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Polymer materials used in endodontic treatment - in vitro testing

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ABSTRACT

Purpose: The paper contains the characteristics of dental materials used for filling the dental root canal as well as presentation of their selection according to the criteria suggested Grossman. Furthermore the paper includes tests on the materials intended to fill the root canal selected according to their attractiveness matrix, while the in vitro tests comprised selection of the most effective material obturating the internal space of the root canal. The filling tightness was assumed to be the effectiveness measure, in other words, tight fusion of the filling material and the root canal wall.

Design/methodology/approach: An attractiveness matrix was created for the materials used to fill the root canals, using the weighted scores method for the preference analysis. The two materials selected were subjected to materialographic tests by means of SUPRA 35, HD scanning microscope from Zeiss and Stereo Discovery V12 stereoscopic light microscope with AxioCam HRC digital camera from Zeiss.

Findings: Based on the analysis of attractiveness matrix results of materials used for filling dental root canal, two materials have been selected for further tests: gutta-percha matrix and matrix of polyester polymer materials. The gutta-percha matrix is characterised with perfect properties, including without limitation strength and relatively high quality level of the obturation. The matrix of polyester polymer materials, in turn, has a lower strength and relatively high level of filling quality. As a result of materialographic tests it was found that the material on gutta-percha matrix thermoplastically applied into the canal, along with the polymer sealer, enables tight fusion of the obturation material and the root canal wall.

Practical implications: The materialographic test results suggest that the most effective root canal obturation material, due to the tightest obturation achieved, is the gutta-percha matrix material applied along with a polymer sealer, thermoplastically applied into the canal. The endodontic procedure carried out in the above way enables avoiding the tooth extraction and enables prosthetic or composite restoration of the tooth crown on its own pillar and is responsible for the patient's functionality, beauty care and health.

Originality/value: The application of matrix analysis in the field of endodontics (usually applied to management education and other) for evaluation of materials intended to obturate root canals.

Keywords: Polymers; Gutta-percha matrix material; Matrix of polyester polymer materials; SEM; LM

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MATERIALS

1. Introduction

Stomatology is a branch of science that strictly applies the material engineering knowledge. Endodontics is an important branch of stomatology, one that assumes the evacuation of inflamed or dead content located in the pulp cavity and root canals, restoration of the canal walls and its tight obturation with substitute material. Thanks to the endodontic procedure carried out properly it is possible to avoid tooth extraction, a traumatic procedure, both psychologically to the patient and functionally for the temporomandibular joints. Furthermore, the prosthetic or composite restoration on own pillar are also made possible, which is responsible for the functionality, beauty care and health of the patient. The tight fusion of the root canal wall and the obturating material represent one of the most significant factors deciding on the endodontic treatment's success, while any irregularities in the restoration and obturation of the root canal might lead to early or delayed complications, while the latter in turn might result in a pathological condition in distant organs. The type of material applied is not only affected by the canal tightness, but also by the way it has been applied inside the canal.

Gutta-percha was one of the first materials used for obturation of root canals, it was first used for such purposely Bowman in 1867, which took place only 31 years after the first extirpation of the pulp from the root canal. However, in mid-19th century it was rejected in favour of non setting pastes and cements, containing paraformaldehyde, such as: formalin resorcinol pastes, N2 paste, Endomethasone [1]. The materials have been withdrawn, due to their high cytotoxicity, neurotoxicity, mutagenity and carcinogenic properties. They were used most of all as sealers of silver points with the silver ions released were to act bactericidally. However the tests of the material showed that the corrosion products of the silver points has a toxic effect on the periapical tissues [2].

Louis Grossman was the first to determine and systematise the requirements for an ideal material to obturate root canal, the said requirements, in spite of the materials varying continuously, are still applicable (Table 1) [3].

Material based on zinc oxide with eugenol has been used in endodontics for more than 40 years. Unfortunately, modern endodontics is forced to reject this material group entirely, due to the presence of eugenol among the componets, which disturbs the polymerisation of the adhesive materials. Another group of materials are calcium hydroxide pastes, in spite of numerous advantages, substantial resorption of this material from the root canal has been shown in long -term tests [4]. The 1990's mean the return to endodontics of gutta-percha matrix material and search for new polymer matrix materials. Gutta-percha is a trans 1.4 polyisoprene that occurs in three isomeric varieties α, β and γ, obtaine from the sap of plants Palaquium gutta and Palaquium oblongifolia. [3, 5-7]. The catalyst of transformation β of gutta-percha into variety α of gutta-percha is temperature rainging from 48.6ºC to 55.7ºC[6], which is used in thermoplastic obturation techniques of this material.

The gutta-percha matrix material is used in endodontics in the form of points and pellets, containing 18-22% gutta-percha and 59-75% zinc oxide and other compounds of metals, such as: 1.1-31.2% barium and strontium sulphates as well as wax and other 1-4.1% polymers [6-10]. The gutta-percha matrix material is always used in combination with the sealer. Both in cold condensation and thermoplastic methods, synthetic resin matrix sealers are recommended, their purpose being the adhesion of the gutta-percha matrix material to the root canal wall and serve as insulator in thermoplastic techniques. An alternative for the matrix of polyester polymer materials is a synthetic polymer with trade name RealSeal. It is composed of organic polymer matrix composed of: urethane dimethacrylate (UDMA), poly(dimethacrylate) (PEGDMA), ethoxylate bisphenol A dimethacrylate (EBPADMA), bisphenol methacrylate A (BIS-GMA), obturants - such as barium borosilicate, barium sulfate, bismuth oxychloride and calcium hydroxide as well as photoinitiators and resin solvents [11].

Table 1.
Requirements for an ideal material to obturate the root canal (according to Grossman)

Requirements for an ideal material to obturate the root canal:
• easy application into the canal
• periapical and lateral canal obturation
• no shrinking inside the canal
• insensitive to humidity
• bactericidal or bacteriostatic effect
• impenetrability to X-rays
• no discoloration of the tooth structure
• no irritations to the periapical tissues
• sterile or easily sterilisable
• easily removable from the canal if endodontic revision becomes necessary

2. Methodology of research

To select an appropriate material to be tested, preliminary analyses were carried out, including without limitation, matrix and scenario analysis, usually applied, without limitation, in management science, particularly to foresight tests being part of knowledge management, described in the works [12-19] and other. The procedural benchmarking technique was used [12], consisting in the application of the existing proven procedures/solutions/approaches related to another topical area or branch of knowledge. Under the analysis of materials for obturation of the root canals, the weighted scores method was used, serving for the preference analysis.

Seven materials most frequently used in endodontics for obturation of the root canals were analysed. The materials were evaluated in terms of material strength index inside the root canal and in terms of the material quality index. In order to determine the material strength index inside the root canal, the evaluation concerned the extent to which the obturating

material reinforces the dental root upon expiration of assumed period of time so as to maintain the root mechanical resistance to breaking combined with maintained leak tightness of the obturation. The material quality index in the root canal was determined during the analysis of the characteristics of the specific materials according to the criteria suggested by Grossman.

The evaluation comprised the effect of the inserted material on the patient's organism, the possibility to eliminate bacteria from the obturated root canal, the sterilisability of the material improving the aseptic technique of the procedure carried out and minimisation of the risk of reintroduction of bacteria into the procedure area, the easiness of the material removal if another treatment becomes necessary and the possibility of proper diagnostics and X-ray apparatus control. Table 2 presents all the materials analysed that are used for obturation of root canals, while Fig. 1 presents the classification of theroot canal obturants (M. Barańska - Gachowska) [20].

To provide the preparations for materialographic tests, the samples were carved along the root, each carving 1 mm deep with the use of a diamond disk mounted on the prosthetic handpiece. The testing material was cooled in liquid nitrogen and then a brittle fracture was made. The samples prepared as above were subjected to preliminary tests in the peri-crown, middle and periapical sections of the root canal on the Stereo Discovery V12 stereoscopic microscope with the AxioCam HRC digital camera from Zeiss. The test results were documented using digital photography method with 50x enlargement.

Then each sample was covered with conductive material - a coat of gold, 50-60 nm thick in the BAL - TEC SCD050 vacuum coating system from Oerlikon Balzers. For the metalographic observations of the fractures with a thin layer of gold - the peri-crown, middle and periapical section -the SUPRA 35 HD electron scanning microscope from Zeiss with accelerating voltage 15-20 kV and 2000x and 5000x enlargement. The samples tested were subjected to tightness analysis of the leakages occurring between the obturating material and root canal wall.

3. Results and discussion

The analysis carried out enables the creation of attractiveness matrix for the materials used to obturate root canals and enables the instantaneous elimination of three types of materials that do not achieve the minimum results within the range of relative states. Silver points, zinc oxide and eugenol matrix materials. The materials produced basing on calcium hydroxide reach a high level of material strength, however, in comparison to the strength index the overall measurement result, because in spite of meeting Grossman's criterion, we cannot be sure that the material tested will be able to assure the patient the maintenance of the tooth for a few years from the treatment.

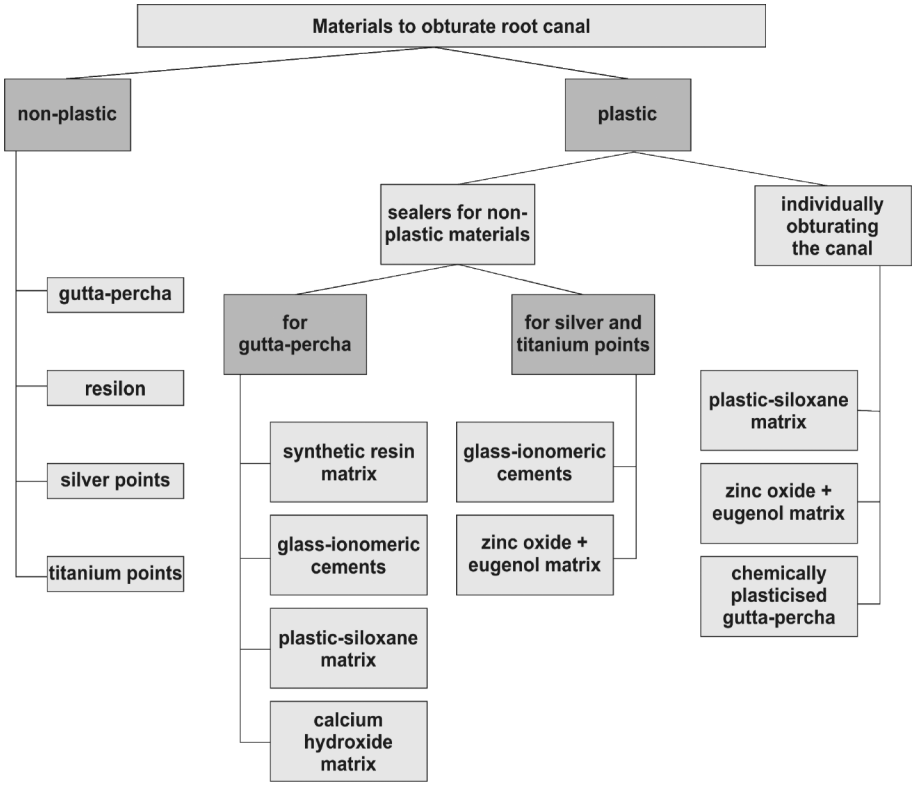

Fig. 1. Classification of materials to obturate root canals (after M. Barańska-Gachowska) [10]

Table 2.
Overview of contemporary root canal obturants

Material	Sterilisability	Easiness of extirpation from the canal in case of revision	Application form/consistency	Non-toxicity	Bactericidability	Method of application into the canal	X-ray penetrability	No resorption in time	Mechanical resistance to breaking of the roots after the material application
gutta-percha matrix	○	○	points, pellets	◔	●	cold and hot techniques	○	○	◔
matrix of polyester polymer materials	○	◔	points, pellets	◔	●	cold and hot techniques	○	○	○
silver points	●	◑	pellets	◔	●	inserted with sealer	○	○	◑
zinc oxide with eugenol matrix	●	○	paste	●	○	individually on Lentulo needle or as sealer for the posts	○	◔	◕
synthetic resins matrix	●	◑	paste	◔	○	as sealer for the posts	○	○	◔
plastic matrix - silicones	●	◔	paste	○	●	individually or as gutta-percha sealers	○	○	◔
calcium hydroxide matrix	●	○	paste	○	○	individually on Lentulo needle or as sealer for the posts	○	●	●
glass ionomer cements	●	◕	paste	○	●	individually on Lentulo needle or as sealer for the posts	○	○	○
○	eminently high / yes		10 points			◑	medium	5 points	
◔	very high / very big		9 points			✣	fairly low	4 points	
◔	high / fairly high		8 points			◕	low	3 points	
◔	medium high		7,5 points			◕	poor	2,5 points	
◐	fairly high		7 points			◕	very low	2 points	
◔	moderate		6 points			●	minimum / no	1 point	

The other four obturation methods reach high index results of strength of materials in the root canal, however none of them achieves the quality of obturation on normal level. The results of the analyses show that none of the materials evaluated is faultless. However, the materials tested can be explicitly classified, concerning the target quality of their application. The results of the analysis of the materials overview two materials have been selected for further tests: the obturation material based on gutta-percha matrix and matrix of polyester polymer materials. The first reaches a very high strength index and relatively high level of obturation quality. The other material, in turn, presents a lower strength level and relatively high quality index.

The materialographic tests carried out on two materials selected in the matrix analysis of the materials for obturation of root canals enabled the observation of differences in obtaining tight adhesion on the border of the root canal wall and obturation materials for each of them (Figs. 2-5).

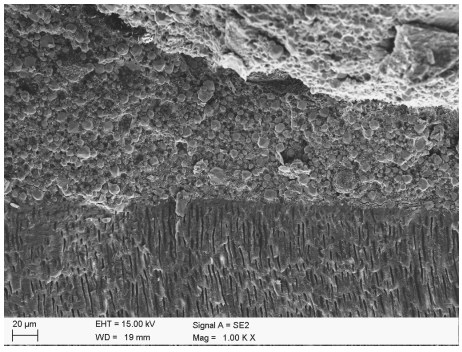

Fig. 2. Tight fusion of gutta-percha matrix material, thick intermediate layer of the sealer and root canal dentine with visible cross section of the microscopic channels along their axis (SEM)

4. Conclusions

The quality of endodontic treatment largely depends on the root canal obturation tightness, so the status expected both by the dental physician and most of all the patient is tight fusion between the obturation material and the root canal dentine. The results of the matrix analysis allow to find that none of the materials selected for evaluation is not faultless, however, the polymer materials, such as the gutta-percha matrix material and the matrix of polyester polymer materials, are clearly distinct against other materials subjected to the analysis. This enables a statement that the polymer materials, whether based on natural resins e.g. gutta-percha matrix or synthetic, such as polyester polymer materials, thanks to the thermoplastic application enable 3D obturation of all the internal space of the root canal. However, it was found that the gutta-percha matrix material, along with the sealer used, enables a tighter fusion with the root canal wall. In case of matrix of polyester polymer materials, the leakages on the border of the material and root canal wall were found much more frequently, which could have been caused by the polymerisation shrinkage.

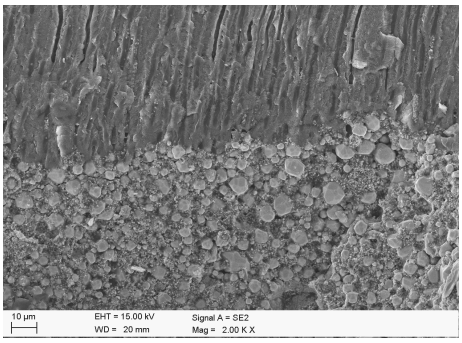

Fig. 3. Tight fusion of the sealer and the root canal dentine with visible cross-section of the dentine microscopic channels along their axis, transversely to the tooth canal axis (SEM)

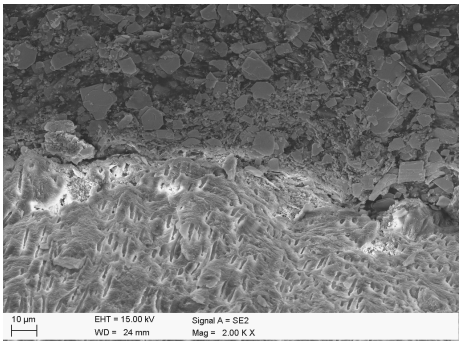

Fig. 4. Tight fusion of the sealer with the root canal dentine with marked adhesion of the sealer to the uncovered microscopic dentine channels (SEM)

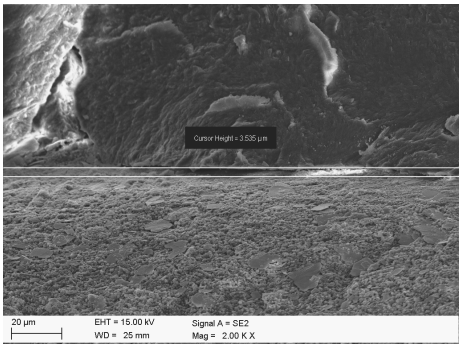

Fig. 5. Leakage on the border of the root canal -sealer with measurement of the gap width of 3.535 µm (SEM)

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