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Treatment methods of deep caries in immature permanent teeth

Metody leczenia próchnicy głębokiej w zębach stałych niedojrzałych

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Keywords

caries, remineralization, indirect capping, immature teeth

Summary

Caries was qualified by UN as non-communicable disease – NCD. It can be avoided by preventive measures. Especially, deep caries lesions in immature permanent teeth constitute a serious clinical problem for contemporary pediatric dentistry.
It is caused by a different anatomical and histological structure compared to mature permanent teeth. The aim of the study was to present contemporary methods of deep caries treatment in histologically and morphologically immature teeth with currently used materials.
The literature review was based on Pubmed and Elsevier databases (2005-2018) and two articles out-of-range. The search criteria were: "caries", "remineralization", "indirect capping" and "immature teeth".
Development in medicine and biomedical science leads to creating more modern procedural records when it comes to deep caries treatment. They are based on minimally invasive dentistry. Development of bioengineering enables creation of more biocompatible materials which do not have irritating influence on dental pulp. These materials allow deeper remineralization of dental tissues.
Deep caries treatment still involves usage of restorations with calcium hydroxide, zinc oxide with eugenol and glass ionomers. Good cooperation with patient, prospects of early diagnosis, and regular examinations of treated teeth have great impact on success of treatment. Further research on methods of diagnosis and treatment needs to be carried out. They should allow regeneration of early qualitative changes to avoid quantitative damages in a tooth's hard tissue.

Słowa kluczowe

próchnica, remineralizacja, pokrycie pośrednie, zęby niedojrzałe

Streszczenie

Próchnica została zakwalifikowana przez ONZ do grupy chorób przewlekłych nieinfekcyjnych (NCD). Można jej uniknąć poprzez działania profilaktyczne. Szczególnie głębokie zmiany próchnicowe w zębach stałych z niedokończonym rozwojem korzenia stanowią poważny problem leczniczy dla współczesnej stomatologii. Spowodowane jest to odmienną budową anatomiczno-histologiczną w porównaniu z zębami dojrzałymi. Uzasadnieniem dla wyboru tematyki było przedstawienie na podstawie przeglądu piśmiennictwa współczesnych metod leczenia próchnicy głębokiej w zębach stałych

z niezakończonym rozwojem morfologicznym i histologicznym z uwzględnieniem stosowanych obecnie materiałów biokompatybilnych.
Dokonano przeglądu piśmiennictwa na podstawie baz Pubmed i Elsevier w przedziale lat 2005-2018 oraz dwóch artykułów spoza zakresu. Kryterium wyszukiwania były następujące hasła: „próchnica", „remineralizacja", „pokrycie pośrednie", „zęby niedojrzałe".
Rozwój medycyny i nauk biologicznych stwarza szansę na powstawanie nowych protokołów postępowania i leczenia próchnicy głębokiej. Większość z nich opiera się na filozofii stomatologii minimalnie inwazyjnej. Rozwój bioinżynierii pozwala na wytworzenie coraz bardziej biozgodnych materiałów, które nie wywierają drażniącego wpływu na miazgę zęba, natomiast umożliwiają głęboką remineralizację tkanek, co jest szczególnie istotne w przypadku zębów niedojrzałych.
W leczeniu próchnicy głębokiej nadal wykorzystywane są preparaty z wodorotlenkiem wapnia czy tlenkiem cynku z eugenolem lub szkło-jonomery. Na powodzenie podjętego leczenia duży wpływ mają: współpraca z pacjentem, możliwość wczesnej diagnozy oraz kontrola już leczonych zębów. Niezbędne są dalsze badania nad metodami diagnostyki i leczenia, pozwalające we wczesnym etapie na regenerację zmian jakościowych, zapobiegając powstawaniu ilościowych uszkodzeń struktury twardych tkanek zęba.

Introduction

Deep caries and its complications in immature permanent teeth still constitute a serious treatment problem for modern dentistry. According to research conducted under the supervision of the Ministry of Health in Poland in 2013-2015, 4% of 12-year-old children had at least one extracted permanent tooth due to caries. Among 18-year-olds, this percentage is as high as 15% (1). According to World Health Organization's (WHO) definition, caries is a local pathological process of extracorporeal origin leading to enamel decalcification, decay of tooth's hard tissues and consequently to formation of cavity (2). In 2011, under the influence of FDI (World Dental Federation) dental caries was qualified by UN Council to the group of chronic non-infectious non-communicable diseases (NCD) which can be avoided through preventive measures. It is a multifactorial process as its etiology was described many years ago. Its etiopathogenesis does not depend on one pathogen causing the disease. Development of caries involves acid-forming bacteria in the biofilm which reside in the oral cavity, however without proper conditions for their growth and thus without significant increase in their number, they will not cause decay. Simultaneously, it is not possible eradicate all oral bacteria that contribute to development of caries (3, 4).

Immature teeth are more susceptible to caries and its complications than teeth with fully developed apices, also due to their lower mineralization, higher amount of interprismatic substance, a thin layer of dentin with wide dentinal tubules, as well as large chambers and prominent pulp horns (5). Fast progress of carious lesions in permanent teeth in children is often an indication for phased treatment including indirect pulp capping with the use of preparations for remineralizing tooth tissues. They are to prevent pulp exposure and limit penetration of microorganisms and products of their metabolism deep into the tissue and, consequently, stop pulp necrosis.

Regenerative abilities of dentin left on the pulpal wall of cavities are used in treatment deep caries. Demineralized layer of dentin, free of bacteria, has remineralizing properties. In response to applied treatment, tertiary dentine is formed on the border with the pulp, which constitutes the body's defense response to irritating external factors.

The aim of the study was to present – on the basis of literature review – methods of treating deep tooth decay in permanent teeth with incomplete morphological and histological development, taking into account currently used biocompatible materials.

Review of the current state of knowledge

Material and methods

The literature review was based on Pubmed and Elsevier databases covering the period 2005-2018 and two papers out-of-range. They were analyzed in terms of therapeutic methods and materials applied in treatment of deep caries in permanent teeth with incomplete development. The search criteria were the following key words in Polish and their equivalents in English: "caries", "remineralization", "indirect capping", "immature teeth". The literature available in text databases of the Medical University of Łódź was used. 44 items were selected. The paper presents methods of indirect pulp capping and materials such as: zinc oxide with eugenol, calcium hydroxide, Biodentin, light-curing liners, biomaterials, glass ionomer materials.

Minimally invasive dentistry

Minimally invasive dentistry is a concept of early detection of carious lesions, bacteria reduction, use of dental materials requiring the least possible tooth preparation, repairing fillings instead of their complete replacement, preparation of the cavity with the least possible loss of tooth's hard tissues in a way that is as little irritating to the pulp as possible (6, 7). In the case of treating deep caries, it consists in removal of

the soft infected layer of irreversibly infected dentin. On the pulpal wall remains affected dentin, undergoing demineralization process to the extent that allows remineralization, because apatite crystals are bonded with collagen fibers by means of cross-links similar to those in healthy dentin, thanks to which the collagen structure is preserved and at the same time devoid of bacteria (8). Research shows that tight closure of a cavity causes inactivation of any bacteria left inside due to lack of carbohydrates needed for their nutrition (7). Further preparation of a deep cavity and removal of demineralized tissue carry a risk of pulp exposure (9). Overpreparation of dental tissues also makes them more susceptible to damage by mechanical and chemical factors.

Methods of deep caries treatment

In clinical practice, the most common method of treating deep caries is the indirect capping method. As defined by the American Association of Endodontists, it consists in placing dental material on a small left layer of demineralized dentin, whose removal would result in pulp exposure (10). There are two types of indirect capping:

1. single-stage method (the "one-visit IPT" [indirect pulp treatment]) – requiring one patient visit, during which the dentist places the final filling,
2. two-stage method (the "two-visit IPT") – during the second visit the previously placed temporary filling is removed and the chamber bottom is thoroughly prepared.

The differences in these methods relate to dental materials used and protocols of tooth surface preparation for treatment procedures.

Indications for indirect pulp capping

Before deciding on treatment with the indirect coating method, the dentist should obtain full history from the patient, which would exclude irreversible pulpitis, and perform a physical examination (8, 11). Teeth qualified for indirect capping cannot demonstrate spontaneous pain ailments, the patient should not feel pain when consuming warm food. However, an increased reaction to cold is allowed. The tooth should not demonstrate sensitivity to vertical and horizontal percussion. The patient can react with pain to drilling during cavity preparation. A radiological examination should show no pathological lesions in the apices of the tooth, periodontium and surrounding bone. Additional examination that can be helpful in diagnosis is the Doppler flowmeter viability test, the result of which should be within the reference ranges. Another useful procedure for determining the degree of cavity preparation is staining of demineralized dentin with preparations based on glycol propylene, which only stains denatured collagen (12). In *in vitro* studies, Krause et al. (13) showed that when determining the thickness of left dentin that separates the cavity bottom from the pulp chamber, optical coherence tomography can be used. It is a non-invasive examination method, using infrared light for evaluation of surfaces of partially transparent objects. It is safe due to the lack of x-ray emission.

The impact of the carious process on adhesion of dental materials to tooth tissues

The carious process causes local increase in the amount of organic substances and water in tooth's hard tissues, which adversely affects adhesion of dental materials, especially light-cured ones, requiring the base to be dry during application. In deep carious cavities, a negative impact on adhesion of fillings is made by large dentinal tubules, especially those present in the vicinity of the pulp of immature teeth, and by smaller surface and lower mineralization of intertubular dentin. After cavity preparation, a layer of impurities is formed called a smear layer, the removal of which is difficult even in the etching process (14).

In response to chronic pathological stimuli, what follows is obliteration of dentinal tubules in the formation process of reparative or sclerotic dentin. Mineral deposits are not susceptible to 15-second etching recommended by producers, they prevent formation of microvilli layer and adhesion of light-curing materials. Extension of curing time to over 15 seconds recommended in adhesive protocols causes excessive demineralization of dentin, degradation of collagen fibers and deterioration of light-curing materials' adhesion. Application of etchant and bonding systems in deep cavities can negatively affect the pulp, especially of immature teeth, because free monomers can pass through a thin, demineralized layer of dentin and its large dentinal tubules (15-17).

Materials used in treatment of deep caries – dentin remineralization

Zinc oxide with eugenol

In fact, for many years the only treatment of deep caries was partial preparation of the cavity leaving slightly demineralized dentin on the pulpal wall, and then filling the tooth for three months with zinc oxide with eugenol. Currently, improved versions of this material are emerging, reinforced with polymethyl methacrylate, e.g. IRM (18). It has antimicrobial properties against bacteria from the *Streptococcus mutans* and *Enterococcus faecalis* groups (19). However, studies show its large marginal leakage and high cytotoxicity to pulp (20, 21). The producer recommends replacement of IRM temporary filling in less than 12 months. The material should not be used as a liner for permanent filling containing resin due to eugenol content and its negative impact on the polymerization process.

Calcium hydroxide

The most common method of deep caries one-visit IPT is placing calcium hydroxide liner on highly demineralized pulpal wall and filling it tightly with light-cured mate-

rial (8, 22). The two-visit IPT protocol assumes partial preparation of carious cavity, application of calcium hydroxide liner and closing the tooth with resin-reinforced zinc oxide with eugenol, e.g. IRM. After three months, the filling is carefully removed and the bottom of the chamber is thoroughly prepared (22). The therapeutic aim of using calcium hydroxide liner is stimulation of reactive dentin formation, and isolation of pulp from thermal and chemical stimuli (23). Calcium hydroxide, so frequently used as a liner in indirect capping, has bactericidal properties resulting from its high pH (24). However, a meta-analysis conducted by Brazilian scientists showed that use of calcium hydroxide liner under clinical conditions does not significantly affect positive treatment outcome in the staged method of caries removal (23).

In their study Pereira et al. (25) divided patients into two groups. In the first group they used calcium hydroxide liner under resin-modified GIC filling, and in the other group – modified GIC by itself. During the control visit, the tooth was tested for viability with a cold test and radiographically analyzed for the distance from pulp chamber to the bottom of the cavity. After removing the filling, the following factors were assessed: the color of the remaining dentin, the degree of humidity and the number of bacteria from the *Streptococcus mutans* and *Lactobacillus* groups. After 90 days of observation, the result showed a lack of statistically and clinically significant differences between the study groups.

Biodentin

Biodentin referred to as bioceramics, dentin substitute, has parameters similar to glass ionomer materials and – according to the manufacturer – it is used in the direct and indirect capping methods, as well as in endodontics in treatment of resorption and filling of root canals. The material containing hydrated calcium bicarbonate is strongly alkaline, pH 11.7-12.3. It tightly adheres to the enamel and dentin, also has an odontotropic effect (26-29). In their study Hashem et al. (11) divided patients with deep caries into two groups. In one group the liner was Biodentin, and in the second group it was Fuji IX material; in both cases the cavities were filled with composite material. Clinical outcomes of treatment were assessed after 24 months and showed positive result in 77.8% of Biodentins patients and in 66.7% of patients in the Fuji IX group. Another study by Aksoy et al. (30) demonstrated that the highest remineralization capacity is characteristic for Biodentin and TheraCal LC materials. They release statistically significantly more Ca2+ ions into dentin compared to MTA and Calcimol.

Light-cured liners

TheraCal LC is a resin-modified calcium silicate liner, containing polymerized methacrylate monomers. According to the manufacturer, it is a preparation intended for direct capping of the pulp, it may be also used in deep cavities, e.g. as an alternative to calcium hydroxide or glass ionomer materials (31). However, Arandi and Rabi (32) point out poor biocompatibility of the material, harmful effects on the pulp, and even inducing inflammation, which can be caused by Bis-GMA monomers.

Biomaterials

Advances in bioengineering, especially in biomimetic materials, influence development of new therapeutic methods and is also visible in dentistry. Similar structure of dentin and bone allows use of research on bone regeneration and remineralization in dentistry. An example of this is research on the use of CMC/ACP nanocomplex in the process of mineralization inside and outside of Type I collagen fibers. The CMC/ACP complex is produced in the stabilization process of ACP (amorphous calcium phosphate) by CMC (carboxymethyl chitosan). *In vitro* studies by Wang et al. (33) showed increased stability of collagen fibers' structure and their resistance to degradation, whereas *in vivo* studies demonstrated high osseointegration potential of the CMC/ACP complex.

Biomineralization of the structure of demineralized dentin is the effect of ACP nanoparticle release and formation of a complex with DMP-1 (dentine matrix protein-1). The ACP/DMP-1 complex penetrates inside the collagen structure and gap zones; it is a precursor to hydroxyapatite (HAP). Chen et al. (34), who conducted experimental studies on biomimetic remineralization of dentin in the case of deep caries, demonstrated remineralization properties of the CMC/ACP complex. Researchers indicate possible use of CMC/ACP in the indirect pulp capping (IPC) procedure.

Glass ionomer materials

In the absence of pathological symptoms from the pulp in deep cavities, the use of glass ionomer materials is a good solution. They show chemical adhesion with tooth tissues, release fluorine, calcium and aluminum, which promotes remineralization of the base. They can also accumulate fluorine from saliva. Glass ionomers of the latest generation are highly resistant to mechanical damage, however the aesthetics of fillings is not always satisfactory. In the case of deep cavities, one can use the sandwich method, combine a glass-ionomer material as a base with an aesthetic and durable light-cured material.

A modern approach to treatment of deep caries is the use of resin-modified glass-ionomer materials. These materials demonstrate much higher release of minerals into tooth tissues and they are characterized by greater tightness and durability compared to conventional glass ionomers. Better mechanical parameters result from their double curing method: with light and based on acid-base reactions (7, 35, 36). Laboratory tests conducted by Duque et al. (37) confirm antibacterial action of conventional glass ionomer materials. Moreover, the tested glassionomer material reinforced with Vitrebond resin showed the most effective antibacterial properties against *S. mutans* and *S. sobrinus*. In relation to *A. viscosus* its action was comparable to 0.2% chlorhexidine.

Resin-modified glass ionomer materials are a good alternative to light-cured materials, especially in patients with high-risk of caries – high DMFT, DMF and OHI indices. They are bioactive, by which we mean their ability to react with living tissues and stimulate hydroxyapatite formation (36). An experiment carried out in Brazil showed that bacterial colonies isolated from the bottom of the cavity by placement of resin-modified glass ionomer demonstrated identical genotypic patterns and genetic similarity – 3 months after application of the preparation. According to the authors it confirms resistance of some bacterial strains as an effect of incomplete removal of carious lesion (38). In another study Duque et al. (9) presented the results of clinical trials on statistically significant reduction of bacteria from *S. mutans* and *Lactobacillus* groups after indirect capping of demineralized dentin with modified GIC Vitrebond material.

One of more modern resin-modified glass ionomer materials is e.g. Equia Forte. It has high mechanical durability and can be successfully used in lateral sections. According to a study by Totad et al. (39), this material has the highest fracture resistance compared to Fuji IX and Miracle Mix. Equia Forte is strengthened by an addition of polyacrylic acid with an increased molecular weight and fine, highly reactive glass particles. An analysis by Duinen et al. (40) indicates that temperature increase in tooth chamber during Equia Forte glass ionomer polymerization is not an irritating agent for the pulp. In the case of cavities 2.6 mm deep, the temperature increase after exposure to an LED lamp for 90 seconds was 1.9°C, and in cavities 4.7 mm deep it equaled 2.4°C. Such an increase in temperature should not pose a threat to the pulp tissue. In a study by Zach and Cohen (41) conducted *in vivo* on monkeys, temperature increase by 5.5°C for 10 seconds caused irreversible pulpitis in 15% of the studied cases, while temperature increase by 11.1°C for 10 seconds caused irreversible pulpitis in almost 70% of the analyzed cases.

Other methods

Other authors propose to eliminate bacteria by proper preparation of cavity surface. In their study Safwat et al. (42), before the final filling, subjected partially prepared dentin to ozone for 40 seconds or to ozone and fluid capable of remineralization and pH equalization, called PH Balancer, Curazone Inc. The study showed no significant effect of ozone or ozone together with a remineralizing agent on the color and consistency of dentin compared to the control group, where calcium hydroxide liner was used. Trairatvorakul and Sastararuji (8) subjected partially prepared dentin of deciduous molars to treatment with 12% EDTA solution for 60 seconds, then applied a mixture of three antibiotics: Metronidazole, Ciprofloxacin and Minocycline. The cavities were filled with conventional Fuji II glass ionomer material. After 6-11 months of follow-up, clinical and radiological assessment demonstrated effectiveness of this method in maintaining vital pulp without signs of inflammation in 81% of cases, and after 12-29 months of follow-up, clinical success was 78%. Long-term observations of effects of the abovementioned method vary greatly compared to use of calcium hydroxide, where after 12-29 months the percentage of teeth with successful treatment outcome was 94%.

Assessment of deep caries treatment effectiveness and possible complications

Assessment of the effectiveness of deep caries treatment can pose difficulties especially for the single-stage method. Periodic clinical checks are aimed at obtaining information on provoked or spontaneous pain ailments, examination of the alveolar process for pathological lesions on the mucosa, such as redness, fistulas and edema (8, 11). It is also justifiable to take an x-ray after a few months to assess possible secondary caries under the filling, check for a presence of pulp inflammation and of the resorption process or periapical lesions. A study by Safwat et al. (42) demonstrated unreliability of the DIAGNOdent device in assessment of deep caries treatment progression. It is probably caused by the proximity of the left dentin to the pulp of immature tooth, which interferes with device reading.

Preparation of a deep cavity and subsequent placement of filling material, even using minimally invasive methods, always constitutes an irritating factor to the pulp. In treatment of deep caries, a thin layer of dentin provides poor insulation against harmful effects of mechanical and chemical factors. At this stage it is important to isolate the tooth from access of saliva and bacteria from the oral cavity, it is beneficial to rinse the cavity with 0.02% chlorhexidine or use ozone in order to reduce the number of cariogenic pathogens. Some authors recommend combining cavity preparation methods prior to filling (43).

A cavity that exceeds half the thickness of dentin is a cause of pulp inflammation. Heat generated during turbine operation or filling polymerization, cooling with cold water, changes in pH may cause irreversible inflammatory lesions. The consequence of inflammation is necessity for endodontic treatment of the tooth or frequently its extraction – in case of multi-rooted teeth with incomplete development of apices (40, 44).

Conclusions

In case of improper or late treatment of caries, especially deep caries in permanent immature teeth, there is a high risk of pulp necrosis. Positive prognosis is possible on condition of correct diagnosis and application of appropriate treatment, as well as good cooperation with the patient and his/her carer.

Periodic interview, physical and radiological examinations of treated teeth is crucial. It is necessary to search for new, more biocompatible materials that – thanks to remineralizing properties – will allow even more effective treatment of advanced caries in children's teeth.

Conflict of interest
Konflikt interesów

None
Brak konfliktu interesów

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