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Tooth discoloration induced by endodontic materials: a literature review

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Abstract – It is common knowledge that materials used in endodontics may cause discoloration and thus impair the aesthetic outcome of the treated tooth. The purpose of this review is to summarise the existing knowledge on the discoloration potential of materials used for endodontic procedures. A comprehensive literature search covering the period from 1966 to 2011 was conducted on Pubmed and the Cochrane Library using different keyword combinations including 'tooth', 'colour', 'discoloration', 'staining', 'endodontic' 'root canal' 'sealer', 'dressing', 'medicament', 'obturation', 'filling', 'treatment', 'portland cement', 'MTA' and 'antibiotic paste'. Any relevant work published in the English language in peer-reviewed journals and presenting pertinent information related to the purpose of this overview was considered for inclusion. In addition, bibliographies of all relevant papers and previous review articles were hand searched and the reference lists from endodontic textbooks were also reviewed. Articles were excluded if an English abstract was unavailable, if only single clinical reports or conference reports were included, or if the topic was unrelated to the subject. Ten *in-vitro* studies, one randomized controlled trial and one multicenter randomized controlled trial met the inclusion criteria. There were not any recently used endodontic materials that would not induce at least measurable colour changes. For a wide range of materials currently available on the market there is only scarce or no evidence available on their staining ability. Endodontic therapy should not focus solely on biological and functional aspects, but take aesthetic considerations into account as well. To reduce the risk of material-induced tooth discoloration all materials should be applied carefully in areas of aesthetic concern. The need for further research in this field and for the development of non-staining endodontic materials is evident.

It is common knowledge that materials used in endodontics may cause discoloration and thus impair the aesthetic outcome of the treated tooth. Among the teeth requiring intracoronal bleaching having had previous dental treatment on a tooth was identified as one of the main causes for discoloration (Fig. 1). Furthermore, internal bleaching of such teeth tends to be less effective compared to traumatically discoloured teeth because more applications of the bleach paste are necessary to obtain a satisfactory result (1). The long-term treatment success of intracoronal bleaching is insecure as colour relapse is likely to occur (2). Thus, endodontic therapy should not focus solely on biological and functional aspects, but take aesthetic considerations into account as well. Material-induced tooth discoloration may be prevented to some extent by avoiding substances with a high risk of staining. The objective of this review is to summarize the existing knowledge on the discoloration potential of materials used for endodontic procedures.

A comprehensive literature search covering the period from 1966 to 2011 was conducted. The references were obtained via several searches on PubMed, and the Cochrane library, using different keyword combinations including 'tooth', 'colour', 'discoloration', 'staining', 'endodontic' 'root canal' 'sealer', 'dressing', 'medicament', 'obturation', 'filling', 'treatment', 'portland cement', 'MTA' and 'antibiotic paste'.

Any relevant work published in the English language in peer-reviewed journals and presenting pertinent information related to the purpose of this overview was considered for inclusion. In addition, bibliographies of all relevant papers and previous review articles were hand-searched, and reference lists from endodontic textbooks were also reviewed.

Articles were excluded if no English abstract was available, if only single clinical reports or conference reports were included or if the topic was not related to the subject.

Ten *in vitro* studies, one randomized controlled trial and one multicentre randomized controlled trial were identified (Table 1). One of the *in vitro* studies was not published in a peer-reviewed journal but appeared as a

Fig. 1. Exposed roots during crown lengthening showing marked discoloration of the root canal treated right central and lateral incisor.

thesis. However, it was included as it was directly related to the topic of this review. Overall, three studies were published in the last millennium (all before 1989) testing materials with low relevance in modern endodontics. The remaining papers were published in the year 2000 or later.

Publications from 1966 to 2000

As early as 1968, Gutierrez and Guzman investigated whether various disinfectants, antibiotics or flushing solutions were capable of producing tooth discoloration in human teeth. Dentin discs were treated with the different materials. The disinfectants camphorated p-monochlorophenol and eugenol did not produce any colour changes. Phenol, cresatin and solutions containing penicillin, streptomycin or chloramphenicol caused a slight discoloration of the dentin discs. Marked discoloration was observed when formocresol, the quaternary ammonium compound Molca or tetracycline solutions

Table 1. Characteristics of the included studies. Substances or materials, which caused discoloration, are highlighted in italics

Title	Author, Publishing Year	Study Type	Tested endodontic materials
Tooth discoloration in endodontic procedures. *Oral Surg Oral Med Oral Pathol*	Gutierrez and Guzman (3)	*In-vitro*	Camphorated p-monochlorophenol, Eugenol, *Phenol*, *Formocresol*, *Cresatin*, *Zefirol*, *Molca* *Sodium Penicillin*, *Streptomycin*, *Chloramphenicol*, *Oxytetracycline*, *Chlortetracycline*, *Tetracycline*, *Sigmamycin*, *Demethylchlortetracycline* *Polyantibiotic Paste 1* (*Penicillin Streptomycin*) *Polyantibiotic Paste 2* (*Penicillin*, *Terramycin*, *Streptomycin*) *Polyantibiotic Paste 3* (*Penicillin*, *Declomycin*, *Streptomycin*) *N2*, *Walkhoff's Paste* (*iodoform + camphorated p-monochlorophenol*), *Cresoform*, *Oxpara*
Staining patterns in teeth discoloured by endodontic sealers	van der Burgt et al. (4)	*In-vitro*	*Grossman's cement*, *zinc oxide-eugenol*, *Diaket*, *Tubli-Seal*, *AH26*, *Endomethasone*, *N2*, *Riebler's paste*
Tooth discoloration induced by endodontic sealers	van der Burgt et al. (5)	*In-vitro*	*Grossman's cement*, *zinc oxide-eugenol*, *Diaket*, *Tubli-Seal*, *AH26*, *Endomethasone*, *N2*, *Riebler's paste*
The effects of Ledermix paste on discoloration of immature teeth	Kim et al. (15)	*In-vitro*	*Ledermix*, *Pulpdent paste*
The effects of Ledermix paste on discoloration of mature teeth	Kim et al. (16)	*In-vitro*	*Ledermix*, Pulpdent paste
In vitro longitudinal assessment of coronal discoloration from endodontic sealers	Parsons et al. (6)	*In-vitro*	*AH26*, *Kerr Pulp Canal Sealer*, *Roths 801*, *Sealapex*
Sealer distribution in coronal dentin	Davis et al. (7)	*In-vitro*	*AH 26*, *Kerr Pulp Canal Sealer*, *Roth 801*, *Sealapex*
Mineral trioxide aggregate as a pulpotomy agent in primary molars: An *in vivo* study	Naik and Hegde (27)	*In-vivo* (randomized controlled trial)	Formocresol, *MTA*
In vitro computer analysis of crown discoloration from commonly used endodontic sealers	Partovi et al. (8)	*In-vitro*	*AH26*, *Endofill*, *Tubliseal*, *Zinc oxide eugenol*, *Apatite root canal sealer III*, *gutta-percha*, *Cavizol*
Analysis of coronal discoloration from common obturation materials	Elkhazin (9)	*In-vitro*	*AH Plus*, *EndoRez*, *Sealapex*, *Kerr Pulp Canal Sealer*
Tooth discoloration of immature permanent incisor associated with triple antibiotic therapy	Kim et al. (38)	*In-vitro*	ciprofloxacin, metronidazole, *minocycline*, *triple antibiotic paste*
Discoloration of teeth after avulsion and replantation: results from a multicentre randomized controlled trial	Day et al. (17)	*In-vivo* (multicenter randomized controlled trial)	*Ledermix*, *Ultracal XS*

were placed. The most severe discoloration was caused by N_2 pastes and polyantibiotic pastes containing tetracyclines, particularly those containing Declomycin. The discolouring effect of the tested chemicals was always stronger when used in the presence of human erythrocytes (3).

In 1986, van der Burgt (4) investigated the staining patterns induced by eight endodontic sealers in human premolars. The root was cut off and different sealers were filled through the apical access into the pulp chamber. Two observers determined the colour changes in the external tooth surfaces visually.

After 7 weeks, the teeth in all experimental groups (excluding the teeth in the control group, which were filled with distilled water) exhibited discoloration that was visible on the external surface. Grossman's cement, zinc oxide-eugenol, endomethasone and N_2 induced a moderate orange-red stain. Diaket and Tubuliseal caused a mild pink discoloration. AH 26 gave a distinct colour shift towards grey. Riebler's paste caused a severe dark red stain. In a second approach, the authors evaluated the penetration depths of the discoloration into the dentin. For this purpose, the premolars were hemisectioned in the buccolingual direction and the sectional areas were examined by two observers.

Tubuliseal, Diaket and AH 26 produced discoloration of the inner one-third of dentin. One-half of the inner dentin was stained by Grossman's cement, zinc oxide-eugenol, endomethasone and N_2. The entire dentinal depth was stained when Riebler's paste was used. The control group showed no discoloration. For each material, the internal staining patterns were in agreement with the discolorations observed on the external surfaces. The same eight sealers were examined in a subsequent study (5). Colour determination was carried out at regular intervals for up to 6 months.

Similar colour changes as seen in the former test were obtained. Each material induced measurable tooth discoloration within 3 weeks. Diaket caused the least discoloration, whereas Riebler's paste produced the most severe staining. Interestingly, the discoloration caused by Diaket appeared to be temporary. The teeth, which initially turned pink, returned to their original hues after 6 months.

Publications from 2000 to 2011

Endodontic Sealers

A huge variety of sealers are available on the market. However, there are only four recent studies evaluating the discoloration potential of some products. Parsons et al. (6) assessed coronal discolorations produced by four different sealers (Sealapex, Roth's 801, AH 26 and Kerr Pulp Canal Sealer). Two control groups were included, in which one was filled with blood and the other was left empty. After 1, 3, 9 and 12 months, standardized pictures were taken of the teeth using a digital imaging system for colour assessment. The teeth in the negative control group showed no evidence of discoloration for all time intervals. The specimens in the positive control group immediately showed severe coronal discoloration. All of the experimental teeth revealed coronal discoloration, with significantly more severe values for AH 26 and Kerr Pulp Canal Sealer. This effect was attributed to the silver ions that were part of the composition of both materials.

A follow-up study published by the same group assessed the penetration depth of the sealers into the dentin (7). Because the described methodology was similar, it can be assumed that the same specimens were used. After a storage time of 2 years in individual vials in a humidor at 37°C, all teeth were split longitudinally in a facio-lingual direction for evaluation. Digital images were taken, and the depth of sealer penetration into dentin was evaluated using an image analysis software. The negative control groups (empty teeth) showed no dentin discoloration. The teeth in the positive control group, which were filled with blood, showed complete penetrations of the dentin up to the dentino-enamel junction. Surprisingly, all four sealers showed only minimal sealer penetration and no evidence of discoloration of the exposed dentinal surfaces. The findings were assumed to be a result of the smear layer not having been removed, which obviously prevented the materials from diffusing into the dentin. However, the 2-year set sealers in the endodontic cavity showed marked levels of discoloration compared to fresh mixes. The most severe colour change was observed for Kerr Pulp Canal Sealer and AH 26, whereas the least amount was observed with Sealapex and Roth 801. Thus, the authors concluded that the visible crown discoloration produced by these sealers may not be necessarily associated with tubule penetration.

A recent study assessed the degree of staining in tooth crowns caused by commonly used endodontic sealers via a computer analysis method (8). Discoloration induced by the root canal sealers AH 26, Endofill, Tubuliseal, zinc oxide-eugenol (ZnOE), Apatite root canal sealer III, gutta-percha and Cavizol (a filling material containing ZnOE) was assessed on extracted human premolars. Teeth in the positive control group were filled with amalgam, while distilled water was used in the negative control group.

The roots were resected 3 mm below the cemento-enamel junction. The pulp chambers were cleaned using Gates Glidden drills and K-files and were irrigated with 2.5% sodium hypochlorite through the apical access opening. No attempt was made to remove the smear layer.

The negative controls showed the least levels of tooth discoloration during all examination periods. The positive controls immediately showed severe discoloration, which was significantly different than seen in the experimental groups.

After 3, 6 and 9 months, the order of severity of tooth discoloration (from highest to lowest values) was as follows: amalgam = Endofill > ZOE > Tubuliseal > AH 26 > gutta-percha > Apatite root sealer III > Cavizol > distilled water. For all groups, the discoloration was most evident in the cervical third of the crown and on the cervical root surface, with minimal changes in the occlusal third.

Elkhazin investigated the discoloration effects of AH Plus, EndoRez, Sealapex and Kerr Pulp Canal Sealer on

extracted human teeth. The teeth were root-filled with gutta-percha and one of the four materials. The tooth colour was evaluated using a spectrophotometer. After 6 and 8 weeks, all four sealers showed significant coronal discoloration, which increased with time. EndoRez produced the least discoloration, although not statistically significant when compared to the other experimental groups (9).

On the basis of the existing evidence, there is not any root canal sealer available that could guarantee colour stability of the treated tooth. Because studies have not been conducted to evaluate the newer materials, a statement cannot be given with regard to this. To minimize the risk of discoloration, all obturation materials should be strictly localized in the area of the root canal.

Endodontic Medicaments

Ledermix, recommended for endodontic use owing to its antibacterial and anti-inflammatory properties, is used since long time (10). In addition, during the last years, Ledermix has gained much attention in dental traumatology as there is increasing evidence that it has the potential to inhibit inflammatory root resorption after severe luxation injuries (11–13).

Clinically, it has been noted that Ledermix paste may cause discoloration, although studies have not proven that claim before 2000 (14). The risk of tooth staining is associated with the demethylchlortetracycline, a tetracycline antibiotic.

Kim investigated the discoloration effects of Ledermix in two studies, first in mature teeth and second in immature teeth. Forty-five mature maxillary and mandibular anterior teeth were prepared using the step-back technique. The smear layer was removed from all involved teeth with a 15% EDTA solution. Each tooth was stored in a separate tube. The teeth were randomly assigned to five experimental groups. In group 1, Ledermix was inserted into the root canals below the cemento-enamel junction (CEJ). In groups 2 and 3, Ledermix was placed both into the canals and in the pulp chambers, respectively. In group 4, the root canals and the pulp chambers were filled with Pulpdent, a calcium hydroxide paste. The teeth in group 5 served as a control group and were filled with saline. The specimens in group 3 were stored in the dark. Colour changes were measured after 12 weeks with a spectrophotometer in a mounting system, which was developed to consistently reproduce the position of each tooth.

In group 2, stronger grey brown colour changes were noticed than seen in group 1. Both groups were significantly darker than the control group (5). No significant changes could be depicted in group 3 (Ledermix) where the specimens have been kept in the dark. Thus, exposure to sunlight was stated to be responsible for the dark brown discoloration in group 2.

Likewise, the specimens filled with calcium hydroxide did not exhibit a significant staining compared to the control group (15).

In a second laboratory study with a similar experimental design, the effect of Ledermix paste on immature teeth was investigated. Again the teeth that were filled with Ledermix paste became dark brown only when exposed to sunlight. More severe staining was noted when Ledermix paste was filled in the pulp chambers than when the paste was restricted to areas below the CEJ. Compared to the findings of the first study, immature teeth seemed to be more severely stained than the mature teeth. The authors explain these findings with the differences in the anatomy of dentinal tubules that allow a higher diffusion rate of the material in immature teeth resulting in greater discoloration. In contrast to the teeth with completed root formation, the immature specimens produced statistically significant colour changes even with the calcium hydroxide paste (16).

Recently, a multicentre randomized controlled trial was published aiming to compare the effects of Ledermix and the calcium hydroxide dressing Ultracal XS on the discoloration of 27 replanted teeth. After 12 months, both medicaments caused measurable discoloration. However, in the Ledermix group, the discoloration was much more severe and warranted further treatment, compared with the Ultracal XS group. In the latter, only one patient was concerned about the colour of the tooth (17).

As non-staining alternative, Odontopaste (Australian Dental Manufacturing, Kenmore Hills, Australia) has recently been released onto the dental market (18). Compared to Ledermix, the tetracycline component was replaced by clindamycin. Even though there is no publication in a peer-reviewed journal available supporting that fact, the results of a recently published thesis suggest that discoloration may be avoided with this medicament (19). Because the inhibiting effect of Ledermix on external root resorption is primarily attributed to the corticosteroid component (20, 21), intracanal corticosteroids may be a reasonable alternative in dental traumatology.

Portland Cement based materials

Mineral trioxide aggregate (MTA) is based on portland cement and was introduced to the field of endodontics in 1993. Owing to its high level of biocompatibility and its good sealing properties, it is regarded as the material of choice in cases of vital pulp therapy (pulp capping, partial pulpotomy) or to seal pathways of communication between the root canal system and the external root surface (perforation, apexification or retrograde filling) (22–24). Especially in dental traumatology, MTA has gained tremendous popularity during the last years, aiming to replace calcium hydroxide in the treatment of a variety of pulpal and periodontal healing complications (25).

However, one of the main drawbacks of MTA is its discoloration potential (26). The grey-coloured formula, which was first introduced to the market, led to visible colour changes on the outer surface. When it was used as a pulpotomy agent in primary molars, discoloration occurred in 60% of all cases (27).

To reduce the discoloration potential, the chemical composition of MTA was changed and an improved formulation was later introduced as white MTA. The most significant difference between the two types of MTA is the lack of iron ions in white MTA (28).

However, it has been reported that white MTA may cause discoloration as well (29, 30). Some authors state that the discoloration induced by MTA may be attributed to bismuth oxide, which is added to improve the radiopacity in both grey and white formulations (31). However, no scientific evidence is available to support this statement.

Because MTA is based on industrial portland cement with bismuth oxide added as an radiopacifier, pure portland cement was suggested as an alternative (32).

Although manufacturers such as Medcem GmbH (Weinfelden, Switzerland) claim that a better colour stability is achieved when using portland cement instead of MTA, no studies were found that investigated colour changes when using portland cement for endodontic procedures.

Keeping in mind that in cases of vital pulp therapy (such as partial pulpotomy after crown fracture with exposed pulp) the capping material is placed in the coronal part of the tooth, there is a considerable need for a non-staining biocompatible portland cement–based material.

Antibiotic pastes

To disinfect the root canal system and set the conditions for subsequent revascularization in the field of regenerative endodontic procedures, a triple antibiotic mixture (3Mix-MP) was suggested (33, 34). The paste contains ciprofloxacin, metronidazole and minocycline. The latter is a derivate of tetracycline and able to induce tooth discoloration after long-term systemic administration (35, 36). Discoloration after canal medication with the triple antibiotic paste has only been scarcely mentioned in the literature (37). Apart from that, there is only one *in vitro* experiment showing evidence of tooth discoloration. In this laboratory test, freshly extracted human anterior teeth were sectioned 3 mm above and 5 mm below the CEJ. The root canals were enlarged and the smear layer was removed with 4 EDTA 17% and NaOCl 6%. The teeth were assigned to four experimental groups with five teeth each and filled with the pastes as follows: the triple antibiotic mixture (group 1), ciprofloxacin (group 2), metronidazole (group 3) and minocycline (group 4). All specimens were stored in the dark. A dark green-brown shade appeared in samples in group 1 containing the triple antibiotic mixture. The discoloration became more severe with time. Of the three groups containing only one antibiotic, only minocycline (group 4) showed similar levels of discoloration as the triple antibiotic mixture. Thus, minocycline was identified as the cause for discoloration. Furthermore, the study demonstrated that sealing the dentine wall with a bonding agent prior to the application of the paste could reduce the overall colour change and, however, would not be able to prevent it (38).

Trope (34) has proposed to use Arestin as a substitute for minocycline. With this approach, the discoloration could be markedly reduced but again not prevented.

As a comparable alternative, a prefabricated triantibiotic mixture with cefuroxim as a substitute for minocycline is available (TreVitaMix, Medcem GmbH). According to clinical observations of the first author, no visible coronal discoloration seems to occur. However, there are no studies to support this finding.

Conclusion

Almost all materials used in modern endodontics may stain teeth. It is noteworthy that in the included studies for this review, there were not any endodontic materials that could be identified that would not induce at least measurable colour changes. For a wide range of materials currently available on the market, there is only scarce or no evidence available on their staining ability. Therefore, endodontic therapy should not focus solely on biological and functional aspects, but take aesthetic considerations into account also. To reduce the risk of material-induced tooth discoloration, all materials should be applied carefully in areas of aesthetic concern. The need for further research in this field and for the development of non-staining endodontic materials is evident.

Conflict of interest

The authors declare no conflict of interests.

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