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Master's Thesis

Alternative Methods of Tooth Hard Tissue Preparation

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I Summary

Dental caries, a disease of dental hard tissues, is the most prevalent non-communicable illness in the world. Traditional therapies for caries removal are frequently connected with pain and anxiety; hence, alternative therapeutic techniques have been created in the direction of more conservative and pleasurable treatments. The alternatives include chemomechanical caries removal and laser treatment. This systematic study intended to evaluate the efficacy, efficiency and patient acceptability of various alternative caries removal techniques in contrast to conventional techniques. The databases of Cochrane Library, Embase, Medline/PubMed, ScienceDirect, Web of Science, semantic scholar, and Clinical Trials were searched. The results for the chemomechanical caries removal showed that there is no statistically significant difference regarding the efficacy. In terms of efficiency it performed worse than the conventional method. Regarding discomfort and anxiety the chemomechanical caries removal performed better. The results for the laser treatment are similar regarding the efficacy but the treatment with laser tended to be longer than the conventional method aswell. In terms of need for anesthesia and patient discomfort the laser is preferred over the conventional treatment. In order to establish their potency as an effective caries removal agent a good number of clinical trials are needed.

Keywords: Dental caries, caries treatment, conventional caries treatment, alternative caries treatment, chemomechanical caries removal, laser caries removal

II Null Hypothesis

There is no significant difference in tooth hard tissue preparation by alternative methods when compared to the conventional method in permanent teeth.

III Alternate Hypothesis

There is a significant difference in tooth hard tissue preparation by alternative methods when compared to the conventional method in permanent teeth.

IV Introduction

Dental caries is the most prevalent chronic dental disease worldwide, along with periodontitis. It is regarded as a complicated infectious microbial disorder. The demineralization of the tooth's inorganic components and the damage of its organic components are features. Dental caries gets formed in the presence of a host, flora, and a substrate. The various microorganisms that cause caries are numerous. Although the prevalence of tooth decay has decreased significantly over the past 30 years due to preventive measures such as fluoridation, caries is still a significant problem for children and adults [Uribe, S. E. et al., 2021]. According to the Global Burden of Disease 2019 report, untreated dental caries in permanent teeth is the most prevalent health condition, with 90 percent of the population having untreated or treated tooth decay [Global Burden of Disease Collaborative Network, 2021]. Furthermore, it can be stated that the decline in caries does not seem to have continued since the end of the last millennium and could therefore possibly be complete [Featherstone, J. D., 1999]. After diagnosing caries that requires treatment, the diseased and infected tooth structure must be removed.

In order to prevent further damage of the teeth, it is essential to treat caries and therefore prevent the involvement of the pulp. There are various methods for removing caries, such as minimally invasive techniques, rotary method with different types of burs, chemomechanical caries removal, kinetic cavity preparation, and lasers [Cardoso, M. et al., 2020].

The following criteria are applied to the preparation process: substance protection through the following criteria; the most selective possible removal of the diseased hard tooth substance; keeping the pulp vital and intact; freedom of pain for the patient, and arresting the caries in order to stop the development of new caries. Since these required criteria are only inadequately met with the "bur", dentistry has made every effort to replace rotary instruments with new technologies. The alternatives offer a perspective here [Widbiller, M. et al. , 2022].

V Literature search strategy

For the identification of studies for this review, an electronic search was performed using the databases: Cochrane Library (www.cochranelibrary.com), Embase (www.embase.com), Medline/PubMed including the advanced and MeSH searches (www.ncbi.nlm.nih.gov/

pubmed), Web of Science (www.webofknowledge.com), ScienceDirect (www.sciencedirect.com), semantic scholar (https://www.semanticscholar.org) and Clinical Trials database (www.clinicaltrials.gov). The search strategy was firstly developed for Medline/PubMed using a combination of controlled vocabulary and free text terms, and then appropriately revised for each database.

VI Main Discussion

6.1 Theoretical Background

6.1.1 Classification of teeth

The human teeth are structured differently according to their different functions. The incisors are chisel-shaped and are used for biting; the long canines with only one chewing cusp are well anchored and are used to hold food. The following premolars have a broader crown and are equipped with two chewing cusps for grinding and squeezing food, while the molars with four or five chewing cusps do the most chewing work [Schuez, I., and Alt, K. W., 2022].

Furthermore, a tooth is divided into different parts. The anatomical crown of the tooth with the incisal edge, or the occlusion is the visible part of the tooth. The root of the tooth is anchored in the alveolus, and the neck of the tooth is surrounded by gingiva and located in between the crown and root. The crown of the tooth is the part covered by the enamel. The root is made up of dentin and cementum. The neck of the tooth is the junction between the crown and the root, the so-called cemento-enamel junction. The root is resiliently attached in the alveolus of the jaw by the connective tissue periodontium [Arola, D. D. et al., 2017]. These collagen fibers run in different directions between the alveolar wall and the cementum. The fibers that descend diagonally to the tip of the root counteract the chewing pressure, while those ascending to the neck counteract the tension on the tooth. Horizontal fibers over the alveolar rim connect adjacent teeth to each other through the cement-to-cement course. In addition, the periodontium is covered and protected by the gums. The periodontium itself is rich in vessels supplied by the artery entering the foramen apicis radicis dentis and the medullary vessels of the alveolar process. Innervation is provided by sensory nerve fibers that are responsible for the sensation of pressure in this area.

All structures involved in tooth attachment, such as cement, alveolar wall, periodontal ligaments and gingiva, form the periodontium [Torabi, S., and Soni, A., 2022].

In order to be able to discuss the topic of this thesis, which is ´Alternative Methods of Tooth hard Tissue Preparation´, the different types of tooth structures should be first differentiated. In general, a tooth is composed of four different dental tissues. Every tooth is made up of three hard substances. The core of the tooth is made up of dentin, which encloses the pulp cavity. Coronally, in the region of the tooth crown, enamel covers the dentin; in the region of the root, tooth cementum. The pulp cavity surrounded by the hard tooth substance contains the pulpa dentis, a soft, or non-calcified, tissue. It merges into the canalis radicis dentis in the area of the root. At the tip of the root, blood vessels, myelinated and unmyelinated nerve fibers enter through the foramen apicis dentis [Farci, F., and Soni, A., 2022].

6.1.2 Tooth structures

6.1.2.1 Dentin

Development and structural features

Dentin makes up the majority of human and mammalian teeth. The odontoblasts, dentin-forming cells, develop from the dental papilla and are of ectomesenchymal origin. In the further differentiation steps, in addition to changes and relocation of the cell organelles, there is an enlargement of the cell and the formation of a strong distal cytoplasmic process. After completion of the developmental steps, the progenitor cell has become a highly specialized, secreting odontoblast which, however, has lost the ability to synthesize type III collagen [Goldberg, M. et al., 2011].

The mature odontoblast forms a primary product, the so-called predentin, which is polymerized extracellularly to form collagen fibrils. The odontoblast ground substance, on the other hand, is made up of non-collagenous building blocks [Goldberg, M. et al., 2011]. Distal to the rows of odontoblasts, an accumulation of organic predentin forms, which, after some time, is mineralized at a distance of 5-20 µm distal to the cells. The subsequent enamel-dentin junction forms from a thickened basal membrane, which consists of a wavy basal lamina and a mat of fine, aperiodic microfibrils. It was also called "membranula praeformativa" by Raschkow [Garbarsch, C. et al., 1994]. Thus, at the interface between the dental papilla and the inner enamel epithelium, a cytoplasmic membrane of the preameloblasts forms on the outside, on which the first prism-free enamel is deposited, and a fibrillar structure on the inside, which becomes peripheral dentin.

The dentin is further subdivided into three different structures: the mantle dentin, the circumpulpal dentin, and the peritubular dentin.
Five elements of dentin are responsible for its characteristic structure [Goldberg, M. et al., 2011]:

- the odontoblasts and their associated cytoplasmic processes
- the dentinal tubules
- the peritubular dentin
- the intertubular dentin
- and the mantle dentin

Owing to their location, the odontoblasts are located in the periphery of the pulp, on the inner surface of the dentin. Since the thickness of the dentin margin varies greatly, the odontoblast process can be up to 5 mm long. This in turn branches into microvilli that reach into the intertubular dentin and can communicate with neighboring odontoblasts. These odontoblast processes lie in dentin tubules that run through the mineralized dentin. In the crown dentin tubules are more S-shaped; in the root area, they are straight. Peritubular dentin can be formed throughout life. It thus fulfills the important function of defending dentin and pulp against pathological processes such as caries [Goldberg, M. et al., 2011].

6.1.2.2 Enamel

Development and structural features

Until 1689, tooth enamel (enamel) was thought to be a bradytrophic tissue made up of fibers in humans and animals. It was shown that neither organic nor inorganic melt components contain fiber structures and that it is a crystalline structure [Havers C., 1691].
Ameloblast differentiation is almost analogous in humans, monkeys (Macaca mulatta/ arctoides), and cats and follows that of the odontoblasts [Rao, A., and Cölfen, H. 2016].
The ameloblasts are hexagonal cells up to 70 µm in size with microvilli at the distal pole and a large cell nucleus, as well as all signs of protein synthesis and secretion. The enamel matrix, proteins with proline, histidine, leucine, glycine, and glutamate, as well as glycoproteins and glycosaminoglycans, are secreted as granules by the ameloblasts and enriched with calcium and phosphate. This is how the first apatite crystals form at the border to the dentin. Tomes' processes are pyramidal protuberances of the ameloblasts

directed towards the odontoblasts, which, together with the change in position of their cells during enamel formation, later produce the typical arrangement of the enamel prisms. Once the enamel has formed, the ameloblasts are transformed into resorbable border cells and the Tomes processes are lost [Lacruz, R. S., 2017]. Tooth enamel is mostly composed of hydroxyapatite crystals, but contains more inorganic material than the comparable hard substances dentin and bone. By weight, mature enamel is composed of around 95% mineral material, 1–2% organic material, and 2–4% water. Tooth enamel is therefore the hardest substance in the organism, comparable to the hardness of quartz. 5 μm thick, multi-edged enamel prisms run through the entire enamel. Tooth enamel contains no collagen and less than 5% proteins [Lacruz, R. S., 2017]. It is striking that the enamel surface of a freshly erupted tooth reveals a line pattern with the naked eye, which can only be seen in about half of the cases in 30 to 40 year olds and only in a maximum of 15% of all teeth in 50 year olds. These lines, emerging as waves, are called perikymata or imbrication lines, which correspond to the intersections of the striae of Retzius with the enamel surface. [Scott J.H. et al., 1949]

6.1.2.3 Pulp

Development and structural features

The pulp develops from an ectomesenchymal accumulation of cells, which already shows the typical structure of the dental papilla at the beginning of the tooth hard tissue formation. In addition to the peripheral papillary cells, which differentiate into odontoblasts, there are mainly undifferentiated mesenchymal cells. In the course of tooth development, the branches of the alveolar arteries sprout and form a capillary network. If the first nerve fibers can already be observed in the papilla at the beginning of the tooth hard tissue formation, the actual subodontoblastic nerve plexus only develops during the final phase of the root formation. Due to the development of the hard tooth substance, the future tooth crown is formed from the tooth bell, while the papilla also enlarges due to cell proliferation. The pulp arises from the papilla. When the tooth erupts, the transformation of the papilla into the pulp is complete. Some mesenchymal cells remain as undifferentiated replacement cells in the mature pulp to replace necrotic odontoblasts if necessary and to serve as defense cells [Ghannam, M. G., 2022]. The pulp space is divided into crown cavity and root canals. The shape of the tooth crown and the crown cavity are the same. In the area of the incisal edges and the cusp tips, there are expansions of the cavity. These are called pulp horns. The roof of the cavity is made up of coronal dentin, and in teeth with multiple roots the floor of the cavity is made up of interradicular dentin. The alignment of the root canals follows the course of the root axes. This varies greatly from person to person. The number of openings at the root tip can vary greatly. Depending on the tooth, one or more foramina can be found. There is usually only one root canal in the front and lateral incisors, the canines and the second premolars.

The first premolars often have two or even three canals. The first lower molar shows very large individual differences in the number of canals. Four canals can usually be prepared here, but in individual cases it can be up to six.

The apical canal openings are distributed around the root tip with a diameter of 0.3-0.4 mm. If cement builds up or there are changes in the dentin, these can shift. In addition, about 70% of all teeth have additional side canals that enter the crown cavity directly from the furcation or also laterally into the root [Ghannam, M. G., 2022].

The pulp cavity is connected to the periodontal space via the root canals, but also via the accessory canals and the apical ramifications. These results show the diversity of the root canal topography, which according to Schroeder was presented by many authors on thousands of teeth. Due to the strong variability, depending on the number of root canals, the pulp chamber volume is also very different. This volume is reduced over the course of life, because secondary dentin is still being formed and leads to a narrowing, especially at the cavity floor and in the area of the pulp horns, and sometimes also on the side walls.

The pulp cavity contains connective tissue with highly specialized cells. There are odontoblasts, fibroblasts, immunological cells, intercellular ground substance with reticular and collagen fibers, as well as nerves and blood vessels.

The main component of the pulp cells are the pulp fibroblasts, which are distributed over the entire pulp as active and inactive cells. These flat and spindle-shaped cells form intercellular substances such as fibronectin, chondroitin sulfate, heparin, dermatan sulfate and reticular or collagen fibers.

Other cells are components of the immune system, histiocytes and lymphocytes. The number of fibrous structures in the pulp tissue is considerable, such as reticular, argyrophilic and collagenous fibrils and fiber bundles. A gel-like matrix surrounds the fibrous elements of the pulp tissue mentioned above. Components of this mass are in particular glycosaminoglycans, glycoproteins, dermatan sulfate and proteoglycans.

The pulp, which is heavily supplied with blood, is primarily supplied by a vessel that enters the pulp tissue through the apical foramen. In teeth with multiple roots, larger vessels can also enter and exit the tooth via the accessory canals [Ghannam, M. G., 2022].

6.1.3 Thermal properties

During the preparation of teeth heat, is generated. Therefore, it is important to determine the critical temperatures at which the tooth structures get damaged. Teeth that are exposed to high temperatures can lead to an evaporation of the organic components of the teeth and result in a separation of the enamel layer, allowing the dentin to get exposed and burned [Fereira J.L., 2008]. At 400°C, only a minimal separation of enamel from dentin is present in teeth from any group. At 700°C and above, enamel separation was clearly visible in teeth from all age groups. The separation became visible along the entire DEJ. Similar findings in teeth at 600°C were reported by Prakash et al. (2014). Deciduous teeth presented at temperatures exceeding 1000°C and more, with a higher separation than at lower temperatures. Even a complete loss of enamel from the underlying dentin occurred in teeth of adolescents. The older permanent group of teeth underwent similar observations. They showed a complete loss of their enamel layer at 1000°C as well.

In many studies, it was considered that the increase of the pulp chamber temperature to 42.4°C was the critical threshold. When the pulp chamber exceeds the threshold, irreversible damage may occur to the pulp [Savio C. et al., 2006].

As a consequence, it is important to take into consideration the generation of heat during the methods of hard tissue preparation in order to not damage the teeth.

6.2 Criteria for a tooth hard tissue preparation

The primary indication for treatment of hard tooth tissue in conservative dentistry is the removal of tissue sections that have undergone carious changes. Conventionally, mechanical methods are used for this, which allow a more or less selective removal due to the existing differences in hardness between healthy and carious material. With the aim of largely sparing healthy hard tooth substance, a selective removal of carious lesions is required, whereby as little healthy tissue as possible is to be removed. The following criteria are therefore applied to the preparation:

- protection of the hard tooth substance
- selective removal of caries

- compatibility with the pulp
- compatibility with the patient
- restoration of the function
- prevention of the development of new caries [Gupta, R. et al., 2021]

6.3 Conventional method of hard tissue preparation

As already mentioned, there are a few methods for removing caries in a minimally invasive technique: rotating instruments with different types of burs, chemomechanical caries removal, kinetic cavity preparation, and lasers. The conventional and most widely used method is the usage of different types of burs.

The conventional method involves the use of a high-speed handpiece and burs, which unquestionably improved the speed and efficiency of cavity preparation but also had a few unavoidable disadvantages, including:

1. unpleasant feeling for the patients
2. local anesthesia is required
3. harmful thermal effects
4. pressure exposure on the pulp
5. healthy dentin might be removed, which results in excessive loss of healthy tooth structure [Bussadori S.K. et al., 2005].

High speeds, multi-edged tools, and fine diamond grinding burs have led from the classic drill into a form of material processing that is more similar to grinding. This made precise and minimally invasive cavity preparation possible. The chattering effect reduced by the fine cutting tools in combination with an efficient cooling technology led to a reduction in the sensation of pain. Nevertheless, pressure, vibration, and temperature-related pain can never be completely prevented, which means that the use of anesthetics is essential in many cases. The wide range of available rotating tools and contra-angle handpieces allows precise adjustment to the required preparation purpose. The advantage of rotating instruments lies in the possibility of creating very precise cavity shapes, due to the geometrically precisely defined shape of the forging tool and the sensitive handling of the tool during preparation. Despite all these advantages, there are limits to rotary instruments when it comes to caries-selective and/or minimally invasive substance removal. When preparing with rotary instruments, a 1-5 µm thick smear layer forms, which must be removed before treatment with modern adhesive techniques. The heat generated when using rotary instruments is also problematic [Kani, E. et al., 2015; De Almeida Neves, A. et al., 2011]. Depending on the user, the temperature development depends on the handling, in particular on the cutting speed, the pressure exerted, and the sharpness of the drill. Accordingly, effective cooling during preparation is essential. Another risk is the possibility of injury to adjacent tissue. Both soft tissue and the intact neighboring teeth adjacent to the preparation site are at risk [Sarmadi, R. et al., 2018].

6.4 Kinetic cavity preparation

This preparation method uses an accelerated particle stream as a tool for material removal. Similar to sandblasting, aluminum oxide particles are entrained by an air flow and directed to the preparation site via a hose. The stream of particles breaks fragments out of the tissue structure and causes the tooth structure to be removed. The pressures of such systems are between 5 and 15 bar, with the spherical particles having a diameter between 10 and 50 µm. This preparation method enables very fine removal and thus, the production of lesion-specific cavity shapes. In addition, micro-retentive patterns are created on the cavity walls, which improve the bond between tissue and adhesive. The smear layer that typically occurs with rotating instruments is eliminated, which also makes the use of acid etching superfluous. The particle dust clouds that occur are a disadvantage. Special precautions are therefore necessary to prevent the particles from being inhaled by the patient, the dentist, or the assistants (rubberdam and good suction) [Laurell, K. A. et al. 1995]. Due to the lack of studies, the kinetic cavity preparation was excluded from the results, and the focus was on the chemomechanical caries removal and the preparation with lasers.

6.5 Chemo-mechanical preparation

Chemomechanical caries removal (CMCR) is a non-invasive technique that removes infected dentin using a chemical agent. This method of caries removal is based on the dissolution of the caries. The soft carious structure is removed without drilling by using a chemical agent in conjunction with a non-traumatic mechanical force. The main reason this alternative method of caries removal was introduced was to minimize the patient'S discomfort caused by the usage of drills and local anesthesia. Further reasons include maintaining a healthy tooth structure, thereby fulfilling the concept of minimally invasive dentistry (MID). Multiple CMCR agents have been used in the past, but only a few have achieved stable results in clinical practice. Among them, we have Carisolv, the most successful and widely used agent, while Papacarie is regarded as the CMCR agent of the future. Carisolv came into use at the end of the 20th century. It consists of a mixture of two components (mainly amino acids and hypochlorite) that form an active gel. Papacarie is an aspiring CMCR agent of the 21st century. Papacarie consists essentially of papain, chloramines, and toluidine blue. Papain interacts with exposed collagen by dissolving dentin minerals via bacteria, softening infected dentin, and allowing its removal with blunt instruments without the usage of local anesthesia or drills [AlHumaid, J., 2020; Hegde, S. et al., 2016].

6.5.1 Carisolv

Due to the high time necessary for CMCR treatment, the high quantities of solution required, and the fact that it was no longer commercially accessible, the usage of CMCR became insignificant, even though it had a big potential. In the beginning of the 1990s the marketing of Caridex (the predecessor of Carisolv) stopped, and the patent expired [Vougiouklakis, G., and Paroussis, D., 1988]. Around this period, Mediteam in Sweden was a developing a new system and the latest CMCR agent known as Carisolv was introduced in January 1998. Carisolv gel was a two-component mixture. The gel is activated by mixing the two components in a 1:1 ratio. One of the components primarily contained three amino acids (glutamic acid, leucine, and lysine) and sodium hydroxide. The other fluid contained the reactive hypochlorite component (NaOCl). The gel was available in two different packages: Carisolv gel multi mix and Carisolv gel single mix. Carisolv gel was initially offered in red. Latterly, the gel has been further developed at the University of Goteborg, Sweden. To improve its efficacy, an increase in the amount of free chloramines was needed, which in turn required a higher concentration of NaOCl. One effect of the higher concentration of NaOCl is that the color agent has been removed; that is, the gel is uncolored. Basic research has been performed on this revised gel composition, and no differences in terms of surface topography, pulp effects, or soft tissue effects have been noted [Yadav, N. et al., 2018].

6.5.1.1 Mechanism of Carisolv

Using one of the hand instruments, the gel is placed on the carious lesion, and after 30 seconds, the carious dentin may be carefully removed. These hand instruments are specially designed by the company to improve the caries removal process. Additional gel is then added, and the treatment is repeated until no more carious dentin remains; a guide to this is when the gel removed from the tooth is clear. The time required for the procedure is about 9 to 12 min (ranges from about 5 to 15 min) and the volume of gel is only 0.2 to 1.0 ml [Ericson et al., 1999]. The method is significantly easier to use than Caridex, its predecessor, and since it uses a gel rather than a liquid, it makes better contact with the carious lesion. After a CMCR with Carisolv, the cavity surface has been proven to be as sound as the surface after traditional drilling [Ganesh, M., and Dhaval, P., 2010]. The new system offered considerable attractions in certain cases, but if such a system had to become routine, it may need to be even more rapid in its mode of action. Toxicity tests have revealed that the solution is harmless and has no negative effects on pulp or healthy tissue; however, a few patients find the taste irritating. This is often not an issue, and patient acceptability is high. Its benefits include the lowered necessity for local anesthesia, the preservation of sound tooth structure, and a lower danger of pulp exposure. It is ideal for treating anxious, medically compromised, as well as pediatric patients [Yadav, N. et al., 2018].

6.5.2 Papacarie

Despite Carisolv being the most effective agent, it has a number of disadvantages, including substantial training needs and a bespoke instrument that raises the price of the treatment. Because of these, there was a restriction on its application. In order to solve these limitations of the Carisolv method, a new CMCR agent was developed in Brazil. The pharmacy Fórmula e Ação by Sao Paulo, introduced papain gel as Papacarie for chemomechanical caries removal agent [Bussadori et al., 2005]. Papacarie is a Brazilian national product that has been patented, registered, and authorized by ANVISA. It is composed mostly of papain, chloramine, and toluidine blue.

6.5.2.1 Papain

Papain is an enzyme derived from the latex of the leaves and fruits of Carica papaya, known as the adult green papaya. Similar to human pepsin, this endoprotein features bacteriocidal, bacteriostatic, anti-inflammatory, and debriding properties. It does not harm sound tissue but speeds up the cicatrization process and possesses bacteriostatic and antibacterial properties. It functions by separating collagen molecules that have been partly degraded by caries and is capable of digesting dead cells and removing the fibrin layer generated by the caries process. It appears to work only on carious tissue, which is lacking the plasmatic protease inhibitor alpha-1-antitrypsin, while its proteolytic activity is blocked on healthy tissue containing this molecule [Bussadori et al., 2008].

6.5.2.2 Chloramine

Chloramine is composed of chlorine and ammonia. It has antibacterial and disinfecting characteristics, and therefore it frequently used as an irrigating solution for radicular canals to chemically soften carious dentin. The chloramine chlorinates the component of the carious dentin collagen that was broken down. This simplifies the removal with an excavator [Sontakke, P. et al., 2019].

6.5.2.3 Toluidine blue

Malachite green was initially utilized as a coloring ingredient, but after a few trials, toluidine blue was shown to be particularly efficient against Streptococcus mutans. It is a photosensitive pigment that attaches to bacterial membranes [Banerjee, A. et al., 2000].

6.5.2.4 Advantages of Papain gel

Papacarie is a biocompatible gel with antibacterial qualities that avoids the need for anesthesia, removes just the infected tissue, and better maintains sound tissue. The use of the gel does not result in the production of a smeared layer. In addition, the gel combines atraumatic therapy with antibacterial qualities without causing damage to sound tissue or leading to discomfort. In vitro evaluation of Papacarie's cytotoxicity was done in fibroblast cultures at various doses (2, 4, 6, 8, and 10%). The conclusion was that any of the papain concentrations were possible for its development and that Papacarie was safe, non-cytotoxic in vitro fibroblast culture, and biocompatible with oral tissues [AlHumaid, J., 2020; Martins, M.D. et al., 2009].

6.5.2.5 Mechanism of Papacarie

The gel is applied on the carious tooth with a hand instrument. In acute caries, 30 seconds are enough; in chronic caries the gel should stay 40 up to 60 seconds. Chemical debridement occurs due to the papain gel, which is acting as a proteolytic agent. The fibrin ´mantle´ which is formed by the carious process, is degraded and eliminated. This ´mantle´ is a structure-less matrix layer present in the necrotic zone of dentinal caries. By digesting dead cells, the breakdown of the collagen molecules is caused. As a next step, this degraded collagen is chlorinated by chloramines, which also liberate the O2, resulting in bubbling action and blearing of the gel. Moreover, the chlorination of collagen disrupts the hydrogen bond and alters the secondary and quaternary structures. Due to that, the carious dentin chemically softens and facilitates the removal of caries tissue. The softened caries tissue can be removed with the opposite side of an excavator in a pendulum movement till the cavity gets a glass-like appearance [Hamama, H. et al., 2014].

6.5.3 Comparison of chemomechanical caries removal to conventional bur method

6.5.3.1 Efficacy (bacterial count, biocompatibility)

Deng et al. [Deng, Y. et al., 2018] drew the conclusion that after the treatment with Papacarie, fewer bacteria remained in comparison with conventional treatment.

Katiyar et al. [Katiyar, A. et al., 2021] stated out that regarding the efficacy statistically, there was no significant difference seen between the conventional and CMCR methods. The conclusion that was drawn from this trial is that the usage of a CMCR is minimally-invasive, selective, and precise.

Santos et al. [Santos, T. M. L. et al., 2020] analyzed the effectiveness and biocompatibility of the chemomechanical agents Papacarie Duo (PG) and Brix 3000 (BG) in comparison with the conventional bur, too. The treatment effectiveness was assessed by Knoop microhardness values, respectively. Human pulp fibroblasts (FP6) were used by incorporating Mtt dye for the evaluation of cytotoxicity, and genotoxicity was evaluated with the micronucleus test. Regarding the Knoop microhardness values, all methods tested were effective ($p < 0.05$). The final mean microhardness values were 48.54 ± 16.31 KHN, 43.23± 13.26 KHN, and 47.63± 22.40 KHN for PG, BG, and conventional bur. PG decreased the cell viability compared to that of BG, but it presented no genotoxicity.

Dr. Jehan AlHumaid [AlHumaid, J., 2020] evaluated the efficacy of Papacarie versus conventional method in caries removal also. The samples were examined under the scanning electron microscope (SEM) for the presence of bacterial colonies to be able to analyze the efficacy. During the in vitro investigation, there was no statistically significant difference in bacterial presence between the two groups under the SEM (Papacarie = 23.3%; conventional method = 16.7%; $P = 0.52$). In conclusion, he stated out that regarding the efficacy there is no significant difference between Papacarie and the conventional caries removal method.

Furthermore, Dogra et al. [Dogra, M. et al., 2021] collected samples of dentin from both groups for microbiological investigation. The conventional method had a mean reduction percentage of total viable count of 75.92 ± 2.49 compared with 61.85 ± 8.31 in the chemomechanical method of caries removal. But the difference was statistically non-significant ($p > 0.05$).

6.5.3.2 Efficiency (Time consumption)

Sontakke et al. [Sontakke, P. et al., 2019] examined the time consumption as well and stated out that the time consumed was statistically significant reduced by ($P < 0.0001$) when comparing the CMCR to the conventional method.
A different conclusion was drawn by Deng et al. [Deng, Y. et al., 2018], who compared the time needed for carious tissue removal as well. The time consumed for the removal of the caries was significantly lower with the conventional method.
According to Katiyar et al. [Katiyar, A. et al., 2021], the time taken with the usage of Carisolv gel was significantly higher statistically as compared to the conventional method ($p < 0.001$).
Additionally, Santos et al. [Santos, T. M. L. et al., 2020] did a clinical trial to analyze the efficiency and effectiveness of the chemomechanical agents Papacarie Duo (PG) and Brix 3000 (BG; similar to the structure of Papacarie as it contains Papaine as well) in comparison with the conventional bur. The treatment efficiency and effectiveness were assessed by the time consumed for caries removal, respectively. The conventional bur was less time consuming in removing the carious structures (median = 54.0 seconds) than compared to the time for chemomechanical agents ($p = 0.0001$). Nonetheless, BG was quicker than PG, with mean times of 85.0 and 110.5 seconds, respectively.
Dr. Jehan AlHumaid [AlHumaid, J., 2020] evaluated the efficiency of Papacarie versus conventional method in caries removal as well. He carried out the study by sectioning 30 extracted teeth mesiodistally into two halves through the center of their caries lesion, and each half was randomly subjected to caries removal by Papacarie and excavation using the conventional bur method. In order to evaluate the efficiency the time required, for the removal of caries was noted using a stopwatch. Caries removal with Papacarie required significantly more time (mean = 351.56 s) than with the conventional bur approach (mean = 158.41 s) ($P < 0.0001$).

Yun et al. [Yun, J. et al., 2018] stated as well that the CMCR is more time-consuming for effective treatment compared to conventional methods.

Dogra et al. [Dogra, M. et al., 2021] measured the time consumption using a stopwatch, too. The mean time required for caries removal with the chemomechanical method (4.64 ± 1.00 seconds) is statistically more when compared with the conventional method of caries removal (1.52 ± 0.35 seconds) ($p < 0.05$).

6.5.3.3 Anxiety and pain management

According to Sontakke et al. [Sontakke, P. et al., 2019], compared to the CMCR, there is a considerable rise in the amount of discomfort in the form of pain during the traditional approach. ($P < 0.0001$). As the CMCR agent Carie-Care was used in this clinical trial, which is similar to Papacarie, which was mentioned before. In total, 60 patients were examined, which were equally distributed between the CMCR and conventional drilling method. The levels of anxiety and acceptance did not show a significant difference in the clinical trial.

Also, Deng et al. [Deng, Y. et al., 2018] confirmed that the pain perception was significantly lower with Papacarie usage in three of the compared trials. The conclusion was drawn after comparing randomized and controlled clinical trials (RCTs and CCTs) to each other.

The Visual Analogue Scale (VAS) is a pain rating scale that was used by Katiyar et al. [Katiyar, A. et al., 2021] in their clinical trial. 30 teeth were treated in the conventional manner and 30 with Carisolv gel. After examining the 60 teeth, the mean VAS was significantly lower in the group with Carisolv usage. The VAS was 24.33 ± 11.04 among the group I patients (conventional method) and 3.00 ± 5.96 among the group II patients (Carisolv). Furthermore, it minimizes the need for anesthesia and enhances patient comfort. Additionally, it can avoid drilling close to the pulp, making treatment painless.

Yun et al. [Yun, J. et al., 2018] did a systematic review to evaluate to what extent CMCR could reduce pain and reduce the need for local anesthesia. The evaluation happened with Carie-Care as the CMCR agent. It is similar to Papacarie as it contains the enzyme Papaine as well. After the literature review, the conclusion was drawn that Carie-Care significantly reduces pain during caries treatment. Local anesthesia was not required in the process of CMCR. Furthermore, the dental anxiety decreased compared to the conventional method, and the patient's cooperation was more positive.

Additionally, Dogra et al. [Dogra, M. et al., 2021] did an in vivo study comparing 20 teeth treated in conventional manner to 20 teeth treated with Apacaries, which is similar to Papacarie as it contains the enzyme Papaine. Using a timer and the Wong–Baker Pain Scale, the duration and intensity of pain were determined. The mean pain score on the Wong-Baker Faces Pain Scale was substantially greater for the traditional approach of caries removal than for the chemomechanical method ($p < 0.05$).

6.6 Preparation with lasers

Not every laser is suitable for processing tooth structure. In 1964, the first attempt was made to remove enamel and dentin with the laser systems available at the time [Stern, R. H., Sognnaes, R. F., 1964]. The ruby laser used was able to melt and vaporize dentin, but the surrounding tissue was subjected to considerable thermal heat. Subsequent attempts with continuously radiating CO_2 lasers were also discontinued because of the low success rate and the large thermal damage. It was only 24 years later that tooth hard tissue could be successfully removed with the Erbium:YAG laser [Paghdiwala, 1988]. In 1989, Hibst and Keller showed that the preparation of cavities in enamel and dentin is possible without clinically relevant side effects [Hibst, R., Keller, U., 1989]. Erbium lasers are still the only systems commercially available for cavity preparation. However, since the CO_2 lasers with an emission wavelength of 9.6 µm and the ultra-short-pulse lasers are gaining in importance as alternatives for processing hard tissue, they are also presented at this point.

6.6.1 The Erbium laser

Erbium is one of the so-called ´rare earth elements´. As a laser-active medium (Er3+ ion), it is embedded in a synthetic carrier matrix that is transparent to the laser. The emission wavelength of the laser varies depending on the selected carrier matrix. For erbium, this is in the spectral range between 2.6 and 3 µm. The two erbium lasers that have become established in dentistry are the Er:YAG laser [Zharikov, E. V. et al., 1975] and the Er,Cr:YSGG laser [Zharikov, E. V. et al., 1984]. In the first case, the laser-active element (Er3+ ion) is embedded in a YAG matrix (carrier matrix). YAG describes nothing other than the chemical composition of this carrier material. For the second type of laser, the chemical composition is somewhat more complex. In addition to erbium, the carrier matrix is doped with chromium ions (Cr3+). This does not affect the emission wavelength of the laser but increases the pumping efficiency during flash lamp operation. The abbreviation

YSGG reflects the chemical composition of these crystals from the elements yttrium (Y), scandium (Sc), and gallium (Ga) in a garnet (G) structure. The chemical formula is Y3Sc2Ga3O12. This results in the naming of these laser systems: The Er:YAG laser with an emission wavelength of 2.94 µm and the Er,Cr:YSGG laser with an emission wavelength of 2.79 µm. Both laser systems emit mid-infrared light [Moulton, P. F. et al., 1988].

6.6.2 The CO_2-Laser

The carbon dioxide (CO_2) laser is the most powerful gas laser. Its technical realization took place in 1964 by Patel [Patel, C. K. N., 1964; Patel, C. K. N., 1964]. It belongs to the family of vibration-rotation lasers and is considered the most important representative of molecular gas lasers. With outputs of >100 kW in CW (continuous wave) operation and energies >100 kJ in pulsed operation with pulse lengths ranging from nanoseconds to milliseconds, this laser is especially suitable for material processing. In the special case of the biological hard tissue preparation of bones and teeth, the CO_2 lasers have to meet special requirements. In dentistry, so-called ´low-power sealed tubes´ with CW powers of up to 50 W and pulsed up to 300 W are generally used. The CO_2 laser has a wide range of uses in dentistry. The strong absorption in water and hydroxyapatite, whose maximum is located at 9.6 µm, makes it an ideal instrument for soft and hard tissue processing. In soft tissue surgery and in the treatment of leukoplakia, this laser has proven itself using the strongest emission line of 10.6 µm established [Ishii, J., 2003]. The use of the 9.6 µm emission line is ideal for the preparation of cavities and bones. With pulse lengths in the nanosecond to microsecond range (up to approx. 100 µs) and repetition rates of a few hundred kilohertz, very good preparations can be achieved using a scanner system [Ivanenko, M., 2005; Wigdor, H. A., 2002]. Such laser systems are currently in the clinical testing phase.

6.6.3 Ultrashort pulse laser

The ultrashort pulse lasers are a novelty. This type of laser is of the greatest interest to medicine. The generated power densities in the range of 10^{11}-10^{16} W/cm^2 generate athermal tissue ablation through photodisruption. Due to the very high intensities in the range from a few 100 gigawatts to the terawatt range, the ionization of the material is wavelength-independent, i.e., the tissue-specific absorption of the erbium and CO_2 lasers used in photoablation is no longer relevant. In dentistry, the first examinations were successfully carried out using a femtosecond laser [Strassl, M. et al. 2002]. However, the technical complexity of these devices is very expensive, which means that the ultra-short pulsed lasers are becoming so expensive that they are currently not profitable for clinical use.

6.6.4 Comparison of preparation with laser to conventional bur method

6.6.4.1 Efficacy

Wong [Wong Y. J., 2018] analyzed a systematic review to be able to evaluate if a laser removes caries as effectively as mechanical drilling. This study includes six split-mouth randomized controlled trials and three parallel group randomized trials with 1,498 primary and permanent teeth from 662 people aged between 3.5 and 84 years. 777 teeth were treated with lasers alone, 732 teeth were treated with mechanical drills alone, and 12 teeth were treated with both procedures in the same tooth for distinct caries. No significant difference in caries eradication efficacy was seen between the two treatment techniques. Intriguingly, the research that provided operator preference revealed that dentists prefer conventional preparation methods over laser ($P<0.001$). In terms of the secondary outcomes of marginal integrity of restorations (three studies), durability (four studies), recurrent caries (two studies), and pulpal inflammation or necrosis (four studies), there was no indication of a significant difference.

Insufficient data were available to evaluate if laser caries removal was more or less effective than traditional mechanical removal.

Vaddamanu et al. [Vaddamanu, S. K. et al., 2022] investigated tooth hard tissue preparation with an Er:YAG laser in vitro compared to that of traditional mechanical therapy. Teeth were treated with the Er:YAG laser on one half and in a conventional way on the other half, or they were left untreated on the other half for control. Each therapy was evaluated in terms of histological examinations of decalcified serial sections, scanning electron microscopy (SEM) analysis, and the density of the dentin. The Er:YAG laser was equally successful as the bur in eliminating diseased and soft carious dentin with no heat damage to adjacent sound dentin.

Johar et al. [Johar, S. et al., 2019] performed an in vivo study for the comparison of caries removal by an Er,Cr:YSGG laser and air-rotor handpiece. 50 teeth were treated by the same dentist. Following caries removal, a caries detection dye was put in the prepared cavity to evaluate the success of the treatment. In all groups, the caries detection dye was entirely eliminated, indicating that both methods were equally effective at removing caries lesions.

Xue et al. [Xue, V. W. et al., 2021] did a concise review on the effects of a 9,300 nm CO_2 laser on dental hard tissue. The conclusion was that a carbon dioxide laser with a wavelength of 9,300 nm fits the absorption properties of hydroxyapatite. Enamel and dentin can efficiently absorb the laser's energy. It transforms carbonated hydroxyapatite into enamel's and dentin's purer hydroxyapatite. Carbon dioxide lasers with a wavelength of 9,300 nm have a shallow depth of heat absorption in enamel and dentin, reducing the danger of thermo-damage to the dentin-pulp complex. The laser enhances the cavity-preventing properties of fluoride. It improves the adhesion of resin to enamel. It can also be utilized at high intensities to ablate cavities for restorative purposes. The 9,300 nm CO_2 laser is preferred over the 10,600 nm carbon dioxide laser, which is the most common carbon dioxide laser device on the market at present. This is due to the fact that it has excessive heat accumulation and lower efficiency in operation, which limits its application in clinical treatment.

Medioni et al. [Medioni, E. et al., 2016] investigated the effectiveness of the Er:YAG laser and low-speed rotary devices in removing carious tissue from 26 excised human molars and premolars with severe decay and no multiple contact. The teeth were separated into three groups of eight, with two teeth serving as controls. After sectioning each tooth through the middle of the carious lesion prior to excavation, each group was assigned randomly to one of three groups: Er:YAG laser against tungsten bur, Er:YAG laser versus polymer bur, and polymer bur versus tungsten bur. To evaluate the efficacy of the three techniques, samples were histologically examined. Histological examination of tooth halves treated with the Er:YAG laser revealed a uniformly stained layer of 5 µm thickness that appeared to be denatured collagen. A smear layer was frequently apparent on carbide bur-treated halves. A superficially disordered layer, identified as impacted dentin, was seen on polymer burs-treated halves. The present data show that the three procedures for removing the diseased dentin layer were clinically and histologically successful.

Marcelino et al. [Marcelino, G. D. S. et al., 2021] examined the application of the Er:YAG laser in dental caries removal in order to demonstrate its benefits and limits in clinical practice and to compare its efficacy with other caries removal techniques. They found that the Er:YAG laser is a suitable therapy option for caries because it may eliminate demineralized tissue without harming the tooth structure. In general, the Er:YAG laser is equally efficient as conventional and chemomechanical caries eradication techniques.

Valenti et al. [Valenti, C. et al., 2021] They assessed the photothermal and mechanical effects of Erbium:Yttrio-Aluminum-Garnet (Er:YAG) lasers on cariogenic species concentration and on the microbial load composition of therapeutic cavities in order to evaluate the potential microorganism reduction and compare it to manual and rotating conventional therapy. Adults with active deep carious lesions on permanent teeth were separated into two groups for a clinical trial: a control group and an intervention group receiving conventional treatment and Er:YAG therapy, respectively. Using a tiny, sterile microbrush to scrape the tissue at the base of the dentinal cavity, two mouth samples were obtained before and after any conservative therapy. The percentage decrease and the number of colony-forming units (CFUs) were compared for total microorganisms, including Candida spp., Streptococcus spp., and Lactobacillus spp., following Er:YAG and conventional treatments. The decrease in microorganisms ranged from 90.2% to 100% and was statistically significant for both total microorganisms and Streptococcus spp. ($p < 0.05$). The Er:YAG laser has the potential for therapeutic applications, particularly with pediatric and complex patients, due to its minimally invasive nature and influence on microbial load reduction.

6.6.4.2 Efficiency

Vaddamanu et al. [Vaddamanu, S. K. et al., 2022] also evaluated the efficiency by measuring the time taken for the complete caries removal. Because of its precise irradiation technique, the Er:YAG laser required a longer treatment time to entirely eliminate carious dentin, according to the authors.

Johar et al. [Johar, S. et al., 2019] used a timer to record the time taken for caries removal. The time taken for the caries removal procedure was longer for the laser preparation than in the conventional way.

Medioni et al. [Medioni, E. et al., 2016] compared the time required for carious treatment of each half as well. It was recorded, and samples were then histologically examined. The average length of caries eradication did not differ substantially by approach.

6.6.4.3 Anxiety and pain management

Three of the five studies that evaluated pain used a five- or six-point pain scale, which concluded that laser therapy reduced discomfort. When assessing the necessity for anesthesia (four studies) and participant pain (five studies), the overall results indicated that laser therapy reduced the need for anesthesia and participant discomfort. Nonetheless, limited data of low quality supported laser treatment for pain management, anesthetic necessity, and patient comfort [Wong Y. J., 2018].

Vaddamanu et al. [Vaddamanu, S. K. et al., 2022] also mentioned that the Er:YAG laser treatment had a lower amount of vibration than other methods, leading to more patient comfort.

Johar et al. [Johar, S. et al., 2019] assessed the pain before and after the operation using the Wong Baker Modified Facial Pain Rating Scale and the Visual Analog Scale. In addition, each patient was asked, following treatment, which type of caries removal was more comfortable: Er,Cr:YSGG Laser or Air-rotor handpiece. Comparing the difference between the mean values for post-procedural Wong Baker Faces Pain Rating Scale scores and Visual Analog Scale scores for both procedures revealed that patients reported less pain with the Er,Cr:YSGG laser than with air-rotor handpiece during the caries removal process. The patients indicated that the caries removal procedure with the laser was more comfortable.

The patients in the study of Johar et al. [Johar, S. et al., 2019] indicated that the caries removal procedure with the laser was more comfortable.

6.6.4.4 Aerosol formation

Grzech-Leśniak et al. [Grzech-Leśniak, K., & Matys, J., 2021] They conducted an intriguing investigation on the influence of Er:YAG lasers on the decrease in dental professionals' aerosol production. The objective of this study was to quantify the amount of aerosol generated during various dental operations (caries and prosthetic treatment, debonding of orthodontic brackets, root canal irrigation) with Er:YAG lasers and high-volume suction. The mandibular second premolar was removed and put in a dental manikin to imitate normal orthodontic treatment. The particle counter was used to measure the aerosol particles (0.3–10.0 m) at three distinct sites: the dental manikin, the operator's, and assistant's mouth regions. Caries treatment and dental crown removal using a high-speed handpiece and the use of high-volume suction created the most aerosol at each assessed site, according to the study's findings. In comparison to conventional handpieces, all three evaluated Er:YAG lasers considerably decreased the amount of aerosol particles during caries treatment and ceramic crown debonding ($p < 0.05$). In addition, the Er:YAG lasers produced less aerosol during orthodontic bracket debonding and root canal irrigation compared to the initial aerosol amount observed at the dental office. The use of Er:YAG lasers during dental procedures creates substantially less aerosol in the dental office, reducing the danger of viral or bacterial transmission.

7 Comparison of all preparation methods, including CMCR, laser preparation, and conventional method

Cardoso et al. [Cardoso, M. et al., 2020] conducted a systematic review to assess the effectiveness and patient acceptability of different caries removal techniques, which means they included both, the CMCR and the preparation with laser. Thirty-seven clinical trials were included in this study, reporting caries removal using alternative (chemomechanical —Brix 3000, Carie-care, Carisolv, and Papacarie, laser—Er:YAG (Erbium-doped Yttrium Aluminum Garnet) and Er,Cr:YSGG (Erbium, Chromium-doped Yttrium, Scandium, Gallium, and Garnet) and conventional methods. After the comparison, the conclusion was drawn: alternative approaches tended to lengthen treatment duration and reduce anesthetic requirements. All treatments were effective in lowering cariogenic flora, and there were no significant differences in restoration efficacy. Chemomechanical caries removal techniques seemed to be the best alternative for minimally invasive treatments, with high control during application and action as well as positive patient treatment experiences. Papacarie was shown to be a successful procedure for removing caries with less discomfort and greater patient acceptability than traditional treatments.

Prabhakar et al. [Prabhakar, A. et al., 2018] They used a scanning electron microscope to compare the effectiveness of the Carie-Care and Erbium-doped Yttrium Aluminum Garnet lasers in removing caries. Thirty removed teeth were sectioned mesiodistally for therapeutic purposes. These sectioned samples were divided into three groups, each including twenty specimens: group I: Carie Care, group II: Er:YAG laser; and group III: round tungsten carbide bur. Following caries removal, all samples were processed and analyzed for bacterial deposits using a standard light microscope. A scanning electron microscope (SEM) was used to study the morphology of caries-extracted tissue from representative samples from each group. Using Fisher's exact test, the Kruskal-Wallis test, and the Mann-Whitney U test, statistical analysis was conducted. The Er:YAG laser produced the greatest results with no smear layer, followed by surfaces excavated chemomechanically with Carie-Care. The quantity of bacterial deposits was found to be greater in group I than in group II ($p < 0.001$). The Mann-Whitney U test and Fisher's exact test indicated statistically significant differences between each of the three groups. In addition, it was determined that the Er:YAG laser was more effective than both Carie-Care and the round tungsten carbide bur. In addition, laser-induced caries excavation using an Er:YAG laser and chemomechanical caries removal with Carie-Care can be viewed as the future of noninvasive preventative dentistry.

Senthilkumar and Ramesh [Senthilkumar, V., & Ramesh, S., 2020] did a systematic review of alternative methods for caries removal in permanent teeth. A comparison of 11 clinical trials was done.

After a summary of the investigated trials, radiographs showed 92% (rotary burs) and 98.6% (Carisolv) healthy results, and bacterial tissue reduction after excavation of caries is about 96.5% in total. Both, the diamond bur and erbium, chromium-doped yttrium, scandium, gallium, and garn262626et (Er: Cr: YSGG) lasers performed equally in all the parameters, such as marginal discoloration and marginal adaptation. In 27 cases, Carisolv removal took an average of 12.19 minutes. The mean time to remove caries with steel burs was 7.4 minutes. The colony-forming unit (CFU) for lactobacilli varied from 0.00 to 2.11 after laser treatment and from 0.00 to 1.68 after bur treatment. For Streptococcus mutans, the CFU ranged from 0.00-0.70 after laser treatment and from 0.00 to 1.52 when the rotary bur was used for preparation.

86% of participants showed some level of anxiety, while 59% of participants were moderately worried during local anesthesia (LA) or the use of a bur. The time required to prepare a cavity with a tungsten carbide bur was 6.3 minutes, compared to 5.4 minutes with Carisolv.

During the six-month recovery review, both conventional bur and Er:Cr:YSGG laser groups were deemed vital. On day 1 of the operation, 87.9% of patients in the conventional bur group and 98.5% of patients in the Er,Cr:YSGG laser group reported no discomfort.

Two of the 29 intact restorations reported by the Carisolv group after one year of follow-up were lost. Two teeth were lost as a result of extraction, and one tooth exhibited secondary caries during follow-up visits. Thirty-one teeth in the Carisolv group were sensitive, whereas 24 teeth in the traditional bur group were sensitive. Patients in the Carisolv group did not prefer anesthesia, but 12 of the 20 patients in the traditional group did. According to Keller et al., the average laser setup time was 7.3 minutes. The mean mechanical preparation time was three minutes. According to J. H. Zinck et al., 21% of Caridex patients and 37% of traditional therapy patients sought a local anesthetic. According to K. J. Anusavice and J. E. Kincheloe, 85.3% of patients said that they would not need local anesthesia for future caries removal treatments. 29.4% of patients would consent to standard therapy without anesthesia. Based on the available research, it was determined that alternative caries removal methods are not as successful as commercially available conventional burs. Nonetheless, a substantial number of clinical trials are required to confirm their efficacy as caries eradication agents.

VIII Conclusion

The CMCR is as effective as the conventional bur method. However, regarding efficiency, the conventional bur methods was significantly less time-consuming compared to the CMCR. In terms of discomfort and anxiety, the conventional bur method performed much worse compared to the CMCR as it minimized pain, made anesthesia mostly unnecessary, and additionally, could avoid drilling close to the pulp, making treatment painless.

The laser preparation is as effective as the conventional bur method, as no statistically significant difference was seen in efficacy. Regarding the time consumption, the laser preparation was either as long as the conventional method or longer. The need for anesthesia and patient discomfort are lower with the laser treatment. The Er:YAG laser treatment has a lower amount of vibration than other methods, leading to more patient comfort, and the patients also indicated that the caries removal procedure with the laser is more comfortable. However, there is some low-quality evidence in favor of laser therapy for pain control, the need for anesthesia, and patient comfort. Furthermore, the use of the Er:YAG lasers during dental treatments significantly generates less aerosol in the dental office setting, which reduces the risk of transmission of viruses or bacteria.

It can be stated out that alternative methods are a good option in specific cases, such as pediatric patients or patients with anxiety. After the review, the alternate hypothesis was correct that there is a significant difference in removing caries by alternative methods when compared to the conventional method in permanent teeth regarding efficiency, anxiety, and pain management.

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