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Review Article
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Characteristics of Root Canal Filling Materials for Primary Teeth: A Review of Literature

Nazanin Zargar[a], Yasaman Rezvani[b], Sindokht Babaie[c], Leila Eftekhar[d]

[a]Assistant professor, Dept. of Endodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[b]Assistant professor, Dept. of Pedodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[c]Dentist, Private practice.
[d]Assistant professor, Dept. of Pedodontics, School of Dentistry, Alborz University of Medical Sciences, Karaj, Iran..
Correspondence to Leila Eftekhar (email: Leila.eftekhar.a@gmail.com).
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Objectives Different root canal filling materials show different clinical and radiographic success rates. Since there is controversy on the best root canal filling material in primary dentition, the aim of this study was to summarize information about root canal filling materials for primary teeth in terms of biocompatibility, cytotoxicity, resorption rate, and survival rate.
Methods By searching online databases, studies that addressed biocompatibility, cytotoxicity, resorption, and survival rates of different root filling materials in primary teeth from 1985 to 2020 were evaluated and the required data were extracted. The results were tabulated and compared.
Results Due to methodological discrepancies, different studies show different and sometimes inconsistent results, which make it hard to reach a final conclusion; but it seems that Vitapex and Maisto's paste are more biocompatible and have a good survival rate. Zinc oxide eugenol (ZOE) and calcium hydroxide have lower cytotoxicity among different filling materials. However, due to low resorption rate, ZOE can affect permanent successors.
Conclusion Based on the unique characteristics of each patient, different filling materials may be used for a clinically optimal dental treatment.
Keywords Materials Testing; Tooth, Deciduous; Root Canal Filling Materials; Survival

Introduction

Root canal treatment of primary dentition is performed to preserve the primary teeth diagnosed with hyperemic or necrotic radicular pulp tissue in order to preserve the masticatory function and save the tooth to serve as a natural space maintainer until normal exfoliation.[1] Pulpectomy in primary dentition includes root canal preparation and obturation with a resorbable antibacterial paste. Success of treatment depends on multiple factors such as case selection, biomechanical preparation, root canal filling material, and its manipulation.[2, 3]

Considering the developmental, anatomical, and physiological differences between primary and permanent teeth, root canal filling materials with different properties are required. An ideal root canal filling material for primary teeth should have a resorption rate comparable to that of primary root. Also, considering the close contact of permanent successors with the paste, it should be harmless and biocompatible with the tooth germ and must be resorbed immediately when the roots are overfilled. The root canal filling paste should be antiseptic and have the ability to eliminate the residual anaerobic microorganisms lodged in dentin and cementum at the periapex. Furthermore, it should be easily manipulated and adhere to root canal walls, should not undergo contraction, and must be easily to remove if required. Besides, it must be radiopaque and should not cause tooth discoloration.[4, 5]

Although none of the available materials meet all the above-mentioned criteria, different filling materials are used for primary root canals such as zinc oxide eugenol (ZOE) paste, Endoflas, Metapex, KRI paste, Maisto paste, calcium hydroxide, Vitapex, Diapaste, calcium enriched mixture (CEM) cement, and mineral trioxide aggregate (MTA).[4, 6]

Multiple studies[7-12] have evaluated different filling materials regarding different characteristics such as resorption rate, biocompatibility, clinical and radiographic survival rates, cytotoxicity, antimicrobial activity, biological and physical properties such as viscosity, and possibility of damage to permanent tooth bud. Since there is controversy regarding the best root canal filling material for primary dentition, the aim of this study was to investigate the biocompatibility, cytotoxicity, survival, and resorption rate of different root filling materials including ZOE, Vitapex, MTA, Biodentine, calcium hydroxide, formocresol, Iodoform, KRI paste, CEM cement, and Maisto paste.

Materials and Methods

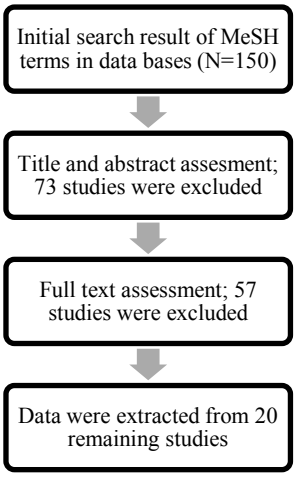
An electronic search was performed in PubMed, Web of Science, Scopus, EMBASE, Cochrane and Medline databases for articles published from 1985 to 2020. The search was based on a pre-specified question using relevant MeSH terms (pulpectomy or "pulp therapy" or "root canal filling" or "endodontic treatment" or "root canal treatment") and ("iodoform Maisto" or Vitapex or "KRI paste" or "root canal filling material" or "ZOE" or "calcium hydroxide" or "MTA" or "CEM cement") and (cytotoxicity or resorption or biocompatibility or survival) and ("deciduous" or "primary teeth"). Descriptive-

observational and interventional studies on humans (4 to 12-year-olds) and animals, in-vitro and cohort studies, case series, case-control studies, and systematic reviews in English or Persian were included. Studies with missing data and duplicates were excluded.

A total of 150 articles were found by searching the keywords in the search engines considering the time period. The title and abstract of the retrieved articles were evaluated by an endodontist and a pediatric dentist, and 77 related articles that met the inclusion criteria (type of article, age of subjects, and relevant content to the research question) were selected for full-text assessment.

After eliminating the studies that compared one filling material with a control group, assessed properties other than biocompatibility, cytotoxicity, survival, and resorption rate, or evaluated materials other than those aimed in this study, and studies with limited access to their full-text, 20 studies were eventually used for data extraction (Table 1).

Table 1- Flowchart of article search process



Results

Cytotoxicity

Of 10 studies[10-19] included in the present review that assessed cytotoxicity, one was an animal study (mice) and reported greater cytotoxicity of iodoform in comparison with ZOE and calcium hydroxide.[18] Among 9 other studies, Pilownic et al.[12] concluded that Vitapex was more cytotoxic than MTA, and MTA was more cytotoxic than ZOE. Huang et al.[19] concluded that ZOE had greater cytotoxicity in comparison with calcium hydroxide and iodoform while Wright et al.[15] stated that ZOE had a less destructive effect than iodoform. In a study conducted by Reddy et al,[16] Maisto paste had greater cytotoxicity in comparison with ZOE. In a study by Pires et al,[11] iodoform had more destructive effects than calcium hydroxide. In a study by Elkhadem and Sami [9] and a study by Dahake et al,[14] Biodentine was less toxic when compared with MTA. In a systematic review and meta-analysis by Smaïl-Faugeron et al,[10] which compared cytotoxicity of MTA, calcium hydroxide, Vitapex, CEM cement, and ZOE, no statistically significant difference was found.

Resorption rate

A total of 9 articles[7, 8, 10, 16, 20-24] comparing the effects of root canal filling materials in terms of resorption rate were included. The only animal study included, stated that calcium hydroxide was resorbed faster than ZOE.[23] Other studies acknowledged faster resorption of Vitapex [8] and Maisto paste [16] in comparison with ZOE. Also, faster resorption of Vitapex in comparison with calcium hydroxide and ZOE was reported by Ozalp et al.[22]

In systematic reviews and meta-analyses by Smaïl-Faugeron et al,[10] and Barcelos et al,[20] no significant differences were noted.

Biocompatibility

Eight articles[7, 10-13, 16, 19, 25] compared different root canal filling materials regarding biocompatibility. An animal study indicated that ZOE was more biocompatible in comparison with calcium hydroxide.[25] In a clinical trial, Maisto paste was more biocompatible than ZOE.[16] In another study, ZOE was more biocompatible than Vitapex [12] while Huang et al. showed different results. They stated that Vitapex and calcium hydroxide were more biocompatible than ZOE.[19] Elkhadem and Sami [9] acknowledged that Biodentine was more biocompatible than MTA. The results of the studies were contradictory on this topic. In a systematic review and meta-analysis, Smaïl-Faugeron et al.[10] showed no statistically significant difference in this regard.

Survival rate:

Of 7 studies [7-10, 19-21, 26] included in this review which compared different root canal filling materials considering the survival rate, the survival rate of Vitapex was more than ZOE [8], or more than iodoform.[19]

A systematic review performed by Coll et al. showed that ZOE was more successful than iodoform.[26] Although in other systematic reviews, no significant differences were observed.[10, 20]

The results obtained from the studies included in the present review are presented in Table 2. Table 3 presents a summary of the findings.

Discussion

Primary teeth with irreversible pulpitis or pulp necrosis should be extracted or subjected to root canal treatment in order to prevent possible damage to permanent successors. Root canal treatment is preferred to prevent negative impacts of premature tooth loss on children's oral health-related quality of life.[27] Different root canal filling materials have been introduced for primary teeth. ZOE was the material of choice until 2009 when the American Academy of Pediatric Dentistry introduced iodoform-based

pastes as suitable alternatives to ZOE.[28,29] Considering the controversial results of available studies, this narrative review was conducted to summarize the information about root canal filling materials of primary teeth regarding four characteristics namely biocompatibility, cytotoxicity, resorption rate, and survival rate.

A systematic review [10] on a large number of articles found no significant difference among different materials regarding these characteristics. Discrepancy in the results of original articles may be attributed to the diversity of definitions for these characteristics, differences in time periods studied, diversity of materials compared, and small sample size and resultantly low power of studies to detect clinically significant effects.

Although the currently available filling materials have marked success rates both clinically and radiographically, none of them can be considered as an ideal root canal filling material. Introducing the best root canal filling material in terms of cytotoxicity seems to require further investigations. However, Biodentine and MTA may be suggested as options with the lowest rate of cytotoxicity, followed by Vitapex, calcium hydroxide, ZOE, and finally Iodoform as an unsuitable option for root canal treatment of primary teeth (Tables 2 and 3).

Table 2- Results of reviewed studies regarding cytotoxicity, resorption rate, biocompatibility, and survival rate of different root canal filling materials for primary teeth

Article	Type	Year	Country	Material	Cytotoxicity	Resorption	Biocompatibility	Survival
Response of stem cells from human exfoliated deciduous teeth (SHED) to three bioinductive materials - An in vitro experimental study [14]	In-vitro	2020	India	Biodentine, MTA	MTA more than biodentine			
A Systematic Review and Meta-Analysis of Nonvital Pulp Therapy for Primary Teeth [26]	Systematic review and meta-analysis	2020	United States	ZOE, Iodoform				ZOE more than Iodoform
Clinical and radiographic evaluation of pulpectomy in primary teeth: a 18-months clinical randomized controlled trial [8]	Clinical trial	2017	China	ZOE, Vitapex		Vitapex faster than ZOE		Vitapex more than ZOE
Cytotoxicity and bioactivity of various pulpotomy materials on stem cells from human exfoliated primary teeth [13]	In-vitro	2017	Spain	Biodentine, MTA	MTA more than Biodentine		Biodentine more than MTA	
Physicochemical and Biological Evaluation of Endodontic Filling Materials for Primary Teeth [12]	In-vitro	2017	Brazil	Vitapex, ZOE, MTA	Vitapex more than MTA, and MTA more than ZOE		Vitapex and MTA less than ZOE	
Comparison of Ferric Sulfate Combined Mineral Trioxide Aggregate Pulpotomy and Zinc Oxide Eugenol Pulpectomy of Primary Maxillary Incisors: An 18-month Randomized, Controlled Trial [21]	Clinical trial	2017	Canada	MTA, ZOE		No significant differences		No significant differences
In vitro toxicity of MTA compared with other primary teeth pulpotomy agents [17]	In- vitro	2016	Saudi Arabia	Calcium hydroxide, formocresol, MTA	Formocresol more than calcium hydroxide and more than MTA			
Evaluation of the genotoxicity and cytotoxicity of filling pastes used for pulp therapy on deciduous teeth using the micronucleus test on bone marrow from mice [18]	In- vitro	2016	Brazil	Iodoform, ZOE, Calcium hydroxide	Iodoform more than ZOE and calcium hydroxide			
Induction of cytotoxicity, oxidative stress and genotoxicity by root filling pastes used in primary teeth [11]	In- vitro	2016	Brazil	Calcium hydroxide, Iodoform	Iodoform more than calcium hydroxide		Calcium hydroxide more than Iodoform	
Pulp treatment for extensive decay in primary teeth [10]	Systematic review and meta-analysis	2014	France	MTA, calcium hydroxide, formocresol, Vitapex, ZOE, CEM	No significant differences	No significant differences	No significant differences	No significant differences
No clear evidence of superiority regarding pulp medicaments in primary molars [9]	Systematic review and meta-analysis	2014	Egypt	MTA, calcium hydroxide, formocresol				MTA more than calcium hydroxide
ZOE paste pulpectomies outcome in primary teeth: a systematic review [20]	Systematic review	2011	Brazil	Vitapex, ZOE		No significant differences		No significant differences

Continuation of Table 2								
Subcutaneous connective tissue response to primary root canal filling material[23]	In- vitro	2011	Brazil	Calcium hydroxide, ZOE		Calcium Hydroxide faster than ZOE		
Formocresol versus Calcium Hydroxide Direct Pulp Capping of Human Primary Molars: Two Year Follow-Up[7]	Clinical trial	2010	Iran	Calcium hydroxide, Formocresol		Calcium Hydroxide faster than Formocresol	Formocresol more than calcium hydroxide	
Biocompatibility of various formula root filling materials for primary teeth[(19)]	In- vitro	2007	Taiwan	Calcium hydroxide, ZOE, iodoform, formocresol, Vitapex	ZOE more than Vitapex, Iodoform and calcium hydroxide		Vitapex and calcium hydroxide more than Zoe and Iodoform	Vitapex more than ZOE and Iodoform
Evaluation of various root canal filling materials in primary molar pulpectomies: an in vivo study[22]	In vivo	2006	Turkey	Vitapex, Calcium hydroxide, ZOE		Vitapex faster than Calcium Hydroxide and ZOE		
Zinc oxide-eugenol and calcium hydroxide pulpectomies in baboon primary molars: histological responses[25]	In-vitro	2004	South Africa	ZOE, Calcium hydroxide			ZOE more than Calcium Hydroxide	
Resorption of a calcium hydroxide/iodoform paste (Vitapex) in root canal therapy for primary teeth: a case report[24]	Case report	2000	United States	Calcium hydroxide, ZOE, iodoform, Vitapex		Vitapex faster than ZOE		
Clinical and radiological evaluation of zinc oxide-eugenol and Maisto's paste as obturating materials in infected primary teeth--nine months study[16]	Clinical trial	1996	India	Maisto's paste, ZOE	Maisto's paste more than ZOE	Maisto's paste faster than ZOE	Maisto's paste more than ZOE	
In vitro antimicrobial and cytotoxic effects of Kri paste and zinc oxide-eugenol used in primary tooth pulpectomy[15]	In- vitro	1994	United States	ZOE, Iodoform, Kri paste	Iodoform more than ZOE			

Table 3- Summary of findings

Survival	Biocompatibility	Resorption	Cytotoxicity
Vitapex > ZOE[8]	Biodentine > MTA[13]	Vitapex >ZOE[8]	MTA > Biodentine[14]
MTA > Calcium hydroxide[9]	ZOE > Vitapex and MTA[12]	Calcium hydroxide>Formocresol[7]	Vitapex> MTA> ZOE[12]
ZOE > Iodoform[26]	Formocresol >Calcium hydroxide[7]	Maisto's paste > ZOE[16]	MTA> Biodentine[13]
Vitapex >ZOE, Iodoform[19]	Maisto's paste >ZOE[16]	Vitapex > Calcium hydroxide, ZOE[22]	Iodoform> ZOE[15]
	Vitapex and calcium hydroxide more than ZOE and Iodoform[19]	Calcium hydroxide > ZOE[23]	Maisto's paste> ZOE[16]
	Calcium hydroxide more than Iodoform[11]	Vitapex > ZOE[24]	Formocresol > calcium hydroxide> MTA[17]
	ZOE more than calcium hydroxide[25]		Iodoform> ZOE, calcium Hydroxide[18]
			Iodoform> Calcium hydroxide[11]
			ZOE> Iodoform, Vitapex, calcium hydroxide[19]

Considering biocompatibility, Maisto Paste and Biodentine performed well and iodoform-containing compounds had lower biocompatibility, especially at higher concentrations (Tables 2 and 3). Lack of significant differences in the findings of the above-mentioned systematic review[10] can be due to great differences in methodologies of different studies. Therefore, more comprehensive studies with a larger ample size and standardized methods are needed to consolidate the current knowledge in this field.

Regarding root resorption, although systematic reviews by Barcelos et al,[20] and Collado-González et al,[13] showed differences in rate of resorption of dental materials, the differences among the studies in this regard were not statistically significant. Inability of statistical tools to aggregate the findings of previous studies may be due to methodological differences among the studies. However, according to the findings of the abovementioned studies, it has been confirmed that ZOE and its compounds in high

concentrations can cause problems for permanent successors due to their low rate of reabsorption. Thus, ZOE is unsuitable for root filling of primary teeth due to its low resorption rate.

The findings of reviewed studies summarized in Table 2 indicate the superiority of Vitapex over ZOE in terms of durability of endodontic treatment and survival rate.[19, 26] However, a number of preliminary studies as well as meta-analyses question the existence of such superiority.[20] Due to the lack of aggregation of the findings of review studies regarding survival rate and the impact of various factors such as crown restoration on this variable, it is difficult to comment on the survival rate of these materials.

Conclusion

A definite statement cannot be made about the superiority of different materials over each other according to the reviewed articles. The published meta-analyses showed no statistically significant differences in various comparisons. However, it seems that by focusing on a specific characteristic, the advantages of different materials over each other can be revealed.

Conflict of Interest

Non Declared

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