Introduction

Pulpitis and periodontitis are the inflammation of the pulp tissue and the periodontium respectively caused by any irritant. Irritant may by vital or non-vital, vital like bacteria and/or viruses, non-vital may be thermal, mechanical, chemical or due to drop in immunity or any other disease.

Pulpitis and periodontitis can be divided into acute and chronic. The acute type is highly painful. Pain is the primary reason that dental patients seek endodontic therapy for endodontic treatment to be considered successful and to be accepted readily by the patient and the dentist; it must be firmly associated with the highly efficient relief of pain.

Emergency treatment to relief the pain of the acute pulpitis is done by removal of the irritant mechanically and/or chemically. Mechanically divided into partially removal of the pulp tissue which called Pulpotomy or totally removal of the pulp tissues ,clean the canal then restore it with any suitable obturating material which called pulpectomy.

Pulpotomy is the most widely treatment used in treating the acute pulpitis in primary teeth and young primary teeth till the roots complete its closure done mechanically by remove the irritant from the pulp chamber with leaving intact vital radicular pulp then chemically by using formcresol, camphorated paramonochlorophenol, eugenol, iodine potassium iodide, Ledermix, or calcium hydroxide or recently pulpotec, Mineral Trioxide Aggregate (MTA) and LAZER.

However, the use of intracanal steroids, non-steriodal anti-inflammatory drugs (NSAIDs) or a corticosteroid–antibiotic compound has been shown to reduce post-treatment pain.

The germicidal medicament placed over the radicular pulp stamp. This procedure is done to promote healing, retention of the vital radicular pulp and provide pain relief. Dentin bridging may occur as a treatment outcome of this procedure depending on the type of medicament used.

Calcium hydroxide ($Ca(OH)_2$) has high alkaline pH 11.5 to 12.9 which is responsible for its antibacterial activity and its ability to form hard tissue.

Pulpotec is radio-opaque, non-resorbable paste for the treatment of pulpitis in vital molars, both permanent and deciduous. It`s presentation is in the form of **Powder:** Polyoxymethylene, Iodoform, excipient & **Liquid:** Dexamethasone Acetate, Formaldehyde, Phenol, Guaiacol, excipient. The addition of pharmacological constituents ensures an aseptic treatment for signs &symptoms of pulpitis. In most cases, Pulpotec treatment is practically painless. With rare exceptions where pain has continued until the second session.

Because no comparative study had been conducted to evaluate the effect of calcium hydroxide and pulpotec in relieving inter-appointement pain, this bough up the idea to study this comparative effect of both medications.

PICO approach

P (Problem, Patient):

Patient with symptomatic pulpitis with apical periodontitis.

I (Intervention):

Pulpotec used as an intracoronal dressing.

C (Comparator):

Calcium hydroxide used as an intracoronal dressing.

O (Outcome):

Interappointment Pain relief measured by operator using visual analogue scale (V.A.S) and patient related.

Review of Literature

I. -Evidence-Based Dentistry:

Evidence-based dentistry (EBD) is an approach to oral healthcare that requires the judicious integration of systematic assessments of clinically relevant scientific evidence, relating to the patient's oral and medical condition and history, with the dentist's clinical expertise and the patient's treatment needs and preferences [Fig.1].

By saying, "relating to the patient's oral and medical condition and history", this definition takes a patient-cantered approach to treatment decisions. It is important to understand that EBD is an approach to practice, making clinical decisions, and is just one component used to reach the best treatment decision. EBD is about providing personalized dental care based on the most current scientific knowledge [(1)].

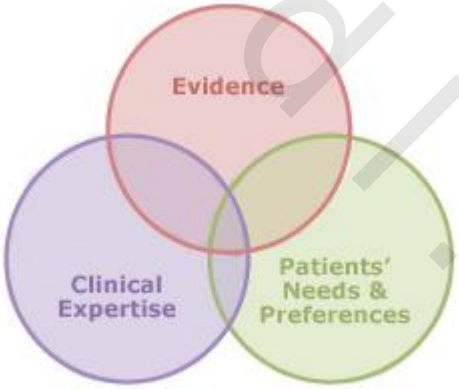

Figure 1: Domains of EBD

Evidence based practice comes from three approaches to medical practice that were used in the late 18th and early 19th centuries. The Clinical Methods approach used to received wisdom, experience, anecdote, and observation to decide how to proceed in each case.

The Patho-physiology approach was based on laboratory investigation and theoretical extension to practice. Claude Bernard [(2)] who thought that a scientific approach was the way forward developed this. He thought that understanding the science of pathology would provide cures or prevention methods for many diseases. This is the method taught by med schools during most of the second half of the 20th century and was the received wisdom of that era. Pierre Louis [(3)] championed the Epidemiological or Numerical approach. He felt that received wisdom wasn't working for treatment of infectious diseases. He stated that therapeutic agent couldn't be employed with any discrimination or probability of success in a given case, unless its general efficacy in analogous cases, has been previously ascertained [(4)].

In 1989, the Oxford Database of Perinatal Trials was launched. This database collected evidence from many trials and synthesized the results in a single database. This developed into the Cochrane Collaboration [(5)], a dynamic form of publication where authors publish systematic reviews on interventions and are required to keep the reviews updated as new evidence becomes available. Cochrane's ideal was for each specialty to produce a series of meta-analyses of all the trials in the discipline, and to regularly update these meta-analyses which is the process or technique of synthesizing research results by using various statistical methods to retrieve, select, and combine results from previous separate but related studies [(6)].

In 1999, Dr. Bader J et al published an article recommending the EBD and explaining the methods of transferring it into practice. The article considered EBD not intended to be "cookbook" dentistry, but it is envisioned as a disciplined process where the best objective information of the risks and benefits is weighted with clinical experience and patient preferences [(7)].

In 2006, Hackshow A et al published an introduction book in EBD it considered Evidence-based dentistry was built upon asking questions with explaining the steps of practicing EBD [8].

In 2007, Faggion C. M demonstrated the practical procedure and model that clinicians can use to apply the results of well-conducted studies to patient care by critically appraising the evidence with checklists and letter grade scales. To demonstrate application of this model for critically appraising the quality of research evidence, a hypothetical case involving an adult male with chronic periodontitis is used as an example. To determine the best clinical approach for this patient, a four-step, evidence-based model is demonstrated, consisting of the following: definition of a research question using the PICO format (Patient, Intervention, Comparison, and Outcome), definition of key words, followed by searching and selecting relevant articles, critical appraisal of selected literature using the CONSORT and QUOROM checklists and application of results to resolve the patient's health care problems.

For this hypothetical periodontics case, application of the model identified the best available evidence for clinical decision making, i.e., one randomized controlled trial and one systematic review of randomized controlled trials. Both studies showed similar answers for the research question. The use of a letter grade scale allowed an objective analysis of the quality of evidence. A checklist-driven model that assesses and applies evidence to dental practice may substantially improve dentists' decision-making skill [9].

In 2008, Dr. Azarpazhooh A. et al published an article describing the procedures undertaken to teach undergraduate dental students at the University Of Toronto Faculty Of Dentistry how to produce systematic reviews as a module in clinical epidemiology, nine selected reports have been summarized as

examples of the outputs of this module. At the end of the module, students are asked to participate in a survey and anonymously fill out a questionnaire to evaluate the module. Students' evaluation of the module in the 2005–06 (n= 64) and 2006–07 (n=57) academic years were extracted for data analysis. Overall, the majority of students found the module an enjoyable way of learning that has improved their ability to gather information, apply existing evidence to a clinical question, evaluate information, and further develop their communication skills. This module was also effective in raising students' awareness of the importance of evidence-based clinical practice [(10)].

II. Randomized Controlled Trial (RCT):

It is the study in which people are allocated at random (by chance alone) to receive one of several clinical interventions. It is quantitative, comparative, controlled experiments in which investigators study two or more interventions in a series of individuals who receive them in random order. The RCT is one of the simplest and most powerful tools in clinical research [(11)].

The history of clinical trials dates back to approximately 600 B.C. when Daniel of Judah conducted what may probably be the earliest recorded clinical trial. He compared the health effects of the vegetarian diet with those of a royal Babylonian diet over a 10-day period [(12-13)]. The nineteenth century saw many major advances as in 1836, the editor of the American Journal of Medical Sciences wrote an introduction to an article that he considered "one of the most important medical works of the present century, marking the start of a new era of science," and stated that the article was "the first formal exposition of the results of the only true method of investigation in regard to the therapeutic value of remedial agents [(14)].

The Credit for the modern randomised trial is usually given **to Sir Austin Bradford Hill** [15], Hill followed up his research with lectures and articles reinforcing his message. The Cochrane Library [5] already lists more than 150,000 such trials, and they have become the underlying basis for what is currently called 'evidence based medicine'. The concept has rightly been hailed as a paradigm shift in our approach to clinical decision-making [14].

Between 1960 and 1970 there was an intense controversy between what trials should be reported and what is actually published in the literature. Between 1993 and 1995, the Standards of Reporting Trials (SORT) group met with Asilomar working group each other in an effort to correct these to checklist then to Consolidated Standards Of Reporting Trials (CONSRT) statement which is a statement table and flow diagram which provides information about the progress of patients throughout 2 parallel groups [16]. During 2001 CONSORT revision, it became clear that explanation and elaboration of the principles underlying the CONSORT statement would help investigators and others to write or appraise trial reports. A CONSORT explanation and elaboration article was published in 2001 alongside the 2010 version of the CONSORT statement [17].

In 2002, Schulz K. F and Grimes D. A described the rationale behind random allocation and its related implementation procedures and they founded that Randomized controlled trials set the methodological standard of excellence in medical research, over that they said The key word is randomized, which must be done properly and generation of a randomization sequence takes little time and effort but affords big rewards in scientific accuracy and credibility, at the end Investigators should devote appropriate sources to doing the generation properly and reporting their methods clearly [18].

Randomized controlled trials are quantitative, comparative, controlled experiments in which a group of investigators study two or more interventions by administering them to groups of individuals who have been randomly assigned to receive each intervention [(14)], it eliminates bias in treatment assignment, facilitates blinding (masking) of the identity of treatments from investigators, participants, and assessors, and it permits the use of probability theory to express the likelihood that any difference in outcome between treatment groups merely indicates chance [(18)].

However, its advantages are very important it has also disadvantages as it is generalize results: they are not a panacea to answer all clinical questions; there are many situations in which they are not feasible, necessary, appropriate, or even sufficient to help solve important problems, also lack of opportunity for blinding and complexity of intervention, are particular features of behavioural and psychosocial research, standardising the content and delivery of a complex intervention other disadvantage [(19,20)].

According to **Jadad A. R**, Randomized Controlled Trials [(13)] Classified to the different aspects of interventions; explanatory or pragmatic trials, efficacy or equivalence trials and phase. According to Participants, Exposure and Response to the Intervention Randomized Controlled Trials Classified to parallel, crossover, and factorial designs. In addition to randomization, the investigators can incorporate other methodological strategies to reduce the risk of other biases. These strategies are known as "blinding." The purpose of blinding is to reduce the risk of ascertainment and observation bias.

An open randomized controlled trial is one in which everybody involved in the trial knows which intervention is given to each participant. Many radiology studies are open randomized controlled trials because blinding is not feasible or

ethical. One cannot for example, perform an interventional procedure with its associated risks without revealing to the patient and the treating physician to which group the patient has been randomized.

A single-blinded randomized controlled trial is one in which a group of individuals involved in the trial (usually patients) does not know which intervention is given to each participant.

A double-blinded randomized controlled trial, on the other hand, is one in which two groups of individuals involved in the trial (usually patients and treating physicians) do not know which intervention is given to each participant. Beyond this, triple-blinded (blinding of patients, treating physicians, and study investigators) and quadruple-blinded randomized controlled trials (blinding of patients, treating physicians, study investigators, and statisticians) have been described but are rarely used [(14)].

III. Inter-appointment (post-operative) pain:

Pain is the most common reason for dentist consultation. It is a main symptom in many dental conditions and can significantly impede with a person's quality of life and general functioning. The toothache is the most common form of oral pain. For many patients, fear of dental pain and avoidance of dentist are identical.

Endodontic post-treatment pain continues to be a significant problem facing the dental profession. It has been reported that up to 80% of this population will continue to report pain after endodontic treatment, with pain levels ranging from mild to severe.

Endodontic pain that may last from several hours to several days is linked to inflammatory reactions. This pain is dependent on the damage sustained by tissues and the nature of the damaging agent. These agents may be of a bacterial, chemical, or mechanical nature. Endodontic pain may occur before, during, or after endodontic treatment. Patients with moderate to severe pain before treatment were five times more likely to experience moderate to severe pain post treatment [(21)].

Knowledge of the causes and the mechanisms behind inter-appointment pain in endodontic is of outmost importance for the clinician to properly prevent or manage this undesirable condition. Inter-appointment pain is almost exclusively due to the development of acute inflammation at the peri-radicular tissues in response to an increase in the intensity of injury coming from the root canal system. When an inter-appointment emergency occurs, proper diagnosis and active treatment are required for the clinician to succeed in solving the problem [(22)].

- **Pain assessment scale:**

A pain scale measures a patient's pain intensity or other features. Pain scales are based on self-report, observational, or physiological data The National Initiative on Pain Control (NIPC™) has provided these diagnostic tools to assist the dentist in assessing the severity and quality of pain experienced by your patients. Types of pain scales are multiple such as Wong-Baker FACES Pain Rating Scale, 0–10 Numeric Pain Rating Scale, Pain Quality Assessment Scale, Box Scale, verbal rating scales and Visual analogue scales which we used in this presented study [(23,24)].

In 1975, Ohnhaus E. E and Adler R compared between the verbal rating scale and the visual analogue scale, they measured The effect of analgesics on pathological pain in a double-blinded trial assessed by means of two rating scales, a verbal rating scale (VRS) and visual analogue scale (VAS) and they found that The VRS is widely used, but has several disadvantages as compared to the VAS, the results obtained by means of the VRS showed higher *F*-ratios (analysis of variance and Kruskall-Wallis H-test) than those obtained by means of the VAS and The correlation between the two scales was highly significant ($r = 0.81$, $P < 0.001$) [(25)].

In 1986, Jensen M. P et al conducted a comparison between sixth methods measuring clinical pain intensity, they founded that Although several scales are currently used to assess the intensity construct, it remains unclear which of these provides the most precise, replicable, and predictively valid measure. The results indicated that, for the present sample, the scales yield similar results in terms of the number of subjects who respond correctly to them and their predictive validity. However, when considering the remaining 3 criteria, the 101-point numerical rating scale appears to be the most practical index [(26)].

In 1994, Price D. D et al compared between pain measurement characteristics of mechanical visual analogue (M-VAS) and simple numerical rating scales (NRS) for their capacity to provide ratio scale measures of experimental pain. They estimated Separate experimental pain sensation intensity and pain unpleasantness were obtained by each method, as were estimates of clinical pain. Both M-VAS and NRS produced reliably different stimulus response functions for pain sensation intensity as compared to pain unpleasantness and both provided consistent measures of experimental and

clinical pain intensity. Finally, they founded that both mechanical and pencil-and-paper VAS produced very similar stimulus-response functions [27].

In 2000, Breivik et al examined agreement and estimated differences in sensitivity between pain assessment scales by patients in acute pain after oral surgery. They used in the comparison a four-category verbal rating scale (VRS-4) and an 11-point numeric rating scale (NRS-11) with a 100-mm visual analogue scale (VAS). The sensitivity of the scales (i.e., their ability [power] to detect differences between treatments) was compared in a simulation model by sampling from true pairs of observations using varying treatment differences of predetermined size. Simulation experiments showed that in this acute pain model, the VRS-4 was less sensitive than the VAS. The simulation results demonstrated similar sensitivity of the NRS-11 and VAS when comparing acute postoperative pain intensity. The choice between the VAS and NRS-11 can thus be based on subjective preferences [28].

In 2005, Williamson A and Hoggart B conducted a research relating to the Visual Analogue Scale, the Verbal Rating Scale and the Numerical Rating Scale by collecting reviews via PubMed and were carried out with no restriction of age of papers retrieved. Papers were examined for methodological soundness before being included. The search terms initially included pain-rating scales, pain measurement, Visual Analogue Scale, VAS, Verbal Rating Scale, VRS, Numerical/numeric Rating Scale, and NRS. The reference lists of retrieved articles were used to generate more papers and search terms. At the end, they founded that all three pain-rating scales are valid, reliable and appropriate for use in clinical practice, although the Visual Analogue Scale has more practical difficulties than the Verbal Rating Scale or the Numerical Rating Scale. For general purposes, the Numerical Rating Scale has good sensitivity and generates data that can be statistically analysed for audit purposes [29].

IV. Vital pulp therapy:

Vital pulp therapy may be broadly defined as any aspect of restorative dental treatment intended to minimize trauma to the dental pulp. More specifically, it may refer to those procedures intended to protect the pulp, in the absence of exposure, from logistic or toxic effects of dental materials, or microbiological, thermal, and mechanical damage. These procedures typically involve the use of cavity liners and bases [(30)].

Cariously exposed permanent teeth remain one of the most controversial areas in dentistry. Because a vital, functioning pulp is capable of initiating several defence mechanisms to protect the body from bacterial invasion, it is beneficial to preserve the vitality and health of an exposed pulp rather than replace it with a root filling material following pulp exposure. Amongst the methods for preservation of a cariously exposed pulp, partial Pulpotomy has yielded a markedly high success rate in young teeth according to capping technique, capping material and, pulpal status at the time of treatment [(31)].

A- Vital pulp therapy for irreversible pulpitis includes several techniques such as:

a. Direct Pulp Capping:

Direct pulp capping definition in the free medical dictionary is the Procedure for covering and protecting exposed vital pulp by placing dental material directly on exposed pulp tissue to stimulate formation of a dentinal bridge [(32)].

When a small exposure of the pulp is encountered during cavity preparation and after haemorrhage, control is obtained; the exposed pulp is capped with a material such as calcium hydroxide or MTA prior to placing a restoration that seals the tooth from micro-leakage.

Direct pulp capping is indicated for a permanent tooth that has a small carious or mechanical exposure in a tooth with a normal pulp. The tooth vitality should be maintained under special conditions judging the success of the treatment; No post-treatment clinical signs or symptoms of sensitivity, pain, or swelling should be evident, Pulp healing and reparative dentin formation should occur. There should be no radio-graphic evidence of internal or external root resorption, periapical radiolucency, abnormal calcification, or other pathologic changes. Teeth with immature roots should show continued root development and apexo-genesis [(33)].

About 80 years ago, it was discovered that wound treatment with calcium hydroxide in a water vehicle was effective at repairing the exposure site. Vital pulp capping was frequently studied by European researchers until the Second World War. With the significant contributions of Hermann, calcium hydroxide has been used extensively in endodontic therapies for the disinfection of infected root canals and for vital pulp therapies. Zander introduced German techniques for pulp capping to North America as an immigrant dentist [(34)]. Although it does not occur consistently, the hard-tissue repair response has been considered a desirable outcome, since wound treatment with calcium hydroxide in a water vehicle indicates pulp healing. Despite the fact that pulpal healing and repair have been reported at a high rate in both experimental and clinical follow-up studies in cases where the tissue was injured either by caries or accidental trauma, capping of the exposed pulp has remained controversial for adult dentition.

Unfortunately, the clinical outcome of conventional pulp capping is very uncertain as to the survival of the vital pulp. **Tronstad and Mjör** [35] reported that the outcome of caries-exposure pulp capping had less than a 50% chance of success. **Al-Hiyasat A. S et al** [36] examined the treatment outcome of pulp capping for both mechanical and caries exposure. Three years after the procedure, patients were recalled, and their teeth were evaluated using radiography only.

The success rate was markedly different for the two types of exposure, with the repair of mechanical exposure producing a 92% success rate, compared to a mere 33% for the caries-exposure cases. Likewise, Barthel et al [37] examined the treatment outcome of pulp capping using $Ca(OH)_2$ for caries exposure after an elapsed time of 5 and 10 years. The patients were recalled, and their teeth were evaluated using both radiography and pulp vitality testing. The success rates for 5 and 10 years were 37% and 13%, respectively. Most of the failures in these reports were asymptomatic; the pulp tended to become necrotic slowly. Thus, most clinicians hesitate to do a direct pulp capping treatment, believing this option should be reserved only for teeth displaying minimal signs of pulpitis. Such a clinical strategy is currently still advocated [38,33,34].

b. Partial-Pulpotomy:

Partial pulpotomy (Cvek pulpotomy) is defined as "the surgical removal of a small portion of the coronal portion of a vital pulp as a means of preserving the remaining coronal and radicular pulp." In this instance, inflamed tissue is removed to expose deeper, healthy coronal pulp tissue.

Direct pulp capping and partial pulpotomy are considered similar procedures and differ only in the amount of undestroyed tissue remaining after treatment [39].

c. Pulpotomy:

Pulpotomy is a more extensive procedure defined as "the surgical removal of the coronal portion of a vital pulp as a means of preserving the vitality of the remaining radicular portion. After the complete removal of the coronal pulp, a material is placed over the canal orifices [40].

A variety of dressing materials, with varying toxicity, have been used for this purpose. They include Formocresol [41,42,43,48], ferric sulphate [42], glutaraldehyde [43], ZOE [44], enamel matrix derivative (EMD) [45,46], MTA [44,47,48], $Ca(OH)_2$ [45,46], and pulpotec [48]which mummifies the remaining tissue.

From the middle of the 20^{th} century the experiments were done on permanent teeth to preserve the tooth structure when Patterson in 1967 [49] points out that the occurrence of diffuse calcification after the use of $Ca(OH)_2$ must be regarded as normal, this led him in 1979 [50] to compare between Dycal and formocresol pulpotomies in young permanent teeth in monkeys when Twelve of twenty teeth treated with Dycal and seventeen of twenty teeth treated with formocresol were judged to be successful as evidenced by continued root development, absence of periapical pathoses, and the presence of non-inflamed or only mildly inflamed pulps.

In 1981, Hermann E. H. et al treated twelve traumatized and carious permanent teeth 11 anterior and one posterior by Pulpotomy with using corticosteroids- antibiotic preparation (Ledermix) .The experiment presented a

highly success rate as in nine anterior teeth and one molar the apex was closed and only two teeth showed no apex formation [(51)].

In 1995, Caliskan M. K. evaluated twenty six permenent vital molars with carious pulp exposure and periapical involvement presenting as radiolucencies or radiopacities in the radiographic examination, in patients aged between 10-24 years when treated by pulpotomy. The healing was evaluated using clinical and radiographic criteria like absence of clinical syptoms,sensitivity of the pulp,formation of a hard tissue barrier resolution of the periapical pathosis and/or no intraradicular pathosis radiographically. Successful results were achieved in 24 teeth in observation period following the treatment 16-72 months . The favourable results of this study demonstrated that pulpotomy in teeth with cariously exposed vital pulp and with periapical involvement may be an alternative treatment to the root canal treatment [(52)].

In 1998, Hasselgren G and Reit C subjected Seventy-three teeth with acute irreversible pulpitis to emergency pulpotomies for evaluating pain-relieving effect with and without the use of sedative dressings. After removal of the coronal portion of the pulp, sterile cotton pellet or zinc oxide-eugenol cement was placed against the remaining pulp tissue. The cotton pellet was either dry or moistened with camphorated phenol, cresatin, eugenol, or isotonic saline. This gave six different groups of treatment following the pulpotomy. All teeth were sealed with zinc oxide eugenol cement. By means of questionnaires, symptoms were recorded after the anesthetic effect was gone and also at 1, 7, and 30 days after treatment. 70 patients (96%) reported pain relief in sequel of removal of irritants, e.g. caries and removal of the inflamed part of the pulp tissue [(53)].

In 2006, Nyerere J. W et al performed emergency Pulpotomy to 180 permanent posterior teeth with dental pain due to acute irreversible pulpitis. They were evaluated for pain after one, three and six week's post-treatment. Pain, if present, was categorised as either mild or acute.They founded that the patients with treated premolars, 25 (13.9%) patients did not experience pain at all while 19 (10.6%) experienced mild pain. None of the patients with treated premolars experienced acute pain. Among 136 patients with treated molars 56 (31%) did not experience any pain,76(42.2%) experienced mild pain and the other 4 (2.2%) suffered acute pain. This results led to that the short term treatment success of emergency pulpotomy was high being 100% for premolars and 97.1% for molars, suggesting that it can be recommended as a measure to alleviate acute dental pain while other conservative treatment options are being considered[(54)].

In 2011, Aguilar P and Linsuwanont P. made a systematic review aiming to illustrate the outcome of vital pulp therapy, direct pulp capping, partial pulpotomy, and full pulpotomy, in vital permanent teeth with cariously exposed pulp using Electronic database MEDLINE via Ovid, PubMed, and Cochrane data bases. Hand searching was performed through reference lists of endodontic textbooks, endodontic-related journals, and relevant articles from electronic searching. The weighted pooled success rate of each treatment was estimated in 4 groups: >6 months-1 year, >1-2 years, >2-3 years, and >3 years. All statistics were performed by STATA version 10. The indirect comparison of success rates for 4 follow-up periods and the indirect comparison of clinical factors influencing the success rate of each treatment were performed by z test for proportion ($P < .05$). Overall they founded that the success rate was in the range of 72.9%-99.4%. The fluctuation of the success rate of direct pulp capping was observed (>6 months-1 year, 87.5%; >1-2 years, 95.4%; >2-3 years, 87.7%; and >3 years, 72.9%). Partial pulpotomy and full pulpotomy

sustained a high success rate up to more than 3 years (partial pulpotomy: >6 months-1 year, 97.6%; >1-2 years, 97.5%; >2-3 years, 97.6%; and >3 years, 99.4%; full pulpotomy: >6 months-1 year, 94%; >1-2 years, 94.9%; >2-3 years, 96.9%; and >3 years, 99.3%).

These results improved those vital permanent teeth with cariously exposed pulp can be treated successfully with vital pulp therapy. The current best evidence provides inconclusive information regarding factors influencing treatment outcome, and this emphasizes the need for further observational studies of high quality [(55)].

In 2013, Asgary S et al performed vital pulp therapy using calcium-enriched mixture cement (VPT/CEM), as a new treatment option. They demonstrated postoperative pain relief in comparison with the long-term root canal treatment (RCT). In 23 healthcare centers, 407 patients aged between 9 to 65 years old were randomly allocated into two study arms including one-visit RCT (n = 202) and VPT/CEM (n = 205). Six- and twelve-month clinical and radiographic successes were assessed. After 6- and 12-month follow-up, the collected data gave a favorable clinical success rates in the two study arms, as they did not show statistical difference; however, the radiographic success rate in the VPT/CEM was significantly greater than RCT arm at the two follow-up. The patients' age had no effect on the treatment outcomes.

Finally, they concluded that treatment outcomes of VPT/CEM might be superior to RCT in mature molars with irreversible pulpitis. The performance of biomaterials such CEM cement may assist in the shift towards more biologic treatments and VPT/CEM may be a realistic alternative treatment for human

mature molar teeth with symptoms of irreversible pulpitis; the use of VPT/CEM is highly beneficial for patients as well as general dentists [56].

B- Materials used in vital pulp therapy:

B.1- Calcium Hydroxide:

Calcium hydroxide is a white odourless powder with the formula $Ca(OH)_2$, and a molecular weight of 74.08.

Limestone is a natural rock mainly composed of calcium carbonate (CaCO3) which forms when the calcium carbonate solution existing in mountain and seawater becomes crystallized. The combustion of limestone between 900 and 12008C causes the following chemical reaction:

$$CaCO3 \rightarrow CaO + CO2$$

The calcium oxide (CaO) formed is called `quicklime' and has a strong corrosive ability. When calcium oxide contacts water, the following reaction occurs:

$$CaO + H2O \rightarrow Ca(OH)_2$$

It has low solubility in water, which decreases as the temperature rises; it has a high pH (about 12.5±12.8) and is insoluble in alcohol. This low solubility is, in turn, a good clinical characteristic because a long period is necessary before it becomes soluble in tissue fluids when in direct contact with vital tissues [57].

In 1920, Hermann B.W. introduced calcium hydroxide for root canal fillings. Between 1928 and 1930, he studied the reaction of vital pulp tissue to calcium hydroxide to prove that it was a biocompatible material. Since then calcium hydroxide has been recommended by several authors for direct pulp

capping. But it took until the middle of 20th century until it was regarded as the standard of care. In 1949, Zander and Glass described the usefulness of calcium hydroxide in dentistry and endodontics. Zander exploited its usefulness as a pulp capping and pulpotomy agent and it later became widely used to help induce apexogenesis and apexification. Calcium hydroxide has become the medicament of choice where interim canal dressing is necessary [(34)].

The works of **Bystrom** [(58)], **Cvek** [(59)] and **Tronstad** [(35)] have shown that calcium hydroxide was a canal dressing that maintained its antibacterial effect when sealed in the canal [(60,61)].

It is a basic compound with an appropriate pH of 11-12.8 .As such, it is mildly irritating to vital pulp tissue. It also has bacteriostatic properties, which means that it keeps bacteria from actively spreading. Both of these qualities make it a good lining material for restoration in close proximity to pulp. Although calcium hydroxide does not bond to dentin, it does have antibacterial property.

It continues to have a high pH after setting because material dissolves readily in aqua solution, liberating hydroxyl ions [(62)].

- **<u>Mechanism of action of calcium hydroxide and role of PH:</u>**

Its mechanism of action is achieved through the ionic dissociation of $Ca(^{2+})$ and OH(-) ions and their effect on vital tissues, the induction of hard-tissue deposition and the antibacterial properties. The lethal effects of calcium hydroxide on bacterial cells are probably due to protein denaturation and damage to DNA and cytoplasmic membranes. It has a wide range of antimicrobial activity against common endodontic pathogens. It continues to

have a high pH after setting because material dissolves readily in aqueous solution, liberating hydroxyl ions. This high pH provides a stimulus for tooth to repair itself in absence of bacterial infection [61,62].

In 1972, Stanley H. R et al subjected 25 teeth from 10 patients suffering from pulp exposure to pulp capping with dycal and later extracted for micro-scoping examination. The experiment explained that when dycal was used as a pulp capping agent the dentinal bridge formed directly against it after the mummified tissue has been replaced by granulation tissue, which differentiate new odontoblast. Macrophages removed the mummified tissue and although this method took a few hours to days, the phagocytosis didn't appear to delay bridge formation by dycal. They faced a problem in the radiographic examination, as it was very difficult because it couldn't be differentiated from the radio-opacity of the dycal [63].

In 1981, Sela J et al induced a reparative dentin bridge in rat molar teeth by pulp exposure and capping with calcium hydroxide. Transmission electron-microscopic examination after 10 days revealed the presence of odontoblastic cells and collagenous matrix with focal calcifications. The calcifying fronts were composed of hydroxyapatite crystals. They detected numerous extracellular matrix vesicles scattered between the forming cells and the calcifying fronts, some of the vesicles contained electron-dense material, and in others apatite crystals. Matrix vesicles could not be identified in normal, mature calcifying dentin matrix. In view of the present observations and studies on surgical manipulations in articular cartilage, they concluded that matrix vesicle calcification may result from alterations in the metabolic state of mesenchymal tissues and these changes can be induced surgically or chemically [64].

In 1985, Schröder U Studied the effect of $Ca(OH)_2$ (containing pulp-capping agents on pulp cell migration, proliferation, and differentiation. He founded that the initial effect of $Ca(OH)_2$ applied to exposed pulp is the development of a superficial three-layer necrosis. He regarded the beneficial effect of $Ca(OH)_2$ as the result of the chemical injury caused by the hydroxyl ions, limited by a zone of firm necrosis against the vital tissue, and the toleration of calcium ions by the tissue. The firm necrosis causes slight irritation and stimulates the pulp to defence and repair.

He expected the sequence of tissue reactions when connective tissue was wounded. It started with vascular and inflammatory cell migration and proliferation, to control and elimination of the irritating agent. This is followed by the repair process, including migration and proliferation of mesenchymal and endothelial pulp cells and formation of collagen. When the pulp is protected from irritation, odontoblasts differentiated, and the tissue formed assumed the appearance of dentin, i.e., the function of the pulp is normalized. The mineralization of the collagen started with dystrophic calcification of both the zone of firm necrosis and the degenerated cells in the adjacent tissue, leading to deposition of mineral in the newly formed collagen. The conclusion of his experiment was the presence of calcium ions stimulating precipitation of calcium carbonate in the wound area and thereby contributing to the initiation of mineralization [(65)].

In 1993, Nerwich A et al examined 12 Root canals of extracted human teeth were cleaned and shaped and subsequently dressed with a calcium hydroxide, pH Changes in the root dentin were measured over a 4-wk period with microelectrodes in small cavities at apical and cervical levels in inner and

outer dentin. The experiment resulted in raised PH within hours in the inner dentin, peaked at pH 10.8 cervically and 9.7 apically. However, 1 to 7 days elapsed but before the pH began to rise in the outer root dentin, reached peak levels of pH 9.3 cervically and 9.0 apically after 2 to 3 wk. The results showed that hydroxyl ions derived from a calcium hydroxide dressing diffused through root dentin. They diffused faster and reached higher levels cervically than apically. Surface pH measurements showed that hydroxyl ions didn't diffuse in more than a minor way through the intact root surface [(66)].

In 2001, Pérez F et al measured the dentinal pH variations following the placement of various forms of calcium hydroxide in A total of 125 teeth were randomly divided into five groups, pure aqueous calcium hydroxide paste placed in the root canal in group 1 and intracoronally in group 2, using Hycal® which is a form of calcium hydroxide paste in group 3 was placed in the pulp chamber, calcium hydroxide gutta-percha points in group 4 was placed in the root canal and group 5 was a controlled group. The results after 8 h and 1, 2, and 3 days showed highest pH values when the aqueous calcium hydroxide paste was placed in the pulp chamber. At 7.14 days, Hycal® had the highest pH values (pH 10.65); however, at 21 days no significant difference was noted amongst these first three groups. By the calcium hydroxide gutta-percha points was lower than for the control group. They concluded in this study that the aqueous calcium hydroxide paste which placed in the pulp chamber showed increasing of dentinal pH more than the other techniques and the pH of dentine is affected by the form of calcium hydroxide used [(67)].

In 2006, Subramaniam P.A et al determined the pH changes of five different commercially available calcium hydroxide liners and variations of pH at different time intervals. The following commercially available materials were

investigated: Dycal (LD Caulk); Calcimol (Vocco Products); calcium hydroxide powder (Deepti Products); Calcimol LC (Vocco Products); Lime-Lite (Pulpdent Corporation). Five samples were prepared from each liner. Dycal, calcium hydroxide powder and Calcimol materials were allowed to harden chemically at 26°C and Calcimol LC and Lime-Lite samples were allowed to harden by means of a visible light curing source.

The pH measurements were recorded at time intervals of 1 h, 24 h, 3 days and 7 days after mixing of the liner. The pH variations of each material at the given time intervals were recorded and the means were calculated. Comparison of the mean values at all interval times with the statistical analysis showed significantly high differences ($P < 0.001$) between pH values induced by each material at all interval times. These results illustrated that among the water-insoluble products, dycal had the strongest alkaline effect at the 3- and 7-day intervals and the materials that chemically hardened produced higher pH values than materials that hardened by a visible light source after 7 days [(68)].

In 2011, Mohammadi Z and Dummer P. M. H. published an article dealing with the Properties and applications of calcium hydroxide in endodontics and dental traumatology. They mentioned that $Ca(OH)_2$ classified chemically as a strong base about (12.5-12.8), its main properties come from the ionic exchange, and its mode of action of may vary Depending on its application [(69)].

In 2012, Barekatain B et al Compared the calcium concentration and pH levels of $Ca(OH)_2$ medicament placed in pulp chamber and root canal. Ninety-nine extracted human mandibular second premolars were instrumented to size #40 k file. Nine teeth served as the control group and the remaining teeth were assigned into two groups. Group 1-$Ca(OH)_2$ was placed in the dried pulp

chamber, while root canals remained wet with normal saline; group 2- $Ca(OH)_2$ was placed in dried root canals. In control group, canals remained wet without medication. Each group was divided into 3 sub-groups of 15 teeth in which pH and calcium concentration were measured in three intervals of 2 days, 1 week, and 2 weeks by pH meter and atomic absorption spectrometer system, respectively. Results demonstrated that At 1 and 2 weeks, the calcium concentration had increased without being significantly different from $Ca(OH)_2$ placed either in the root canal or in the pulp chamber. $Ca(OH)_2$ placed in the pulp chamber or root canal provided similar pH values (P=0.362). Finally they founded that Placing $Ca(OH)_2$ in pulp chamber was as effective as placing it in the root canal [70].

- **Properties of the calcium hydroxide and application:**

Calcium hydroxide has been included within several materials and antimicrobial formulations that are used in a number of treatment modalities in endodontics. These include inter-appointment intra-canal medicaments, pulp-capping agents, and pulpotomy and root canal sealers.

Calcium hydroxide has an antimicrobial, remineralizing activity and act as a physical barrier against microorganisms.

In 1999, Estrela C et al [71] conducted a review demonstrated the Biological characteristics of calcium hydroxide and divided it into:

i. Antibacterial effect of calcium hydroxide:

Dental caries is a bacterially based disease that progresses when acid produced by bacterial action which demineralize the affected tooth, the disease

does not occur without infection by cariogenic bacteria. To prevent, detect, and manage caries [72].

In 1964, Southan D. E discussed the rationale of operative and restorative procedures that are least traumatic to the pulp of a tooth and he mentioned that the presence of microorganisms, acid softening of the calcified dental tissues, and proteolysis, distinguishes dental caries from other processes which affect tooth structure more over the advanced caries presents a high microorganisms level of calculated risk. Although the role of $Ca(OH)_2$ due to it's high pH effectively neutralizes either phosphoric acid from cements or acids elaborated by bacteria, its pH is at least bacteriostatic [73].

In 1985, Bystrom A et al evaluated the bactericidal efficacy of $Ca(OH)_2$, camphorated phenol and camphorated paramonochlorophenol as intracanal dressings clinically when the root canals of 65 single-rooted teeth with periapical lesions were treated. After treatment, the results indicated that the endodontic treatment of infected root canals can be completed in two appointments when $Ca(OH)_2$ paste is used as an intracanal dressing [58].

In 1991, Sjögren U et al evaluated The antibacterial effect of $Ca(OH)_2$ e as a short-term intracanal dressing clinically by applying the medicament for 10 minutes or 7 days in root canals of teeth with periapical lesions. The results showed that the 7-day dressing efficiently eliminated bacteria, which survived biomechanical instrumentation of the canal, while the 10-minute application was ineffective [74].

In 1993, Safavi K. E, and Nichols F. C evaluated the effects of calcium hydroxide on bacterial LPS. The free hydroxy fatty acids quantified in samples of LPS treated with calcium hydroxide. Calcium hydroxide treatment of LPS

showed to release elevated quantities of hydroxy fatty acids. They concluded that $Ca(OH)_2$ hydrolyzed the lipid moiety of bacterial LPS, resulting in the release of free hydroxy fatty acids. This result suggested that calcium hydroxide-mediated degradation of LPS may be an important reason for the beneficial effects obtained with calcium hydroxide use in clinical endodontics [(75)].

In 1999, Siqueira J. F. and Lopes H. P. published an article demonstrating the mechanisms of antimicrobial activity of $Ca(OH)_2$. They related the antimicrobial activity of calcium hydroxide to the release of hydroxyl ions in an aqueous environment as hydroxyl ions are highly oxidant free radicals showed extreme reactivity, reacting with several biomolecules. They illustrated that free radical rarely diffuses away from sites of generation and their lethal effects on bacterial cells are probably due to the following mechanisms: Damage to the bacterial cytoplasmic membrane, Protein denaturation and Damage to the DNA. Finally, they concluded that Calcium hydroxide has a limited antibacterial spectrum that does not affect all members of the endodontic microbiota. In addition, physicochemical properties of this substance may limit its effectiveness in disinfecting the entire root canal system after a short-term use [(76)].

In 2007, Ballal V et al investigated the antimicrobial efficacy of $Ca(OH)_2$ paste, 2% chlorhexidine gel and their combination against Candida albicans and Enterococcus faecalis . They noted that These organisms showed to be resistant to antimicrobial action of $Ca(OH)_2$ but are sensitive to chlorhexidine gluconate. They inoculated these organisms at 37˚C and the zone of inhibition was examined after 24 and 72 hours in lawn cultures on Sabouraud's dextrose agar and blood agar plates.

The results suggested that 2% chlorhexidine gel alone is more effective at 72 hours than $Ca(OH)_2$ paste alone or in combination with 2% chlorhexidine gel against both the organisms, even though $Ca(OH)_2$ showed better antifungal efficacy against Candida albicans at 24 hours [77].

In 2014, Suvarna R et al evaluated the antibacterial activity of ethanolic fraction of turmeric powder against E.faecalis and to find its efficacy as an intracanal medicament by comparing the activity with calcium hydroxide and 2% chlorhexidine. The concentrations tested were 10microgram/disc, 50 microgm/disc, 100 microgm/disc and 1000 microgm/disc. The study showed similar results to all medicaments; calcium hydroxide and ethanolic fraction of turmeric powder at all tested concentrations did not show any clear zone around the disc indicating no activity against E.faecalis however 0.2%chlorexidine (20 microlitres) of solution showed a clear zone of inhibition (19.5mm) around the disc loaded with E. faecalis [78].

ii. Remineralizing action of calcium hydroxide:

The important property of calcium hydroxide is the ability to activate alkaline phosphatase. The pH necessary for the activation of this enzyme varies from 8.6 to 10.3 according to the type and concentration of substratum, temperature and source of enzymes. Alkaline phosphatase is a hydrolytic enzyme that acts by means of the liberation of inorganic phosphatase from the esters of phosphate [71].

In 1988, Tziafas D and Beltes P. compared the radiographic and histological findings 2, 4 and 13 weeks after pulp capping dog teeth with 2 hard setting calcium hydroxide containing agents and with $Ca(OH)_2$ powder mixed with physiologic saline .

The results illustrated radioopacity of the treated pulp regions and dentin bridge formation and they observed zone of pulp necrosis subjacent to the capping material and a radiopaque zone beneath the exposure site [(79)].

In 1991, Mjor l. A et al studied The fine structure of tissue changes during the first 14 days following pulp exposure and capping with a hard setting $Ca(OH)_2$ cement. They observed early changes included hemorrhage and moderate inflammation, which were largely resolved during the first week. During the second week differentiation of cells occurred at the wound surface. These cells had the characteristic features of odontoblasts and formed a predentin-like collagen matrix. The capping material was closely adapted to cellular structures at the wound surface or to the predentin-like matrix at all observation periods. Dentin fragments displaced into the pulp tissue during cavity preparation, acted as sites for pulp stone formation. They noticed also that no stimulating effect from a necrotic layer that is necessary for dentin bridge formation [(80)].

In 1995, Sübay R. K et al studied the pulpal response of two calcium hydroxide products, Dycal and Pulpdent Multi-Cal, after partial pulpotomy on Twenty human permanent teeth were extracted at 4 months, fixed, and prepared for histologic examination. All 10 teeth treated with Dycal showed complete soft tissue healing and bridge formation. No stained bacteria were seen throughout the serial sections. One tooth treated with Dycal showed irregular reparative dentin deposition in the root canal. Six cases dressed with Pulpdent Multi-Cal showed acceptable histologic results, whereas four teeth showed severe inflammation or necrosis associated with bacterial penetration into the pulp tissue. Clinically, one tooth treated with Pulpdent Multi-Cal showed pulpal pain and was extracted at 90 days [(81)].

In 2001, Faraco I. M. Jr et al conducted a study to observe the response of dogs' dental pulp to mineral trioxide aggregate (MTA) and a calcium hydroxide cement when used as pulp capping materials. After the pulps of 30 teeth were exposed, they were capped with either MTA or a calcium hydroxide cement. Histological analysis was performed 2 months after treatment.

Results showed a healing process with complete tubular dentin bridge formation and no inflammation in any of the pulps capped with MTA. On the other hand, only five specimens from the calcium hydroxide cement group formed a complete dentin bridge. Pulp inflammation was observed in all but three cases MTA exhibited better results than the calcium hydroxide cement for the capping of the pulp in dogs [(82)].

In 2004, Conrado C. evaluated the possible remineralization of human carious dentin by means of chemical and microradiographic studies in a vivo study. Eighty-six samples of carious dentin were removed from 36 permanent teeth of 24 patients. These were divided into untreated (control) and chemically pure calcium hydroxide-capped (experimental) samples and analyzed at intervals varying from 10 to 120 days. They were classified according to depth of caries and degree of dentin softening and evaluated in relation to weight, phosphorus concentration, qualitative and quantitative microradiography and absolute values of total mineral content. One of two halves of each sample was selected for chemical studies and the other for total content of mineral salts. Experimental samples were examined with a light microscope.

Results demonstrated that a comparison between calcium hydroxide-treated and untreated samples of carious dentin as determined chemically and micro-radiographically showed an increase in mineral content of the treated samples interpreted as remineralization. It showed a qualitative increase in

radiopacity. Quantitatively, it was observed that, in the case of samples analyzed for phosphorus concentration, the average mean of differences in percentage increase after treatment was 9.6%, while for the samples evaluated micro-radiographically for total mineral content, it was 22.29%. In both cases, the differences were statistically significant [(83)].

In 2007, Hasheminia S. M et al evaluated the histological outcome from three treatment methods (Laser+MTA, Laser+$Ca(OH)_2$ and MTA alone) in direct pulp capping of cat's canines. They selected thirty-six canine teeth of 9 cats for this experimental study. The teeth randomly divided into three treatment groups; group I, the pulp exposures were covered by Mineral Trioxide Aggregate (MTA) alone, group II, the pulps after treating with Er: YAG laser, were covered by MTA, and group III, treating with laser and covering with $Ca(OH)_2$ was performed. All cavities filled by Amalgam after DPC. After 4 months, the block sections were prepared. Then, the specimens were evaluated histologically. Results demonstrated, dentinal barrier formed in all groups and they concluded that although Laser+MTA had slightly better effects, but this difference was not statistically significant [(84)].

In 2009, Reston E. G and Costa C. A. S. investigated the morphology and localisation of calcium hydroxide- and mineral trioxide aggregate (MTA)-induced hard tissue barriers after pulpotomy in dogs' teeth. Pulpotomies were performed on maxillary and mandibular premolars of five dogs. The teeth were assigned into three groups according to the pulp-capping agent used. The pulpal wounds were capped with $Ca(OH)_2$ (control), MTA or ProRoot MTA, and the cavities were restored with amalgam. After a 90-day follow-up period, the dogs were euthanised and the teeth were examined under scanning electron microscopy (SEM). Image-processing and analysis software was used to delimit

the perimeters of the root canal area and the hard tissue barrier to determine the percentage of root canal obliteration.

Localisation data showed that ProRoot MTA was statistically different from MTA and Ca(OH)2 ($P < 0.05$) regarding tissue barrier morphology. And there's no statistically significant difference ($P > 0.01$; $P > 0.05$) was observed between MTA and Ca(OH)2. A larger number of complete (centroperipheral) hard tissue barriers with predominance of dentinal tubules was observed to the ProRoot MTA when compared with the $Ca(OH)_2$ group [(85)].

In 2012, Benoist F. L et al assessed the effectiveness of calcium hydroxide (Dycal®) and mineral trioxide aggregate (MTA) used as an indirect pulp-capping material in 60 human molar and premolar teeth. $Ca(OH)_2$ was compared with MTA and the thickness of the newly formed dentine was measured at regular time intervals. The follow-up was at 3 and 6 months, and dentine formation was monitored by radiological measurements on digitised images using Mesurim Pro® software.

Results showed at 3 months, clinical success rates to MTA and $Ca(OH)_2$ were 93% and 73%, respectively ($P = 0.02$). At 6 months, the success rate was 89.6% with MTA, and remained steady at 73% with $Ca(OH)_2$ ($P = 0.63$). The mean initial residual dentine thickness was 0.23 mm, and increased by 0.121 mm with MTA and by 0.136 mm with $Ca(OH)_2$ at 3 months. At 6 months, there was an increase of 0.235 mm with MTA and of 0.221 mm with $Ca(OH)_2$. They concluded that a higher success rate was observed in the MTA group relative to the Dycal® group after 3 months, which was statistically significant. After 6 months, no statistically significant difference was found in the dentine thickness between the two groups [(86)].

ii. Pulpotomy with calcium hydroxide:

Pulpotomy and direct pulp capping with calcium hydroxide preserve the radicular pulp vitality, maximize the opportunity for apexification and enhance dentin formation.

In 1982, RAVN J. J investigated and evaluated the prognosis for the different types of endodontic treatments following complicated crown fractures. Only 448 incisors applied Pulp capping for 111, pulpotomy for 142, pulpectomy for 165, root canal treatment for 18, and extraction for 12 incisors with an observation period of more than 23 months.

The collected results indicated that Pulp capping was successful in 90.5% of the cases. Pulpotomy with calcium hydroxide was used as amputation material it had been observed that root canal obliteration and pulp necrosis were the most complications. If calcium hydroxide used 90% was successful. The healing frequency was 83.9% for teeth treated with pulpectomy but there was a clear correlation between the standard of the root filling and the success rate. For all three-treatment groups there was a correlation between damage to the supportive tissue and treatment success [(87)].

In 1986, Fuks A. B et al treated Sixty-three vital permanent incisors with complicated crown fractures by partial pulpotomy with calcium hydroxide and assessed clinically and radiographically for healing. Healing of the pulp was considered to have taken place when the following criteria were fulfilled: absence of clinical symptoms, radiographic evidence of dentin bridge formation, no intrapulpal or periapical pathosis, continued root development in immature teeth, and a positive response to electrical pulp testing.

The treatment was successful in 59 teeth (94%). In the remaining 4 teeth, necrosis of the pulp was diagnosed clinically and radiographically 3 weeks to 6 months after treatment. They observed high frequency of healing and recommended partial pulpotomy as a treatment of choice in crown fractured teeth with pulp exposure [88].

In 1993, Mejare I and Cvek M. presented an experiment on 37 comprised young posterior teeth with deep carious lesions and exposed pulps, treated with partial pulpotomy and dressed with $Ca(OH)_2$. The teeth divided into two groups. Group 1 consisted of 31 teeth with no clinical or radiographic symptoms before treatment. Group 2 of 6 teeth with temporary pain, widened periodontal space periapically and/or productive osteitis, i.e. increased density of the surrounding alveolar bone. Although an observation time of 24 to 140 months (x = 56 months), healing occurred in 29 of 31 teeth in Group 1 (93.5%) and in 4 of 6 teeth in Group 2. They concluded that, as well as previously reported results indicate that partial pulpotomy may be an adequate treatment for permanent molars with a carious exposure, although more studies needed before the treatment can be recommended for routine clinical use [59].

In 1994, **Caliskan M. K** represented a case report on exposed pulp with a crown-fractured vital permanent young tooth, which treated with pulpotomy using a calcium hydroxide dressing. In this case, Calcium hydroxide stimulated dentine bridge formation, which is a good indicator of pulp vitality, and reported that, although the case seriously contaminated for a long period with debris from the oral environment, the dentine bridge, which formed after pulpotomy, was able to function as a protective pulpal barrier. The tooth responded to an electrical pulp tester within normal limits and the periapical

radiographic appearance was normal at review after 7 years [89].

In 1998, Nosrat I. V, and Nosrat C. A. performed partial pulpotomy on six permanent molars with deep carious lesions and pulpal involvement with $Ca(OH)_2$ followed by zinc oxide eugenol, and finally covered with a semi-permanent restoration. All teeth showed hard tissue barrier formation, both clinically and radiographically, within three months and were free from subjective and objective symptoms and with observation period 26 months the patients also experienced the therapy positively. These findings and those of others helped gain more recognition for partial pulpotomy as a strong possible alternative therapy when pulps were exposed by deep carious lesions and a bleeding pulp during the excavation process. The rationale for this therapy was to remove the infected and/or inflamed pulpal areas beneath the carious lesion and disintegrated tissue [90].

In 2006, Albuquerque D. S et al evaluated histological aspects of the pulp-dentin complex of dogs submitted to pulpotomy and capped with ethyl-cyanoacrylate and calcium hydroxide. Thirty dog teeth were divided into 2 groups of 15 as follows: Group 1 - ethyl-cyanoacrylate; Group 2 - calcium hydroxide. The pulpotomies were carried out following all of the treatment precautions recommended for dogs. After 30 days, the specimens were submitted to histological preparation and were then blindly evaluated by a histologist. Data were analyzed statistically by the Fisher exact test, comparing the two groups.

After 30 days, the presence of a hard tissue barrier was observed in 83.3% of Group 1, and in 100% of Group 2 ($p = 0.478$). A continuous hard tissue barrier was observed in 50% of the ethyl-cyanoacrylate group and 75% of the calcium hydroxide group ($p = 0.652$).

This was concluded that both materials induced hard tissue barrier formation, but Group 2 had a higher percentage than Group 1, with no significant statistical differences; the differences observed between the different barriers (continuous/non-continuous) were not significant between groups and there was no pulpal necrosis in either group [(91)].

In 2009, Kiatwateeratana T et al compared the effect of enamel matrix derivative (EMD) and $Ca(OH)_2$ on Fifteen pairs of human contralateral premolars were intentionally and partially pulpotomized. The subjects recorded pain or discomfort during the first 10 days and were also interviewed and examined by a blinded examiner at 1 day, 2 weeks, 3 and 6 months post-operation using visual analogue scale (VAS). Periapical radiographs were taken prior to the operation, and 3 and 6 months post-operation. After 6 months, the teeth were extracted and processed for histological evaluation.

Results showed that After 6 months, healthy pulps capped with $Ca(OH)_2$ had more favourable results than counterparts capped with EMDgel. However, similar clinical and radiographic results were seen in both groups. Histological evaluation demonstrated that the $Ca(OH)_2$-treated teeth had less inflammation andmore dentine bridge formation than those in the EMDgel-treated teeth [(92)].

In 2010, Giro E. M. A et al evaluated Forty-six premolars obtained from 23 patients aged between 12 and 16 years and treated with corticosteroid/antibiotic dressing in pulpotomy with calcium hydroxide the teeth randomly were assigned into 3 groups. In Group I, pulpal wound was directly capped with $Ca(OH)_2$, and Group II and Group III received corticosteroid/antibiotic dressing for 10 min or 48 h, respectively, before pulp capping. Teeth were processed for histological analysis after 7, 30 or 60 days to determine inflammatory cell response, tissue disorganization, dentin bridge

formation and presence of bacteria. After direct pulp-capping with $Ca(OH)_2$, tissue healing and dentin bridge formation promoted by the pulp as long as bacterial microleakage is prevented.

It concluded that the use of a corticosteroid/antibiotic dressing before remaining tissue protection with $Ca(OH)_2$ had no influence on pulp tissue healing [(93)].

In 2013, Nosrat A et al evaluated human dental pulp response to pulpotomy with $Ca(OH)_2$, mineral trioxide aggregate (MTA), and calcium enriched mixture (CEM) cement. A total of nine erupted third molars were randomly assigned to each pulpotomy group. The same clinician performed full pulpotomies and coronal restorations with amlgm. The patients were followed clinically for six months; the teeth were then extracted and prepared for histological assessments. The samples were blindly assessed by an independent observer for pulp vitality, pulp inflammation, and calcified bridge formation. All patients were free of clinical signs/symptoms of pulpal/periradicular diseases during the follow up period.

In $Ca(OH)_2$ group, one tooth had necrotic radicular pulp; other two teeth in this group had vital un-inflamed pulps with complete dentinal bridge formation. In CEM cement and MTA groups all teeth had vital un-inflamed radicular pulps with complete dentinal bridge. This study revealed that human dental pulp response to $Ca(OH)_2$ might be unpredictable in comparison with CEM cement and MTA [(94)].

In 2014, Darwish S. S et al evaluated the histological and histomorphometric response of dentin–pulp complex to the enamel matrix derivative (Emdogain® gel) compared to that of $Ca(OH)_2$ when used as a pulp dressing in immature young permanent dogs' teeth. Dentin-like tissues bridging the full width of the coronal pulp at the interface between the injured and

healthy pulp tissues were seen after 1 month in both groups. They founded that with time; the dentin bridge increased in thickness for calcium hydroxide but disintegrated and fully disappeared for Emdogain-treated group. Progressive inflammation and total pulp degeneration were only evident with Emdogain-treated group. The root apices of Emdogain-treated teeth became matured and closed by cementum that attached to new alveolar bone by a well-oriented periodontal ligament. They concluded that in young permanent dentition, Emdogain could be a good candidate for periodontium but not dentino–pulpal complex regeneration as calcium hydroxide [(95)].

B.2-Pulpotec:

According to the company, Pulpotec is a preparation designed and tested for the permanent treatment, after pulpotomy, of pulpitis in vital molars as well as for infected molars of deciduous teeth. It was introduced for more than 20 years but largely confirmed by clinical studies carried out for more than 10 years.

It is Radiopaque, non resorbable paste for the treatment of pulpitis by pulpotomy in vital molars, both permanent and deciduous.

Composition

Powder : Polyoxymethylene, Iodoform, excipient

Liquid : Dexamethasone Acetate, Formaldehyde, Phenol, Guaiacol , excipient

According to the manufacturing description It is indicated for :

Adults: treatment of pulpitis on permanent vital molars.
Gerodontics : treatment by pulpotomy of molars suffering calcified root-canal.
Pedodontics : treatment of pulpitis on immature permanent vital molars,

enabling a complete radicular restoration of the tooth. Treatment of pulpitis in temporary vital molars, infected deciduous molars by pulpotomy even in the presence of an abscess. This indication is the only exception to the rule of pulpotomy on vital teeth, and must be treated by regular pulpotomy, without going beyond the floor of the pulp chamber in order Pulpotec never to be introduced in the radicular canal of deciduous teeth [(96)].

In 2003, Dedeyan S.A, and Donkaya I.P used Pulpotec in treatment of odontitis in temporary and permanent teeth of children with keeping of viable root pulp. 42 patients, male and female, ages from 4 to 56 years have taken part in clinical trials. Treatment of odontitis in molars by method of vital amputation was provided. The results showed the absence of pains at all patients without exception after used of Pulpotec. The clinical trial provided the high efficiency of Pulpotec for treatment of odontitis in molars of temporary and permanent teeth by vital amputation method and absence of negative dynamics during 6 months of the observation.

They concluded that the preparation surpasses in efficiency similar drugs being in possession of pediatric dentists. Simplicity in use, absence of pain symptoms during the treatment, decreasing of terms of treatment to two visits, keeping of pulp vital shall be considered to be advantages of the preparation. Positive results of medical trials of 'Pulpotec' preparation enable to recommend it for use in extensive clinical practice [(97)].

In 2004, Melekhov et al. evaluated efficiency of the using the Pulpotec material on 16 patients for Eighteen multi-rooted teeth pulpitis treated by amputation method. Twelve teeth (66,7%) have been characterized by carious cavity as per II class by Black, six teeth (33,3%) as per I class respectively.

Prior to and after treatment procedure pulp viability was determined and immediately upon the treatment procedure a tooth radiography was made.

The results showed that at the time of investigation the pulp was vital. The pain disappeared with 15 patients immediately after treatment procedure and three patients referred to it the next day. After 6 months, the pulp electro excitability was reduced although relevant clinical and roentgenologic conditions have been kept constant [(98)].

In 2008, **Tairov V.V and Melekhov S.V** published a research demonstrated the high levels of effectiveness in Collap-An and Pulpotec, for sealing the pulp stumps of teeth treated for pulpitis by the vital pulpotomy method on 31 molars in 31 patients of both sexes. On the day of the treatment no pain to the percussion of the teeth in all 31 patients, after one year, 1 patient (3.7%) who had been treated with Pulpotec and 2 patients (50%) treated with CollapAn had complained of pain when biting down. The results concluded that when treating pulpitis in teeth with unformed roots, a reliable isolation of pulp from external pathological irritants can be achieved, favourable conditions can be created for creating defence mechanisms in highly differentiated pulps and, to sum up, full tissue structures are formed, such as will stabilise further development of caries and associated complications [(99)].

In 2008, Tairov V.V, et al compared clinical data of modern treatments of the pulp by the method of the vital amputation using Pulpotec, Kollap An-K and as a control traditional Zinc Oxide paste. The clinical effects had been observed on 36 molars of 36 patients of the 2 sexes, aged between 17 and 54 years. 27 molars, presenting various types of pulps, have been treated by the method of vital amputation with Pulpotec, 4 have been treated using the Kollap An-K gel, and, finally, 4 molars by using a Zinc Oxide paste. The following periods of

control have been fixed: the day of the treatment by vital amputation, 3 days later, 6 months later, 1 year later. The irritation of the pulp stump at the evaluated patients can be characterized from weak to strong.

The analysis conducted during the various periods has shown that the result corresponds to the data of a large number of authors who suggest different treatments when performing a vital amputation. This analysis confirms the efficiency of the various evaluated treatments as well as the positive results obtained in 80 to 94% of the cases [(100)].

In 2010 **Mahmood M.A**. conducted a study concerned with the assessment of the antibacterial effects of pulpotomy with two materials medicament, mineral trioxide aggregate (MTA) and Pulpotec on various species of microorganisms, using agar diffusion test as the specimen incubated at 37◦C, the inhibition zone diameters were measured in (mm) at 24, 48 and 72 hours. Results showed that the highest mean diameters of growth inhibition zones were observed around Pulpotec against all tested microorganisms over 72 hours. According to t-test, there was a high significant difference between Pulpotec in comparison with MTA ($P< 0.01$). The difference was highly significance between the tested microorganisms. So in vitro antibacterial activity of pulpotec offered additional advantage over MTA [(101)].

In 2011, Agrwal M et al conducted a study to assess the clinical efficacy of using pulpotec and LSTR and compared with the conventional ZnO pulpectomy at 1, 3, 6, and 12 months postoperatively. Around 34 children aged between 4 to 9 years with deep carious lesions affecting the pulps of 60 primary mandibular molars were randomly divided into three groups for 20 teeth for each group. The results concluded that pulpotomy and pulpotec could be a good alternative treatment for conventional ZnO pulpectomy [(102)].

In 2012, Al-Salman K et al evaluated the effectiveness of Pulpotec paste in treatment of Thirty children suffering from pulpitis by pulpotomy of vital deciduous molars and immature permanent molars of children. Follow up extended to 6 months, each 2 month recall to evaluate the treated teeth-clinically and radiographically. The results showed Immediate pain relief after treatment in 80% of cases; mild pain which lasts only 2 to 3 days in 20% of cases. These teeth are clinically and functionally normal. Clinical and radiographical examinations carried out on follow up visits revealed that all cases showed a healthy physiological image with no trace of any pathological changes.

This study provided high efficiency of Pulpotec for treatment of odontitis in molars of temporary and permanent teeth, as the preparation surpassed simplicity in use, absence of pain symptoms during the treatment, decreasing of terms of treatment to two visits, keeping of pulp vital which considered to be advantages to Pulpotec [(103)].

In 2013. Al- Dahan Z. A. A evaluated the relative success of pulpotec, formocresol and Mineral Trioxide Aggregate (MTA) pulpotomy in cariously 45 primary molars of Thirty nine children, 15 teeth treated by each type of pulpotomy medicament, using clinical and radiographical examinations after 1 month, 3 months and 6 months respectively. After six months, the clinical success rate of the Pulpotec group was (93.3%), formocresol group was (73.3%) and (100%) for the MTA group, although the success rate of the formocresol group was the least comparing to the other two groups, it was statistically not significant (P= 0.05). The highest and lowest radio graphical success rates after six months, were encountered in the MTA (100%) and formocresol (66.7%) groups respectively, which showed a significant difference (P=0.04). The

radiographical success rate of the pulpotec group was (86.7%).This study suggested that Pulpotec and MTA can be used as a replacement for formocresol as a pulpotomy medicament in primary molar teeth [(104)].

In 2013, Shmakov A.M et al conducted a research of enamel and dentin microhardness in human teeth as well as in the teeth of experimental animals (dogs). Intact and nonvital human teeth as well as intact, nonvital and teeth treated with Pulpotec following vital pulpotomy. In this study Vickers microhardness test was used to measure microhardness of dental hard tissues. The results of the study showed that enamel and dental microhardness of non-vital human teeth decreased by 40 %, whereas in the teeth of dogs it decreased by 35 %. There were insignificant changes in dentin microhardness of non-vital human teeth and in the teeth of the experimental animals. It was noted that microhardness of dental hard tissues treated with Pulpotec following vital pulpotomy remained unchanged in comparison with intact teeth ($p < 0,05$). It concluded that treatment of teeth in dogs with Pulpotec following vital pulpotomy preserves strength characteristics of dental crowns in comparison with non-vital teeth [(105)].

In 2013, Kakarla P et al evaluated the pulpal response to collagen particles impregnated in antibiotics (Biofil-AB™) and Pulpotec that can be used as pulpal medicament.The total sample of 40 teeth from 20 children in the age group of 7-10 years which are non-carious had bilateral retained primary teeth were enrolled for the study. Nine teeth each were treated with collagen particles (group I) and Pulpotec cement (group II), Both groups were randomly subdivided into three teeth each that were extracted after 7, 15, and 30 days intervals and examined histologically.

Results demonsterated moderate to severe inflammatory cells in group I after all three intervals with dentinal bridge formation in two specimens. On contrary, none of the specimens in group II showed any signs of inflammation, but there was a discontinuity in the odontoblastic layer lining along the dentin walls. It concluded that both materials were proven to be promising alternatives as pulp medicaments. However, collagen was found to be a better material [(106)].

In 2013, Faraj BM. discovered clinically the influence of Pulpotec on the incidence of inter-appointment flare-up, with a view to advance the resolution of pain and/or swelling in patients presented for emergency root canal treatment of 860 teeth (510 symptomatic and 350 asymptomatic). Pulpotec paste was used as an intracanal medicament. The follow-up visit was scheduled, and the incidence and severity of inter-appointment pain was recorded at different time periods (8, 24, and 48 h, 3 days, and 1 week after the treatment) on simple descriptive pain intensity scale. The incidence of intense pain was 10 and 6 of the treatment cases at 24 and 48 h, respectively. Moderate pain was described only by 137 patients within the 24 h 3 days' time interval after treatment. At 7 days, all patients experienced no pain or only weak pain levels. Final, it recommended Pulpotec intracanal dressing as it is beneficial in rapid resolution of pain and/or swelling in emergency root canal treatment and in controlling postoperative pain in multi-appointment root canal treatment [(107)].

In 2014, Talaat D.M et al histologically evaluated the inflammatory response of dental pulp to Pulpotec versus Formocresol on 24 primary molars of three Mongrel puppies between the ages of six to ten weeks. The mouth of each puppy was divided into two halves; the teeth on the left half were treated using the Pulpotec while those on the right half were treated with the Formocresol. The portions of the jaws including pulpotomized teeth were carefully sectioned, stained and examined histologically by light microscope.

The results of the two groups showed pulpal inflammation that varied from mild, moderate to severe, hydropic degeneration, increased fibrosis, capillary dilatation, disruption of odontoblastic layer and internal root resorption that started earlier in the Formocresol group. It has been concluded that both groups showed comparable unfavourable histological response [(108)].