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The Effectivity of Acemannan Sponge and Calcium Phosphate Cement-Calcium Sulfate Hemihydrate (CPC-CSH)-Diode Laser-Assisted Method on the Direct Pulp Capping

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Abstract

Dental caries, the decay of tooth, affects approximately 2.3 billion people worldwide and reaches 88.8% of the total Indonesians. Caries reaching the pulp requires direct pulp capping (DPC) therapy to preserve pulp vitality. $Ca(OH)_2$ is the golden standard DPC material, but its adhesion and mechanical properties are poor. Therefore, an alternative therapy is needed to improve the success of DPC using acemannan sponge and calcium phosphate cement-calcium sulfate hemihydrate (CPC-CSH)-diode laser. Acemannan, polymannose extracted from aloe vera gel, plays a role in reparative dentin formation that is immunomodulatory, antimicrobial, biocompatible, and accelerates wound healing. Calcium Phosphate Cement (CPC), bioactive material used in tissue engineering. Calcium sulfate hemihydrate (CSH), inorganic component and biocompatible. The combination of CPC-CSH can shorten the setting time, maintain compressive strength, and has good handling properties. Low level diode laser (LLDL) plays a role in reparative dentin formation by altering growth factors expression to stimulate cell proliferation and fibroblast development. LLDL is applied before pulp capping material application between the pulp-dentin so that aggregated collagen fibrils are collected and stimulate the formation of odontoblasts. This paper aims **t**o describe The Effectiveness of Acemannan Sponge and Calcium Phosphate Cement-Calcium Sulfate Hemihydrate (CPC-CSH)-Diode Laser Assisted Method in Direct Pulp Capping Therapy. Article searching uses the Preferred Reporting Items for Systematic Reviews and Meta-analyses with keywords (MeSH): "DPC and Acemannan", "DPC and CPC-CSH", and "DPC and Diode Laser" from Pubmed, ScienceDirect, and Google Scholar databases in 2019-2024. Acemannan Sponge and Calcium Phosphate Cement-Calcium Sulfate Hemihydrate (CPC-CSH)-Diode Laser Assisted Method are effective as Alternative Direct Pulp Capping Therapy.

Keywords: Acemannan Sponge, CPC-CSH, Diode Laser, DPC, Reparative Dentin, Good Health and Well Being

Introduction

Dental caries is one of the most prominent oral health problems in developing countries, where 2.3 billion people experienced dental caries on their permanent teeth at some point in their lives, and at least 530 million children have dental caries on their primary teeth. Currently, 88.8% Indonesians suffer from caries. Dental caries which have exposed the pulp requires therapy to maintain pulp vitality [1]. A procedure that can be utilized is direct pulp capping (DPC), which uses the proliferative ability of human dental pulp cells to seal the pulp chamber using bioactive materials to form reparative dentin [2].

Any DPC material must not induce pulp inflammation or necrosis. Calcium hydroxide ($Ca(OH)_2$) is considered the golden standard for DPC material due to its high biocompatibility, alkaline pH, antibacterial properties, and ability to form reparative dentin on exposed pulp chamber. However, $CaOH_2$ is alkaline, which can induce pulp inflammation and necrosis [3].

Innovative alternatives are now explored to search the ideal material to stimulate reparative dentin formation to preserve tooth vitality in teeth with deep carries and exposed pulp chamber. For example, acemannan is a polymannose extracted from aloe vera gel which plays a role in forming reparative dentin. This material is immunomodulatory, antimicrobial, and biocompatible. Acemannan is also shown to accelerate wound healing. Due to its structure, however, acemannan has a radiolucent appearance on radiographs, which in turn needs to be combined with an opaquer to prevent misinterpretations on radiographs, such as empty cavities or occult caries [4].

Calcium phosphate cement (CPC) is a radiopaque material which is typically used for hard tissue repair because of its biocompatible and non-exothermic properties. The addition of calcium sulfate hemihydrate (CSH), which is also biocompatible and non-toxic, shortens the setting time and has the potential to be introduced as an alternative DPC material [5]. Laser diodes is a laser beam which provides photothermal and biostimulating effects via excellent and smooth hemostasis, which then becomes a suitable place for migrating fibroblasts and inflammatory cells to aid the formation of reparative dentin [6]. Laser diodes is also cheap, small, and easy to set up [7, 8]. Utilization of low level diode laser (LLDL) can increase odontoblasts' metabolic activity which aid the closure of dentinal tubules via reparative dentin formation [9].

Based on the description above, this paper aims to explain the effectiveness of Acemannan Sponge and Calcium Phosphate Cement-Calcium Sulfate Hemihydrate (CPC-CSH)-Diode Laser Assisted Method in Direct Pulp Capping Therapy.

Literature Review

Caries

According to World Health Organization (WHO), dental caries is a localized post-eruption pathological process which softens hard tissue of the tooth with external etiologies. The etiology of caries is complex, and is further complicated by other factors which may interfere in diagnosing its direct cause [23].

As far as science has known, dental caries is strongly associated with the presence of S. mutans in the oral cavity. The etiology of dental caries is a combination of 4 factors occurring simultaneously, which are: 1) vulnerable host; 2) cariogenic oral flora; 3) substances which can be metabolized by cariogenic oral flora; and 4) time [23].

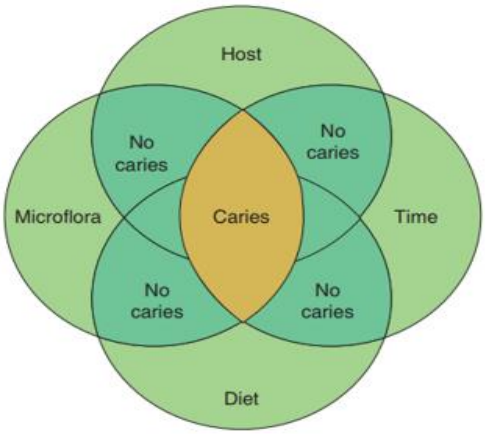
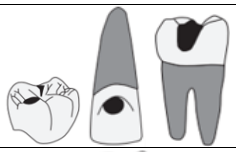


Fig 1: *Caries tetrad* proposed by Newbrun in 1982 [23].

Several classifications of dental caries are often used today, such as the Black's and Mount's classifications. The classification of caries according to Black refers to the anatomical area involved and the type of treatment, divided into 5 classes and then ad 6th class added by Simons (class I to class VI) [23]. The table below lists the Black's caries classification.

Table 1: Black's caries classification, including its description of cavity location and illustration [23]

Class	Cavity location	Illustration
I	Molars and premolars: Occlusal surface Maxillary incisors: Palatal surface Molars: $^2/_3$ occluso-facial/occluso-lingual surface	
II	Proximal surface of posterior teeth	
III	Proximal surface of anterior teeth, no incisal surface involvement	
IV	Proximal surface of anterior teeth, with incisal surface involvement	
V	Gingival $^1/_3$ of the facial or lingual surface of any tooth	
VI (Simon)	Anterior teeth: Incisal surface Posterior teeth: cusp apexes	

Meanwhile, Mount classifies cavities based on their location and size, namely caries in the pit and fissure, on the proximal surface and on the cervical surface [23].

Table 1: Classification of caries according to Mount [23]

Location	0 = No Cavity	1 = Minimal	2 = Moderate	3 = Advanced	4 = Extensive
Site 1: Pits and fissures	1.0	1.1	1.2	1.3	1.4
Site 2: Proximal surfaces	2.0	2.1	2.2	2.3	2.4
Site 3: Cervical surfaces	3.0	3.1	3.2	3.3	3.4

Pit and fissure caries are dental caries on the occlusal surfaces of posterior teeth, the buccal and lingual surfaces of molars, as well as the palatal surfaces of maxillary incisors. This caries is the most common type of dental caries found because of its narrow and deep physical characteristics, making it more challenging to clean [23].

Fig 3: Pit and fissure caries: Clinical appearance (left), diagram (middle) and radiographic appearance of the mandibular second molar (right) [23]

Smooth surface caries, is caries that is found on the proximal surface of the tooth or on the gingival third of the facial/buccal and lingual/palatal surfaces. This caries appears like white spots on the enamel but with intact enamel surface. In some cases, it appears as a yellowish or brown area [23].

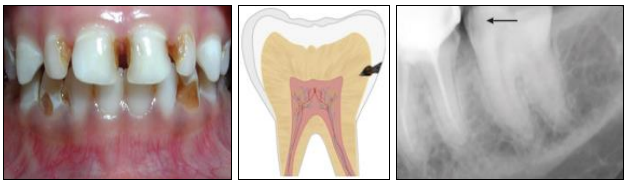


Fig 4: Smooth surface caries: Clinical appearance on the mesial surface of the maxillary central and lateral incisors and on the labial surface of the mandibular canine (left), caries diagram *smooth surface* (middle), and radiographic appearance of smooth surface caries indicated by the black arrow (right) [23]

According to Hazen *et al*, root caries is defined as a progressive soft lesion found on the root surface of a tooth that has lost its connective tissue attachment and is exposed to the oral environment. This caries is also often referred to as *senile caries*. This caries is often found in the teeth of older people with gingival recession and exposed tooth roots. The most frequently found pathogens are *Actinomycetes* [23].

Direct Pulp Capping

Direct pulp capping (DPC) is a procedure which include covering the exposed pulp with a dressing/bioactive material. This procedure is intended to prevent pulp extirpations and root canal treatments. DPC involves applying the material directly above the pulp, followed by immediate permanent restoration [10].

Calcium hydroxide ($Ca(OH)_2$) is a golden standard DPC material. However, $Ca(OH)_2$ lacks adhering ability to the dentin wall, might form tunnel defects in reparative dentin, and minimal antibacterial properties. $Ca(OH)_2$ also has highly variable success rates in the application as a DPC material, often unsuccessful and unpredictable [10]. DPC is indicated for non-carious lesions with a small pulp exposure (<1.5 mm). Bleeding area must also be controlled and the tooth does not react to bite test and percussion test. DPC is contraindicated if the tooth experiences pain on the pulpal or periapical site [23].

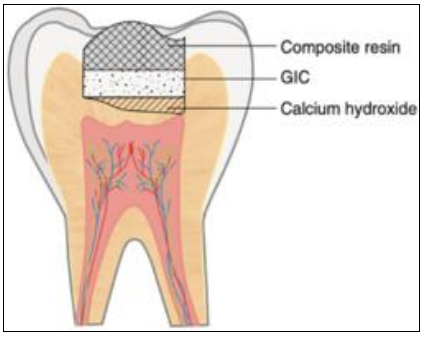


Fig 5: Direct pulp capping [23]

DPC begins by debriding the carious lesion. Any bleeding site must be sealed and suppressed using cotton pellets soaked in sodium hypochlorite (NaOCl). Afterwards, a liner with antibacterial properties is applied on top of the pulp chamber and sealed well. Usually, $Ca(OH)_2$ is used for its antibacterial properties and affordable price. Innovative materials such as mineral trioxide aggregate (MTA) and Biodentin have also been utilized [23].

Reparative Dentin

Reparative dentin is one of the two types of tertiary dentin matrix which is produced by odontoblast-like cells, replacing post-mitotic odontoblasts' function that produces primary and secondary dentin, due to significant damage. Reparative dentin will form on the surface of the pulp when caries has invaded the enamel through to the dentin. The formation of reparative dentin which covers the pulp chamber is a bone-like structure made of collagen and non-collagen proteins, namely osteocalcin and osteopontin, is called osteodentin [11].

Acemannan Sponge

Acemannan sponge (AS) is an ingredient which is traditionally used to prevent cancer, metabolic diseases, skin diseases, and cardiovascular diseases. AS is a polymannose acetate B-(1–4) molecule extracted from aloe vera gel. AS has the potential to be a DPC material due to its ability to avoid new stimuli to the pulp. AS has proven to have good biocompatibility, non-toxic, and does not irritate the pulp while being able to sterilize and encourage repair and regeneration of pulp tissue [14]. AS also induces the expression of dentin matrix proteins, secretion growth factors, and mineralization by pulp cells. AS also modulates proteins immunologically by selectively binding to TLR5, increasing DNA binding of NF-Kb, and increasing IL-6 and IL-8 expression. As a result, AS can accelerate wound healing from inflammatory phase to formative phase [24].

Fig 6: Acemannan sponge [25]

In-vivo studies have shown that AS induces pulp healing and reparative dentin formation in reversible pulpitis due to LPS. AS also sparked the formation of histological-mineralized bridge with unharmed pulp tissue without inflammation and necrosis. AS can also serve as a scaffold to facilitate the formation of gel-like blood clots, which attracts odontoblasts, fibroblasts, and progenitor stem cells in the pulp to form reparative dentin. However, its monosaccharide structure makes AS radiolucent and is easily absorbed by the pulp. CBCT photographs of DPC-treated teeth using AS shows the radiolucent dentin bridge covering the pulp is between the pulp and AS. In short, AS has the potential to be a DPC alternative biomaterial, but it needs to be combined with inorganic radiopaque fillers to reduce radiography misinterpretations [24].

Calcium Phosphate Cement-calcium Sulfate Hemihydrate (CPC-CSH)

Calcium phosphate cement (CPC) is a bioactive material used for hard tissue engineering due to its similarity in chemical structure to bones and teeth [12]. CPC contains tetracalcium phosphate (TCP) and dicalcium phosphate anhydrous (DCPA). CPC is biocompatible, non-exothermic, easy to handle and has a paste-like consistency. CPC is synthesized via mixing calcium phosphate powder with water or an aqueous solution, which undergoes a hydrolysis process, then dissolves and precipitates at room temperature. CPC has a trait called molding capability, e.g. CPC able to fit into cavities or defects [12].

Calcium sulfate hemihydrate (CSH) is an inorganic material used to treat periradicular lesions, periodontal defects, root perforations, and as a membrane barrier. CSH is biocompatible, non-toxic, cheap, and easy to set up. CSH is able to increase osteoblastic activity by releasing Ca^{2+}. CSH also has a decent success rate as a DPC material. Combining CPC and CSH results in shortened setting time, maintained compressive strength, and easy manipulation [5].

Diode Laser

Diode laser is a laser developed in the field of dentistry with a wavelength ranging from 800-980 nm. Diode laser can coagulate, cut, whiten, and disinfect with minimal damage to hard tissue and better post-operative healing thanks to its ability to absorb high levels of melanin and hemoglobin [16]. Diode laser also increases tooth resistance to acid byproducts from microorganisms. Laser diodes indirectly destroy microorganisms by causing detrimental damage which leads to inhibited growth and accumulated metabolic products in their cytoplasms, resulting in cellular stress and changes in interaction leading to death. These phenomena are also replicated in various types of soft tissue surgery [16]. Low-level diode laser (LLDL) can reduce the heat produced during usage on the target area, as excessive heat might harm tissues. Using LLDL as a photoactivator causes damage to membranes and DNA of microorganisms, a technique called photoactivated disinfection (PAD). PAD effectively kills resistant subgingival plaque bacteria in deep periodontal pockets [26].

Fig 7: Biolase diode laser (biolase.com)

LLDL is also known as biostimulation. Low-energy laser therapy (2 J/cm^2) can stimulate fibroblast proliferation, wheras high-energy laser (16 J/cm^2) can inhibit its proliferation. Increased proliferation and locomotion of fibroblasts may increase the tensile strength of scar tissue. LLDL also promotes mitosis and osteoblast-like cells differentiation 72 hours after irradiation. With its potential, LLDL can be combined with other regenerative methods or utilized on its own to stimulate tissue repair and accelerate wound healing [26].

Discussion

Vital pulp therapy (commonly known as root canal treatment) is the main treatment for exposed pulp due to caries, trauma, or iatrogenic procedure. Root canal treatment (RCT) is indicated only to mature permanent teeth, however, as conducting this procedure on otherwise mature teeth will result in immature root formation and widened apical foramen [18]. This would cause the teeth to be vulnerable to fracture. As an alternative, DPC aims to maintain pulp vitality which will not harm developing teeth [4].

DPC is an open pulp treatment which includes applying a dressing to maintain pulp vitality and induce reparative dentin formation. The indications for DPC are vital pulp tissue, no pain due to pulp exposure, a lesion <1.5 mm, no periapical lesions, sufficient tooth structure for restoration, lesion located near the pulp, intact lamina dura, no radiolucency around furcation area, no root resorptions, and no pulp obliteration [19, 20].

DPC materials have been developed to increase treatment success rate [3]. An ideal DPC material is easy to handle during operation, adhere to tooth surface, antibacterial, good sealing ability, insoluble in tissue fluid, biocompatible and bioactive, capable of forming a mineralized tissue barrier, radiopaque, and does not cause tooth discoloration [21]. Also, a DPC material must be able to stimulate reparative dentin formation [12]. However, current materials available are not ideal for DPC. For example, $Ca(OH)_2$ can cause damage to

the pulp tissue layer and creates an uncontrolled necrotic zone. This layer will then be attacked by immune cells through a long inflammatory process, which then forms an intrapulpal calcification. $Ca(OH)_2$ is also highly soluble [14].

Acemannan has been studied to be used as a DPC material [14]. Acemannan is an ingredient which is able to stimulate dentin matrix proteins expression, including type I collagen, osteopontin, dentin sialophosphoprotein, alkaline phosphatase, bone morphogenetic protein 2 (BMP-2), BMP-4, vascular endothelial growth factor (VEGF), and dental pulp cells mineralization. Acemannan also has immunomodulatory properties. For example, acemannan induces pulp healing and dentin formation of reversible pulpitis due to LPS in canine teeth and reversible pulpitis due to caries in human primary teeth [4]. Acemannan has also shown its capability as a DPC material, as studied by Ahmed *et al*. in 2020 with 77.8% success rate. This is due to it being biocompatible, anti-inflammatory, and antimicrobial. This can play a crucial role in reparative dentin formation. Clinical studies shown that acemannan and $Ca(OH)_2$ have no significant difference in success on DPC treatment after 6 months, 72.73% and 70% respectively. However, acemannan prevail in milder pulp inflammation compared to $Ca(OH)_2$. Acemannan also formed a dentin layer similar to secondary dentin [14].

Fig 8: Application of acemannan as a direct pulp capping material and $Ca(OH)_2$ [14]

Acemannan with all its beneficial properties has one major problem in radiology due to its radiolucency. To overcome this issue, a radiopaque material such as calcium phosphate must be added into acemannan to produce a hybrid organic-inorganic material [12].

Diode laser with its biostimulating beam activates cells and increase wound healing speed by altering gene expression of PDGF, TGF-β, and bFGF, all responsible for cellular proliferation and fibroblast development [22]. Utilizing diode laser at low-level energy (LLDL) will have lower thermal effect, which then lessen the possibility of pulp tissue damage [17]. LLDL also blocks C fiber depolarization and stimulates sodium-potassium channel pumps in cell membranes, which reduces nerve impulses and increases pain threshold [9]. Combining acemannan with CPC-CSH as a DPC material, coupled with LLDL which stimulates hemostasis on exposed pulp, may have the potential to be an alternative DPC treatment.

Conclusion

Acemannan Sponge and Calcium Phosphate Cement-Calcium Sulfate Hemihydrate (CPC-CSH)-Diode Laser Assisted Method are Effective as an Alternative to Direct Pulp Capping Therapy.

Acknowledgment

Nil.

Conflict of Interest

The author declares no conflict of interest.

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