami B, Ghanbariha M, Saffar AS. Mineral trioxide aggregate (MTA) and calcium hydroxide as pulp-capping agents in human teeth: A preliminary report. Int Endod J 2003;36:225-231.
20. Mitchell PJ, Pitt Ford TR, Torabinejad M, McDonald F. Osteoblast biocompatibility of mineral trioxide aggregate. Biometerials 1999;20:167-173.
21. Zhu Q, Haglund R, Safari KE, Spangberg LSW. Adhesion of human osteoblasts on root-end filling materials. J Endod 2000;26:404-406.

22. Sousa CJA, Loyola AM, Versiani MA, Biffi JCG, Oliveira RP, Pascon EA. A comparative histological evaluation of the biocompatibility of materials used in apical surgery. Int Endod J 2004;37:738-748.
23. Pitt Ford TR, Torabinejad M, McKendry DJ, Hong CU, Kariyawasam SP. Use of mineral trioxide aggregate for repair of furcal perforations. Oral Surg Oral Med Oral Pathol 1995;79:756-762.
24. Koh ET, McDonald F, Pitt Ford TR, Torabinejad M. Cellular response to mineral trioxide aggregate. J Endod 1998;24:543-547.
25. Torabinejad M, Hong CU, Pitt Ford TR, Kettering JD. Antibacterial effects of some root-end filling materials. J Endod 1995;21:403-406.
26. Al-Nazhan S, Al-Judai A. Evaluation of antifungal activity of mineral trioxide aggregate. J Endod 2003;29:826-827.
27. Osorio RM, Hefti A, Vertucci FJ, Shawley AL. Cytotoxicity of endodontic materials. J Endod 1998;24:91-96.
28. Keiser K, Johnson C, Chad B, David A. Cytotoxicity of mineral trioxide aggregate using human periodontal ligament fibroblasts. J Endod 2000;26:288-291.
29. Schmitt D, Lee J, Bogen G. Multifaceted use of ProRoot MTA root canal repair material. Pediatr Dent 2001;234:326-330.
30. Holan G, Eidelman E, Fucks AB. Long-term evaluation of pulpotomy in primary molars using mineral trioxide aggregate or formocresol. Pediatr Dent 2005;27:129-136.
31. Shabahang S, Boyne PJ, Abedi HR, McMillan P, Torabinejad M. Apexification in immature dog teeth using osteogenic protein-1, mineral trioxide aggregate, and calcium hydroxide. J Endod 1997;23:265.
32. Giuliani V, Baccetti T, Pace R, Pagavino G. The use of MTA in teeth with necrotic pulps and open apices. Dent Traumatol 2002;18:217-221.
33. Maroto M, Barberia E, Planells P, Vera V. Treatment of a non-vital immature incisor with mineral trioxide aggregate (MTA). Dent Traumatol 2003;19:165-169.
34. Hayashi M, Shimizu A, Fbisu S. MTA for obturation of mandibular central incisors with open apices: Case report. J Endodon 2004;30:120-122.
35. Dentsply Tulsa Dental. *Materials Safety Data Sheet (MSDS): White ProRoot MTA Root Canal Repair Material.* Tulsa, Okla: Dentpsly Tulsa Dental; 2001.
36. Rinn Corporation. *Intraoral Radiography With Rinn XCP/BAI Instruments.* Elgin, Ill: Rinn Corporation; 1989.
37. Parashos P. Apexification: Case report. Aust Dent J 1997;42:43-46.
38. Metzger Z, Solomonov M, Mass E. Calcium hydroxide retention in wide root canals with flaring apices. Dent Traumatol 2001;17:86-92.
39. Selden HS. Apexification: An interesting case. J Endod 2002;28:44-45.
40. Leonardo M, et al. Histological evaluation of therapy using a calcium hydroxide dressing for teeth with incompletely formed apices and periapical lesion. J Endod 1993;19:348-352.
41. Tronstad L, Asbjornsen K, Pedersen I, Eriksen HM. Influence of coronal restorations on the periapical health of endodontically treated teeth. Endod Dent Traumatol 2000;16:218-221.
42. Torabinejad M, Smith PW, Kettering JD, Pitt Ford TR. Comparative investigation of marginal adaptation of MTA and other commonly used root-end filling materials. J Endod 1995;21:295-299.
43. Glickman GN, Koch KA. 21st century endodontics. J Am Dent Assoc 2000;131(suppl):39S-46S.

## Abstract of the Scientific Literature

## Attention Deficit Hyperactivity Disorder During Adolescence

The American Academy of Pediatrics developed practice guidelines for diagnosis and treatment of attention deficit hyperactivity disorder (ADHD) among children 6 to 12 years old at a time when it was generally thought that these children would “outgrow” the condition by puberty. Therefore, the guidelines did not include adolescents and young adults. It is now clear that, for as many as 65% of ADHD children, the diagnosis will persist into adolescence. This article reviews changes that occur in the clinical manifestations of ADHD during adolescence (including decreased hyperactivity, socialization issues, and increased comorbid diagnoses), unique challenges to assessment and diagnosis related to increased independence, and treatment of ADHD as a chronic care model. There is a discussion of the transition to college and into adulthood.

**Comments:** This article offers a comprehensive overview of current knowledge regarding the unique clinical presentations, evaluation and treatment modalities for children past puberty who are diagnosed with attention deficit hyperactivity disorder. This article also discusses some of the challenges presented to those who interact with ADHD children, including health professionals and family members. An extensive list of references is included. **GEM**

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**Wolraich ML, et al. Attention deficit hyperactivity disorder among adolescents: A review of the diagnosis, treatment, and clinical implication. Pediatrics 2005;115:1734-1746.**

162 references