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LOSS OF PULP VITALITY FOLLOWING PREPARATION OF VITAL TEETH FOR CROWNS/FDPS RESTORATIONS FOR AT LEAST 5 YEARS OF FOLLOW UP PERIOD: A SYSTEMATIC REVIEW AND META-ANALYSIS

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ABSTRACT

Loss of pulp vitality following preparation of vital teeth for crowns/FDPs restorations for at least 5 years of follow up period: A Systematic Review and Meta-Analysis

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Background: Loss of pulp vitality is a common biological complication after full coverage indirect restorations, and dental practitioners should be aware of the contributing factors to achieve best treatment outcome.

Aim: The aim of current review was to investigate the incidence of loss of pulp vitality in the vital teeth restored with full coverage crown or FPDs (fixed dental prostheses) and the factors that might lead to loss of pulp vitality following crown preparation procedure.

Material and Methods: An electronic PubMed search accompanied with manual searching was conducted for the clinical studies on full coverage single crown or full coverage FPDs of vital teeth were performed from 1960 to November 2021 for at least 5 years of follow up period. Risk of bias was assessed with the Newcastle-Ottawa Scale. Statistical analyses were used to identify instantaneous incidence of loss of pulp vitality for the single crowns and bridge abutments groups, and subgroup of restorations according to the type of restoration material.

Results: The search provided 1964 records, after duplicates removal and screening of titles and abstracts, 27 records were eligible for full text reading resulting in 12 studies being included on full coverage crowns/bridges restorations in initially vital teeth. The instantaneous incidence of loss of pulp vitality in full coverage crowns/bridges group was 5.4% (95% CI,2.3-

12.3) and 7.4% (95% CI,4.4-12) respectively and the mean incidence of both groups was 6.5% (95% CI,4-10.4). The value of z is 3.1486, and the value of p is 0.00164, the result is significant at ($p < 0.05$) when comparing the loss of pulp vitality incidence of crowns and abutments.

A Sub Mata-analysis conducted to identify the incidence in the type of material groups (Metal-Ceramic, All Ceramic and Zirconia) and yield incidence of pulp vitality loss among all ceramic material with an incidence of 5.3% (95%CI, 1.7-15.1), out of one study, and 6.5% (95%CI, 2.6-15.6) among metal ceramic restorations in three studies, while the incidence was 6.3% (95%CI,0.4-53.9) of zirconia crowns in one study.

Conclusion: Preserving the pulp vitality after cementation of crown or bridge is important for the best treatment outcome. The incidence of loss of pulp vitality in full coverage FDPs abutments is more compared to full coverage single crown in the vital teeth.

DEDICATION

First and foremost, I would like to thank the Almighty God, for the grace and all the blessings. With great gratitude and appreciation, I would like to dedicate this work to; my beloved husband Dr. Ahmad who has been incredibly supporting me and being my rock all the way, who has always believed in me and stood by my side to finish with success, for being the best friend- dentist ever.

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To Juman Pearls Dental Center, we are all working on the dream.

DECLARATION

I declare that all the content of the thesis is my own work. There is no conflict of interest with any other entity or organization.

Name: Jumana EyalSalman

Signature: ……...

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1. INTRODUCTION

Full-coverage indirect restorations include either full coverage single crowns or fixed-fixed partial denture retainers for the abutment teeth which are used to support and protect teeth after extensive caries removal, root canal therapy, cracks in tooth structure or tooth surfaces loss. Generally, full-coverage restorations are indicated for several clinical situations including dental caries, root canal treatment, worn dentition or occlusal problems, aesthetic, failed restoration or crown replacement, and to replace adjacent missing tooth/teeth, where is the most common reason for the provision of crowns was tooth fracture (Wilson 2003)

Pulp health is important for the long-term prognosis of the restored teeth and should be taken seriously during dental treatment to avoid any further complications which may totally affect the treatment outcome. For instance, it may be necessary for dental practitioners to perform root canal therapy after delivering definitive restoration because of loss of pulp vitality happening later, which could require removal of the crown or bridge, or treating the tooth through drilling of access hole without removing the crown or bridge to avoid the need for replacement with new restoration. This is a complex process, but it may help patient to save on cost because the removed restoration usually cannot be used again. Some dental practitioners provide intentional root canal therapy before crowning the vital teeth to avoid having such problems which is not advised and considered a malpractice and only indicated for few cases. In spite of all efforts to identify the dental pulp status before delivering of definitive indirect restoration (JM Whitworth 2002) the possibility to loss of pulp vitality should be considered in all cases and the patients should be informed and aware of treatment complications in addition to the need for future root canal treatment.

More importantly, dental practitioners should follow the correct protocol when providing treatment and considering the history of dental diseases, the factors affect the pulp vitality during crowning producers and maintaining a regular follow up for the cases.

Many studies have been conducted to find the incidence of loss of pulp vitality in crowned vital teeth with different follow up period, and much more studies performed to investigate the survival and success rate of fixed restorations and to determine the complications associated with treatment. The need for endodontic treatment in fixed prosthodontics is considered one of the most common complications in fixed restorative treatment (Goodacre 2003).

Since no adequate number of studies related to endodontic complications on the vital teeth solely in prosthodontics work, the aim of current systematic review is to identify the incidence of pulp devitalization and factors affecting the pulp vitality in fixed prosthodontic treatment, including full-coverage single crowns and fixed-fixed partial dentures abutments.

Different clinical studies have reported the loss of pulp vitality as an outcome of crown or FPD restorations. In the present study, we considered the reports with the observational period being more than 5 years, in order to be able to draw a clinical conclusion that will help the dental practitioner as well as the patient, in terms of awareness towards the long-term treatment complications, helping dental practitioners/patients making better treatment decision considering clearly risks and benefits for each treatment options. Furthermore, the need for long-term follow up is important to monitor the treatment outcome and to investigate the need to manage treatment complications. Moreover, the results could be useful for the health care decision-making and policymakers.

2. REVIEW OF THE LITERATURE

Full coverage indirect fixed prosthodontic treatment for defective tooth structure and the missing teeth is considered a predictable treatment option either by single crown or fixed partial dentures (Pejtursson 2015; Pieger S 2014; Sailer 2015; Sailer I 2018). There are some biological complications associated with this type of treatment, even with high survival rate, secondary caries and endodontic complications being the most common type of complication (Pejtursson 2015; Sailer I 2015).

Many teeth lose vitality after crowning process, as crown preparations bring the pulp to risk in different ways including pulpal overheating during high-speed hard tissue cutting. Furthermore, tooth preparation opens dentinal tubules that exposes the pulp to the oral environment. The deeper cutting in dentinal tubules results in the more permeability towards the oral flora. According to Bergenholtz and Nyman's (Bergenholtz 1983) study 9% of crowned teeth and only 2% of uncrowned controls lost vitality during long-term review, and higher levels of pulp death were recorded by Felton et al (Felton 1989) 13.3% of teeth restored with full coverage crowns, compared with 0.5% of unrestored controls lost vitality during the 3–30 year review period.

A number of studies have attempted to estimate the incidence of loss of pulp vitality after the placement of fixed prostheses. This incidence was found to range between 2 and 33.8% after an observation period of 6 months to 30 years (Bergenholtz 1983; Cheung 1991b; Cheung GS 1990; Cheung GS 2005; Dawson 2014; Dutta A 2014; J.Valderhauge 1997; Jackson 1992a; Karlsson 1986; Palmqvist 1993b; Saunders WP 1998; Walton 1999).

Another group of studies reported that 2% to 10% of crowned teeth show signs of loss of pulp vitality and/or necrosis after treatment (Eckerbom M 1991; Randow K 1986; Walton 1999) which is in the same prevalence of asymptomatic apical periodontitis that was reported by (de Oliveira BP 2017; Dutta A 2014; Filippo GD 2014).

Endodontic complications are the third most common cause of tooth extraction for the crowned teeth (Dikbas I 2013; Eckerbom M 1991; Eriksen HM 1991; Erikssen HM 1995) But before of tooth extraction patient may experience pain and may suffer from infection and subsequently loss of the restoration and the need for new replacement treatment.

2.1. Dental Pulp and Dentin

Dental pulp is a unique tissue surrounded by dentin, enamel and cementum, hard tissues protect the pulp from external irritants like oral microflora, which will find the pathway towards the dental pulp and irritating it if the structural integrity of the hard tissues is affected, this irritation process by bacterial toxins will stimulate pulp inflammation, and if it is not treated it will lead to loss of pulp vitality and spreading of infection to surrounding alveolar bone and tissue, resulting in oral sepsis, which can be life threatening and can cause significant morbidity (Walsh 1997). Always in all dental treatment still the most serious risk factor for pulpal health is the bacterial fluids and bacterial contamination (Cohen 2002))

There is specialized cells in dental pulp, odontoblast and undifferentiated mesenchymal cells, dental pulp can retain the ability to form dentin throughout the life by presence of mesenchymal cells which differentiated into dentin forming cells if stimulated, which assist the tooth to withstand more by forming more hard tissue to compensate the loss of enamel and dentin from caries and tooth wearing or tooth structure cutting, making barriers around the pulp to protect the dental pulp from harmful irritants (Murray 2003).

Teeth with vital pulp resist bacterial invasion more than pulp-less teeth (Nagaoka 1995), in a vital tooth there is dentinal fluid and odontoblast process which play an important role in defense process against bacterial invasion. Dentinal fluids movement resist entry of harmful substances from oral cavity by outflow of dentinal tubules fluids (Vongsavan N 1992). There are 50,000 to 70,000 tubules/mm^2 at the pulpal wall.

The pulp is a sensory organ, registering different sensory stimuli, such as thermal and mechanical changes, and trauma such as pain. Also, this is a part of pulp defense mechanism allowing patient to seek treatment in earlier stages, thus preventing the damage to reach the surrounding tissue. Moreover, proprioception from pulp tissue decreases the load applied from masticatory muscles during functioning, giving more protection for the teeth from injury (Matsutani K 2000; Paphangkorakit J 1998).

Among several hypotheses about dental pain transmission, the hydrodynamic theory is the most accepted one than odontoblastic transduction and dentin innervation theories, (Matthews B 1994), In this theory rapid movement of dentinal tubules fluid deform nerve membrane directly or indirectly by odontoblast cells to start action potential.

The number and the diameter of the tubule close to the pulp are considerably larger than at the dentin-enamel junction (Schmalz G 2001), the tubules are wider in the young patient, so this will increase the risk on the pulp in young patients than that in older patients.

The greater the area of exposed dentin, the greater is the effect on the pulp and the dentin is not only permeable, but it is also a vital tissue biologically responsive, and thus any contact of a material or substance with dentin may possibly interfere with the dental pulp health.

Pulp inflammation could be acute, chronic, partial or complete. Preparation of the tooth may develop an acute partial pulpitis which might be mild or severe. And the previously restored tooth might have a history of acute inflammation from the past treatment which accelerated with further tooth preparation during crowning and developing chronic inflammation of the pulp after insertion of the final restoration and endodontic treatment will be considered later.

Endodontic testing should be performed before cementation of the definitive restoration to determine the pulp status, which has two main components, pulp sensibility and periapical tests. Traditional pulp tests include electric, cold and heat pulp tests, and each test has weaknesses, strengths, and common errors (H. Jafarzadeh 2010), In addition to pain history,

clinical and radiographic examination. But still a necrotic pulp may be asymptomatic for a few months to years after restoration insertion that is why some teeth develop loss of pulp vitality after crown or bridge cementation permanently, and the only reliable method of evaluating pulp status is through histologic investigation which is not applicable clinically (Chambers 1982; Langeland 1965; Seltzer 1963).

In general, pulp irritants could be constant or specific events that affect the dental pulp health which could be also classified to long-term, short-term or trauma, and each type could lead to acute, chronic inflammation or loss of pulp necrosis. Short-term irritants usually cause acute inflammation which followed by resolution of the inflammation, long-term irritants will cause chronic pulp inflammation and if not investigated will cause loss of pulp necrosis. Trauma pulp irritants like tooth displacement or trauma from occlusion could interfere the blood supply causing pulp injury then loss of pulp vitality.

Many factors can cause loss of pulp vitality after crown procedures, including traumatic tooth preparation, inadequate provisional restorations, pulp injury caused by cements or cementing procedures, use of local anaesthetics containing adrenaline, occlusal trauma, or cumulative effect from caries, periodontal disease, trauma or restorative treatment.

Pulpal complications involving inflammation, degradation and necrosis are the result of a series of traumatic external injuries. So, it is the responsibility of the restorative dentist to minimize the trauma to dentin and pulp during all clinical procedures, especially in the tooth preparation phase (Vitalariu 2005).

Potential risk factors that can irritate dental pulp and can lead to loss of pulp vitality during crown preparation and the factors might be categorized as microbial, thermal, mechanical, chemical, and electrical (Seltzer 1963)

Christensen 1997 considered the cutting of tooth structure, inadequacy of provisional restoration and the effect of cement and cementing procedures to be the major causes of subsequent loss of pulp vitality in fixed restorative treatment (Christensen 1997).

2.2. Pulp irritants during full coverage crown/FPD procedures

The following are the most important factors that put the dental pulp health at risk during crown/FPD prosthetic works:

2.2.1 Tooth preparation:

Amount of tooth structure removal during tooth preparation determined by the type of restoration and restoration material would be used. For instant, materials for full coverage indirect restorations could be, metallic, non-metallic or a combination. Edelhoff and Soresenson (Daniel E 2002), stated that the PFM crowns removed 8% more tooth structure than all-ceramic crowns and 20% greater than all-metal crowns. While a minimal reduction of 1.5mm is routinely indicated for acceptable aesthetic and function for all ceramic restorations (Christensen 2005).

Bridge retainers require more amount of tooth reduction to align the preparation for a common path of insertion (Cheung GS 1990). For instance, severely tilted teeth have higher risk of pulp exposure, the size of the pulp chamber should be considered especially if realignment of the tooth is important. Root canal treatment should be considered in the case of the pulp exposure during crown preparation (JM Whitworth 2002).

The deeper the amount of tooth structure reduction in preparation the wider the dentinal tubule are present subsequently the more chemicals or bacterial fluids could penetrate the vital pulp and the more likely that severe damage will be inflicted on the pulp.

History of the past dental diseases or treatments can be a predictor of the future dental pulp complications (Cheung 2005). There is an agreement in the literature that each step which is

involved in the fabrication of a crown or fixed dental prosthesis can cause pulp damage (Jackson 1992a).

Undoubtedly the speed of hand piece and the heat generated during tooth preparation affect the pulp vitality. Increasing of pulp temperature more than 5.6^{o} during tooth structure cutting could affect the pulp vitality and cause loss of pulp vitality (Zach 1965). There are other factors during tooth preparation could influence the pulp temperature raise like ; type of coolant that used during tooth preparation whether it is water spray, water/air spray or air spray and degree of water flow, design of bur, applied load (Cavalcanti 2002; Laforgia 1991a), speed of rotary instrument, thickness of remained dentin and preparation proximity to pulp (Castelnuovo 1997; Christensen 2002; Laforgia 1991b; P Ottle 1998; Pashley 1990; Vitalariu 2005).

Desiccation is often associated with heat and may also be a contributing factor to pulpal inflammation during crown preparations (Daniel E 2002). Odontoblasts and erythrocytes aspirated into the dentinal tubules from desiccation and that could cause injury to the pulp (Langeland 1965) Odontoblasts aspiration can disappear within 24 hours by autolysis and do not cause inflammation of the pulp, but a reduction in number of odontoblasts lead to the formation of reparative dentin after 1 to 3 months (Brannstrom 1996).

Another mechanical harm from tooth preparation is produced by eccentricity of dental hand pieces which may result from multiple sterilizations cycles. This may cause trauma to the tooth if the eccentricity of the hand piece is reduced or the bur is dull, more force is required for tooth reduction which can generate more heat affecting the pulp health (Christensen 2002).

Tooth preparation into dentin produces smear layer which contains tooth debris in addition to organic matters like blood, saliva and micro-organisms, this smear layer prevents bacteria from accessing dentinal tubules and reduces surface wetness from dentinal fluids at cementation time. Although, some microorganism trapped during tooth preparation or provisional restoration period or during cementation and can survive and grow, if micro leakage occurs

later on, or if the dentinal tubules open for enough to allow for a source of nourishment then pulpal damage or recurrent caries could result, so the dentin cleaning process before cementation without blocking of the tubules is an essential step to enhance the bonding strength of cement and to decrease tooth sensitivity later. Such cleaning process by using mechanical or chemical agents should be determined according to the adhesive system that used for cementation (Magne 2005).

During tooth preparation, frictional heat results in expansion of fluid in the tubules. Blood flow and lymphatics should drain this fluid, but this may not occur if blood flow has been reduced because of the use of a vasoconstrictor-containing local anaesthetic. Therefore, it is important to use an anaesthetic solution such as Citanest/Octapressin (Astra) that does not disturb blood flow (Brannstrom 1996)

All are risk factors that could increase the severity of pulp reaction to chemical and mechanical irritation during preparation procedure.

2.2.2 Provisional restorations

A provisional restoration has been introduced as an important component in the various dental disciplines to be used for the function, protection and aesthetic demands during restorative treatment, and most of the time provisional restoration made from resin material which may develop pulp irritation either by chemical, thermal or poorly sealed margins of the interim restoration.

Heat generated from polymerization of provisional resin restoration, or the close contact between the vital dentin and monomer or residual monomer in the set material all have biologic concerns on the pulp health (Smith 1982), so reseating techniques during fabrication of provisional restoration by multiple removal and insertion of restoration in elastic stage would decrease the heat from exothermic reaction of the resin (Castelnuovo 1997). However, using light activated resin provisional material have shown less temperature rise during

polymerization compared with (poly)methylmethacrylate, vinyl ethyl methacrylate, and Bis-acryl composite resin provisional materials (Driscoll 1991; Michalakis 2006). Moreover, a poorly fitting provisional restoration may expose the dentin to oral fluids and microflora and with the prolonged time of using provisional restorations the possibility of pulp injury will increase.

Dental practitioners should ensure of the fitness and marginal seal of the temporary crowns to protect the pulp from bacteria and their metabolic by-products (Brannstrom 1996). It is recommended to fabricate provisional restorations with indirect method and to use modern composite resin material to decrease the thermal and chemical effects on pulp and to ensure adequate marginal seal. Because the bacteria may reach the pulp after 1 to 2 weeks from area of exposed dentin under the provisional restoration then the dentin will be very sensitive when the provisional crown is removed.

However, the most important to success is the choice of proper luting cement and cementation procedure because of cement dissolution can cause restoration marginal leakage. While the most dangerous period for the pulp during crown and bridge work is the period where the provisional restoration is in place, and it should be minimized with cementation of the definitive restoration as soon as possible.

(Langeland 1965) stated that “the definitive cementation of a crown restoration will cause no reaction if the pulp has not been injured by previous procedures”.

2.2.3 Impression material

To ensure accurate registering for the preparation details and margins during impression taking, drying of exposed dentin is essential for the current impression materials, since the dentin is a moist vital tissue then dentin should not be aggressively dried during all dental treatment.

Immediate dentin sealing for the fresh cut dentin is a preferred clinical step to do it directly after tooth preparation and before taking impression to prevent contamination of dentinal

tubules with the impression material or microbial contents which affect the bonding strength of the crown later and may cause sensitivity (Bruna Sinjari 2020). Some studies have reported the effectiveness of application of desensitizers before final cementation to reduce the pre-and after cementation hypersensitivity (Gupta 2013; Jalalian 2009). However, there is a concern regarding the effect of dental desensitizers on the quality of the bond and retention of the full coverage restorations.

The use of retraction cord has proved to be an effective method of gingival displacement during impression making, injury to sulcular epithelium may be caused by placement of retraction cord and cotton strings into the gingival sulcus, this type of trauma depends on the amount of force used by the clinician for cord packing, the duration of time that the cord being left in the gingival sulcus and chemical material that the cord has been impregnated with. Injury to the gingival sulcus and deterioration in the biological width might result in permanent recession later, put the tooth at risk of exposed dentin contamination and sensitivity after definitive crown cementation (PV Harish 2015).

2.2.4 Cement for provisional and definitive restorations

Resin-based materials such as self-adhesive resin cements used to lute crowns/ FDPs have been shown to have cytotoxic effects on specific cell types, such as fibroblasts. These cements release uncured, free monomers that can diffuse through dentinal tubules to the pulp. These uncured resin components have been shown to inflict localized pulpal inflammation when in close proximity to pulp tissues (Şişmanoğlu 2020).

The performance of cements and risk of micro leakage under definitive or provisional restorations is affected by the marginal integrity of the restoration. Bergenholtz found that poorer marginal fit of a crown was directly proportional to the amount of inflammation in the associated pulp tissues. Poor crown margins can lead to an accumulation of plaque, increasing the risk for recurrent decay under a restoration. As anytime a dentinal tubule is exposed, there

is risk for pulpal contamination with the smear layer that left after tooth substance cutting. Inadequate margins can encourage the ingress of bacteria to otherwise healthy pulp tissue (Bergenholtz 1983).

The pulp will react favourably to a more rigid provisional restoration and rigid cement such as zinc phosphate or polycarboxylate cement. A perfect seal may result in sensitivity and even toothache, possibly because the outward movement of dentinal fluids has been blocked in partially infected dental pulp. It is better that if this occurs during the placement of a provisional crown than after permanent cementation (Brannstrom 1996).

Luting cements may not cause pulp irritation, and as the dentin should be kept wet until the time of cementation, and to prevent formation of voids or fluid spaces under the restoration, the cement should be applied over the dentin and the crown as well, at the same time during cementation, these fluid spaces may lead to thermal sensitivity and can harbor bacteria from previously contaminated dentinal tubules.

2.2.5 Occlusion

Both traumas produced by frictional heat during preparation and excessive stress associated with malocclusion may interfere with the flow of blood to the pulp, increasing sensory nerve excitability and producing hemorrhage and local necrosis. Excessive load during functioning applied on a high crown could results in injury to the pulp and this may lead to a poor cellular response, inadequate blood supply and hypersensitivity. Occlusion should be evaluated during provision restoration period and prior and during to permanent cementation of the definitive restoration.

3. AIMS

Aims

The aims of the present systematic review are:

- To find the instantaneous incidence of loss of pulp vitality among full coverage crowns and full coverage fixed partial dentures abutments for initially vital teeth in restorative treatment
- To study the effect of crown/bridge preparation of vital teeth on pulp vitality and the factors associated with loss of pulp vitality following preparation of vital teeth for full coverage crown/bridge restorations.

4. MATERIALS AND METHODS

4.1. Protocol development and registration

The presented systematic review was prepared in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses PRISMA (Moher 2009).

Systematic review was conducted through the literature in PubMed library in English language, and articles published from 1960 to November 2021 reporting the loss of pulp vitality after crown/bridge abutment preparation procedure in a single full coverage crown or in full coverage abutments in FDPs.

Searching process included study types: randomized controlled clinical trials, non-randomized controlled clinical trials, prospective and retrospective cohort case were searched according to search terms and selection criteria.

The present review will attempt to address the aims using PICO elements: Population, intervention, comparison, and outcome approach (Syrene A. Miller BA 2001).

4.2. PICO criteria

P - Population: Vital teeth prepared for single crowns or FDP abutments

I - Intervention: full coverage crowns/FDP retainers for vital teeth

C - Comparison:

- Vital full coverage crowns/abutments with non-vital crowns/abutments of initially vital teeth after preparation in prosthodontic treatment
- Loss of vitality in a single crown versus FDPs abutments after prosthodontic treatment
- Loss of pulp vitality in metal-ceramic, full ceramic and zirconia crowns/abutments FDP

O - Outcome:

Primary outcome:

The Incidence of loss of pulp vitality after crown/FDP procedure

Secondary outcome:

- Restoration material either metal-ceramic or full ceramic and how the type of restoration material affect the pulp health after crown/FDP treatment
- Factors contributing to loss of pulp vitality

4.3. Eligibility criteria

Inclusion criteria

- Studies based on humans
- Studies including randomized- controlled clinical trials (RCTs), controlled clinical trials (CCTs), prospective cohort studies and retrospective case series.
- Studies on full coverage crowns
- Studies on full coverage FDP abutments
- Studies with determined mean follow up period; more than 5 years
- Radiographic and clinical examination used to detect the loss of pulp vitality
- Studies with quantitative outcomes about loss of pulp vitality
- Studies described the restoration type clearly either full coverage single crown or FDP retainers
- Studies on full metal, metal- ceramic or full ceramic of full coverage single crowns or FDP retainers
- Studies in English language will be included.

Exclusion criteria:

All the studies that not meeting all inclusion criteria will be excluded.

- *In vitro* studies
- Animal studies
- Case report studies
- Studies without determined follow up period

- Studies with less than five years of follow up period
- Studies did not mention the material of restoration
- Studies did not describe the restoration type clearly
- Studies did not mention the radiograph and clinical examination to determine the loss of pulp vitality after prosthodontic treatment
- Studies not in the English language

4.4. Information sources and search strategy

The principal investigator (J.E) and primary supervisor (M.A) and co-supervisor (H.E) developed detailed search strategies for PubMed database involving MeSH terms and PubMed entry terms were examined to find synonyms, a separate search was performed for each PICO element. The studies search was supported by specialized librarian, and it was included only publications with English title and abstract.

Search terms

(((((("Patients"[Mesh]) OR "Adult"[Mesh]) OR "Young Adult"[Mesh]) AND (((((((("Crowns"[Mesh] OR "Tooth Crown"[Mesh]) OR "Dental Abutments"[Mesh]) OR "Dental Restoration, Permanent"[Mesh]) OR "Dental Porcelain"[Mesh]) OR "Dental Restoration Failure"[Mesh]) OR "Dental Prosthesis Design"[Mesh]) OR ((((((((((((Full coverage indirect restoration) OR (crown restorations)) OR (complications)) OR (crown)) OR (survival rates)) OR (Bridge)) OR (metal ceramic crown)) OR (full crown)) OR (all ceramic crown)) OR (zirconia crown)) OR (fixed prosthodontics)) OR (fixed dental prosthesis)) AND ((((((("Dental Pulp"[Mesh]) OR "Dental Loss of pulp vitality"[Mesh]) OR "Dental Pulp Diseases"[Mesh]) OR "Dental Pulp Devitalization"[Mesh] AND (1970:2022[pdat])) OR (((((Crown pulp) OR (periapical)) OR (loss of pulp vitality)) OR (apical periodontitis)) OR (Biological complications)))) AND ((("Dental Pulp Devitalization"[Mesh]) OR "Dental Pulp Diseases"[Mesh]) OR ((Loss of pulp vitality) OR (Periapical changes))).

4.5. Study selection

All the results from primary search process were imported into the Rayyan online software (https://rayyan.qcri.org) for the screening process by title and abstract. Rayyan was also used to find and remove duplicate publications.

The principal investigator (J.E) assessed the studies for eligibility using Rayyan software. The studies were assessed first at the title and abstract level and later at the full-text level according to the PRISMA guidelines (Figure 1). If the abstract was not available online, the full-text article including the abstract was used. Finally, as the last step, an additional search was performed by screening the reference lists of all relevant full-text articles, and further search process performed by using Google scholar search engine.

4.6. Assessment of risk of bias of included studies

Risk of bias (RoB) of the included publications was assessed depending on each study design, the Newcastle–Ottawa Scale (NOS) for interventional non- randomized controlled trials and Cochrane recommendation RoB 2.0. tool for interventional RCTs.

4.7. Data extraction and management

Data extraction and management was done using data extracting tables to get the information about the following parameters: authors, year of publication, type of study, incidence of loss of pulp vitality, number of patients, number of crowns/abutments of initially vital teeth, age of patients, gender of patients, restoration type either crown or bridge retainer, restoration material type either full metal, metal-ceramic or full ceramic, follow up period length, tests used to determine the loss of vitality either radiographic or clinical examination, treatment provider.

Results from comparable groups of studies pooled into statistical meta-analysis using an appropriate software. Heterogeneity between combined studies will be tested, and when the statistical pooling is not possible, the findings will be presented in narrative way.

4.8. Statistical Analysis

Instantaneous incidence in percentage were calculated to describe the incidence of the pulp vitality rate in general (crowns and bridge abutments), by crown, by abutment and for materials that used, and the mean and 95% confidence intervals (CI) were calculated for the variables proportion and 95% CI was used to describe the characteristic of this variable.

Meta-Analysis using the random-effect model was performed to estimate the parameters and 95% CI. Pooled percentage, proportion, and corresponding 95% CI were calculated to summarize the weighted effect size for all parameter variables. The measure of heterogeneity reported included the Cochran's Q statistics to determine if there are differences on a dichotomous dependent variable between three or more related groups.

I^2 index with the level of heterogeneity defined as poor < 25, moderate > 50, and high > 75, and the T square (T^2) test. Publication bias was assessed with a funnel plot and the Egger test.

5. RESULTS

5.1. Study selection

Data search was performed in November 2021, the flowchart of records through the reviewing process is shown in Figure 1. Initially from preliminary search 1964 were found, 1951 records remained after exclusion of duplicates, Furthermore, 1924 were excluded after screening the titles and abstracts. Twenty-seven studies were eligible for full-text review. During the full text evaluation of the total twenty-seven studies, twelve studies were included, fifteen studies were subsequently excluded. The reason behind excluding each of the fifteen studies are summarized in Table 1.

Five studies excluded (Bergenholtz 1983; Cheung GS 1999; Dikbas I 2013; Jackson 1992a; Palmqvist 1993b), because of the restoration material types were not clearly specified.

Four studies excluded (Carlson BR 1996; J.Valderhauge 1997; Nagaoka 1995; Nevalainen M 1995; Walton 2013) because of the type of restorations material were not one of the three material that we need to intervene in our systematic review, not full metal, metal-ceramic or full ceramic/Zirconia.

Four studies with reported observational period of less than 5 years were also excluded (Cheung 1991a; Ericson S 1966; Raigrodski AJ 2006; Uzgur Z 2016), and one study had no follow up period (Saunders WP 1998).

One study excluded (Wolfart 2009) because of the lack of details on the examination methods that were used to detect the pulp vitality loss or the details about radiographic examination.

Thus, twelve records remained for systematic review Table 2 (Bart I Dobler B 2012; Cheung GS 2005; Dogan S 2017; Ioannidis 2016a; 2016b; Jokstad A 1996; Karlsson 1986; Lockard 2002; Palmqvist 1993a; Reuter JE 1984; Walton 1999; 2002; Wolleb K 2012)

no additional studies could be identified from the manual search in Google scholar and from reference lists.

Figure 1: Flow diagram of the selection process

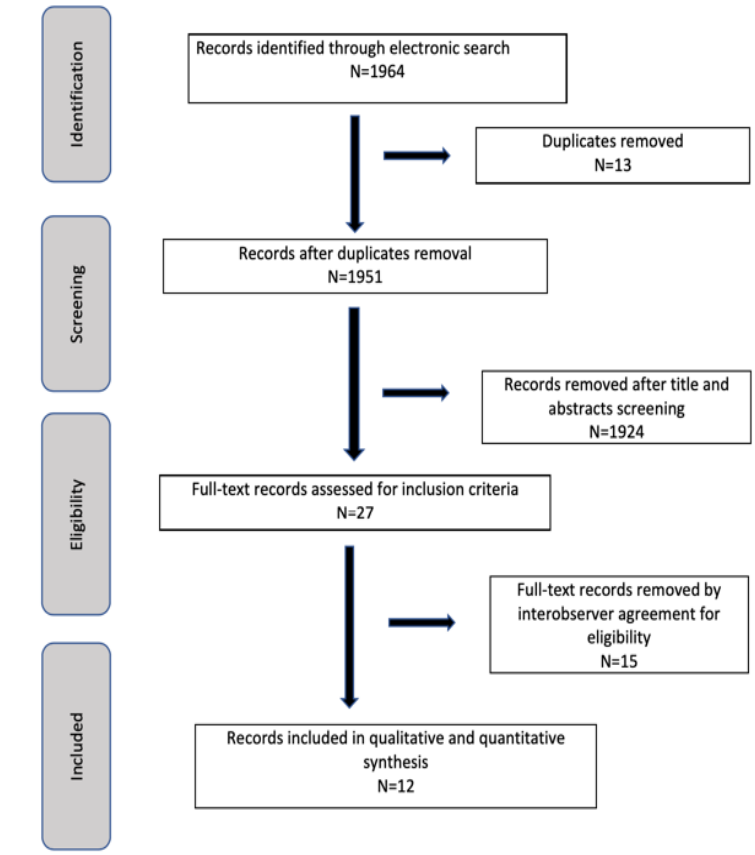


Table 1: Studies excluded and reason for exclusion

No	Study	Year of publication	Reason for exclusion
1	Cheung	1990	Material not mentioned
2	Cheung	1991	Follow up period less than 5 years
3	Bergenholtz	1984	Material not mentioned
4	Valderhauge	1997	Not metal-ceramic or full ceramic
5	Nevalainen	1995	Not metal-ceramic or full ceramic
6	Raigrodski AJ	2006	Follow up period less than 5 years

7	Dikbas I	2013	- Material not mentioned - We don't know whether the teeth were vital or non- vital before getting periapical periodontitis in 12% from extracted teeth
8	Carlson BR	1996	Not metal-ceramic or full ceramic
9	Jackson CR	1992	Material not mentioned
10	Uzgur	2016	Follow up period less than 5 years
11	Ericson	1998	Follow up period less than 5 years
12	Swartz	1996	Material not mentioned
13	Stefan Walfart	2009	No details about radiographic examination
14	Walton TR	2013	Not metal-ceramic or full ceramic
15	Saunders	1998	No follow up period

5.2. Studies Characteristics

The general characteristics of the studies included in the present systematic review, as well as sample characteristics, are presented in Tables 2 and 3. The selected eligible studies were published between 1984 and 2017. All were retrospective cohort studies except three studies (Dogan S 2017; Ioannidis 2016a; Jokstad A 1996) which were prospective cohort studies.

In all studies a group of patients treated to receive single full coverage crown/crowns or FDP/FDPs with full coverage retainers on a vital tooth as a part of prosthodontics treatment. In two studies (Dogan S 2017; Walton 1999) the treatments were provided with single full coverage crown as outcome evaluated for the loss of pulp vitality after crown treatment. In five studies (Bart I Dobler B 2012; Loannidis 2016; Karlson 1986; Reuter JE 1984; Walton 2002) the treatments were provided with FDP, and the rest of five studies the treatments were done with single full coverage crowns together with full coverage FDP retainers for vital teeth as part of prosthodontics rehabilitation (Cheung 2005; Jokstad A 1996; Lockard 2002; Palmqvist 1993b; Wolleb K 2012).

5.3. Results of individual studies and synthesis of results

The total observed number of indirect restorations in the selected studies was 6046. The total number of indirect prostheses were cemented in 1557 patients. The single crowns counted 2782 while FPDs retainers counted 3264.

All patients followed for more than 5 years according to inclusion criteria of the present review. The follow up period ranged from 5 years which was the shortest (Dogan S 2017) where the incidence of pulp vitality was 0%, to 31 years which was the longest (Lockard 2002) and the incidence of pulp vitality was 2.19%.

Incidence of loss of pulp vitality in single crowns varied from 0% (Dogan S 2017) to 15.6 % (Cheung 2005), while for abutment ranged from 2.19% (Lockard 2002) to 32% (Cheung 2005), The incidence of pulp vitality in both crowns and abutments is illustrated in Figure 2.

The overall incidence of pulp vitality loss in the included studies was 6.5% (95% CI,4-10.4), while the incidence of pulp vitality loss among crowns was 5.4% (95%CI,2.3-12.3), while in abutments was 7.4% (95% CI,4.4-12), the value of Z is 3.1486, and the value of p is 0.00164, the result is significant at $p < 0.05$ when comparing the loss of pulp vitality incidence of single crowns and bridge abutments and the result is statistically significant, Figure 2.

Material of the restoration varied between Gold based metal ceramic, all metal, porcelain fused to metal, all ceramic, full gold, zirconia, gold resin, porcelain bonded to gold and acrylic veneered gold crown, Table 2. The material that used exactly for the initially restored vital teeth were not specified in the studies (Jokstad A 1996; Karlsson 1986; Lockard 2002; Palmqvist 1993b; Reuter JE 1984; Wolleb K 2012), They used different types of restoration material to restore the vital and non-vital teeth, and no details about the material used for the vital teeth only. Hence, no conclusion regarding the restoration material and how the restoration material affects the results from these studies. But in the rest of the studies there is one specific type of material for each study, where metal ceramic restorations only used in the

studies (Baert I Dobler 2012; Walton 1999;2002). All ceramic for vital abutments in study of (Ioannidis 2016a) , zirconia crowns in study of (Dogan S 2017).

A subtype Meta-Analysis was conducted in general using materials (Metal-Ceramic, All Ceramic and Zirconia) as subtype, and yield incidence of pulp vitality loss among all ceramic material an incidence of 5.3% (95%CI, 1.7-15.1), out of one study, (Ioannidis 2016a), and 6.5% (95%CI, 2.6-15.6) among metal ceramic restorations in the studies, (Bart I Dobler B 2012; Walton 1999; 2002) while the incidence is 6.3% (95%CI,0.4-53.9) in zirconia crowns of study (Dogan S 2017). The value of z is -0.3617, the value of p is 0.71884, the result is statistically not significant at $p < 0.05$, when comparing the incidence of loss of pulp vitality between all ceramic, metal ceramic and zirconia groups, Figure 6.

Radiographic and clinical examination are the methods used to examine the pulp status after prosthodontics work. Clinical examination varied between all the selected studies which included percussion test, heat/cold test, palpation to the surrounded mucosa, biting pressure and electric pulp tests before and after restorations delivery and during follow up visits.

In three studies (Cheung GS 2005; Jokstad A 1996; Reuter JE 1984) no details about patients' gender, and the total number of females in the other nine studies is 768, and 488 for male, the majority of study population are female, but most of the studies included both female and male.

The mean age of treated patients was not described by the authors in the studies (Cheung GS 2005; Jokstad A 1996; Lockard 2002; Reuter JE 1984), there was no mean of age in the study of (Palmqvis 1993), they had three groups of patients according to patients age, groups of less than or equal 29 years, from 30 to 49 years and over or equal 50 years, in the other eight studies the mean age of patients was 52 years.

All the initially vital restored teeth in the included studies varied in distribution between anterior and posterior teeth in maxilla and mandible.

All the prosthodontics work in this study were provided by general dental practitioners, university settings or specialist prosthodontics.

5.4. Quality assessment

Assessment of risk of bias of included studies

The Newcastle-Ottawa scale, which is used to assess the quality of observational studies in systematic review and meta-analysis, was used to assess the quality of the included studies since no RCTs among the included studies. The scale awards up to 9 stars per study: 4 stars for selecting participants and measuring exposure; 2 stars for comparability; and 3 stars for assessing the adequacy of results and follow-up. The quality of the studies was determined on the basis of the obtained scores: low quality: 0-3, medium quality: 4-6, and high quality: 7-9. From all twelve included studies six studies have high quality (7-9) and six studies have medium quality (4-6). Table 4.

Table 2: Included studies

Author and year	Type of study	Number of abutments	Number of crowns	Material	Restoration type	Loss of pulp vitality incidence	Examination used	Follow up period
Bart 2012	Retrospective	135 vital abutments	--	Metal -ceramic	Bridge retainers	11.3 % at 15 years	Clinical examination and radiograph	7-20 years
Cheung 2005	Retrospective	Bridge Abutments =77	Metal-ceramic crowns =122	Crowns: metal-ceramic Bridge retainers: Metal-ceramic crown Full gold crown Partial veneer crown Onlay	Metal-ceramic crowns Bridge retainers: Metal-ceramic crown Full gold crown Partial veneer crown Onlay	- S-ingle metal-ceramic crown 15.6% - Bridge abutments 32.5%	Clinical examination, clod, percussion palpation, electric pulp tests, radio-graph	Metal-ceramic crowns= mean observation period of 169 month (14 years) Bridge abutments: mean observation periods were 169 ± 25 for Metal-ceramic

								crowns, and 187 ± 23 months for bridge retainers
Dogan 2017	Prospective	no	7 teeth were vital form 20 teeth:	Zirconia	Single crowns	0%	Clinical examination and X ray	5 years
Jokstad 1996	Prospective	86 vital abutments	11 vital single crowns	Gold -resin, metal -ceramic	Retainers and single crown	6%	Clinical and radiographic	10 years
Karlsson 1986	Retrospective	944 abutment / 238 bridges	no	75% were acrylic resin veneer gold crowns (ARV) and the rest porcelain bonded to gold (PBG)	Bridge retainers	10%	Radiographic	10 years
Ioannidis 2016	Prospective	57	no	All ceramic	Retainers in FPD	5.2%	Clinical examination using modified United States Public Health Services (USPHS) rating criteria, included X ray	10 years
Lockard 2002	Retrospective,	1847 teeth 182 fixed partial denture abutment teeth and 1665 single teeth restored with 21 all-ceramic, 1095 metal-ceramic, and 731 all-metal restorations)	1847 teeth 182 fixed partial denture abutment teeth and 1665 single teeth restored with 21 all-ceramic, 1095 metal-ceramic,	21 all-ceramic, 1095 metal-ceramic, and 731 all-metal restorations)	182 fixed partial denture abutment teeth and 1665 single teeth	2.19%	radiographic evidence of periapical radiolucency and clinical signs and symptoms of pulpal sensitivity or pain recorded in the clinical record	31 years

			and 731 all-metal restorations)					
Palmqvist 1993	Retrospective	In post treatment=365 abutment on vital teeth, & 278 after follow-up	25 single crowns and 103 FDP	Crowns: there were 6 gold crowns, 3 gold-resin crowns, and 16 metal ceramic crowns. FDP: A total of 103 FPDs were placed; 69 were gold- resin and 34 metal ceramic.	Crowns Retainers	15%: Abatements Crowns: no details	From the clinical examinations and the radio-graphs	18-23 years
Reuter 1984	Retrospective	bridges (porcelain fused gold- 110 acrylic veneered gold crowns- 10) 249= vital teeth	no	(Porcelain fused gold- 110 //acrylic veneered gold crowns- 10)	Bridges retainers	2.8%	Clinical and radiograph	10 years (in 4.9 years average)
Walton 1999	Retrospective	no	461	Gold-Based metal-Ceramic	Single crown	2%	Radiographic examination and clinical examination	25 Years
Walton 2002	Retrospective	858	no	Gold-Based metal-Ceramic	Bridge retainers	4% in group a 2% in group b 5% in group c	Radiographic examination and clinical examination	15 years: group a=1-5 Group b=5-10 Group c=10-15
Wollwb 2012	Retrospective	76 bridges on 311 vital teeth	296 crowns	porcelain-fused-to-metal (PFM) and all-ceramic FDPs	Crowns and bridges retainers	2.9 %	Clinical and radiographic	5.26 ± 0.47 years

Table 3: other characteristics of included studies

Study author	Number of patients	Age of patients	Gender of patient	Position of the tooth in dentition	Provider.
Bart 2012	56 patients with 95 FDPs accepted the invitation to be re-examined in 2009.	mean age was 62 years (range: 41 to 85 years),	32 women, 24 men)	58 FDP bridge in maxilla, and 37 in mandible	undergraduate students during their state board examinations in fixed prosthodontics between 1990 and 1999 at the School of Dental Medicine, under supervision.
Cheung 2005	114 CMCs in 79 patients/ 38 bridges with 77 vital abutments in 33 patients	Not specifies	Not specifies	More in maxillary anterior: there is numbers	Teaching hospital, but no details
Dogan 2017	18	27-60	Female=9 Male=9	No details	University
Jokstad 1996	61 patients	No details	No details	There is table for the distribution of abutments in the dentition, but no association between loss of pulp vitality and abutment location.	three Scandinavian general practitioners
Karlsson 1986	164 patients	34-78 in (58 mean)	57% women and 43% men, 89 female, 75 male	No details	private general practitioners
Ioannidis 2016	55	Mean age =52.6 ± 10.1	32 women, 23 men	29 FDP in upper, 30 in lower, to replace premolar and molar, there is details for each	No details
Lockard 2002	256	no	172 females, 84 males	No details	No details
Palmqvist 1993	66	Less than 29 and less than 50 years	43 female, 23 male	23 % mandibular teeth	Public Dental Service in Orebro, no details about the provider
Reuter 1984	121	no	no	Anterior, posterior, ant-posterior	General dental practice

Walton 1999	239	30-59	F=65%, M= 35%	no	specialist prosthodontic practice over a 10-year period.
Walton 2002	357	30-59	F=72%, M= 71%	NO	private specialist prosthodontic practice over 15 years.
Wollwb 2012	-52: treated -45: evaluated for the follow up period	34.3 - 84.0	F= 28, M= 17	no	undergraduate students in their final year during two specific courses between 2001 and 2003.

Table 4: Quality assessment for cohort studies using Newcastle–Ottawa scale

Study	Selection	Comparability	Outcomes	Total score
Bart 2012	***	---	**	5
Cheung 2005	***	---	**	5
Dogan 2017	**	*	*	4
Jokstad 1996	***	*	**	6
Karlsson 1986	***	---	**	5
Ioannidis 2016	***	*	***	7
Lockard 2002	****	*	***	8
Palmqvist 1993	***	---	**	5
Reuter 1984	***	*	***	7
Walton 1999	****	*	***	8
Walton 2002	****	*	***	8
Wollwb 2012	****	*	***	8

Note: Stars (*) indicate the quality of the study. Up-to 9 stars for the highest quality assessment.

Table 5: Meta-Analysis pulp vitality loss

Item	No. of studies	Incidence	95% CI	n	Q	I^2	T^2	P-value	Egger's test P
General									
Incidence	12	6.5	4 – 10.4	11	201.91	94.55	0.69	< 0.001	0.3086
Crown									
Incidence	7	5.4	2.3 – 12.3	6	63.72	90.58	1.34	<0.001	0.4945
Abutment									
Incidence	9	7.4	4.4 – 12	8	103.37	92.26	0.59	<0.001	0.4541
Material									
All ceramic	1	5.3	1.7 – 15.1	1	00000	0000	0000		
Metal ceramic	3	6.5	2.6 – 15.6	2	26.90	92.56	0.67	<0.001	
Zirconia	1	6.3	0.4 – 53.9	1	0000	00000	0000		

Q Cochran's Q statistic for heterogeneity.

I^2 Index for the degree of heterogeneity.

T^2 Tau-squared measure of heterogeneity.

Figure 2. A: Incidence of pulp vitality loss in crowns and abutments

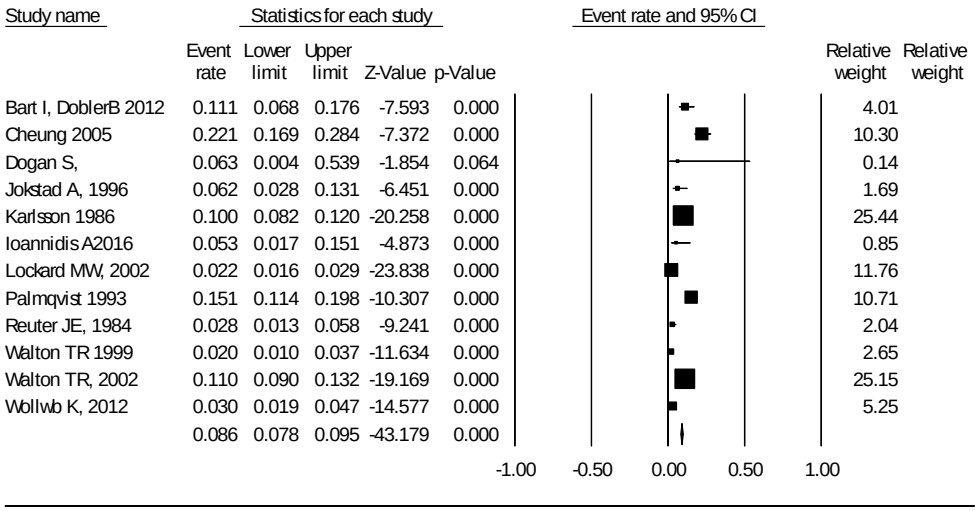


Figure 2.B: Funnel plot for incidence of pulp vitality loss in crowns and abutments

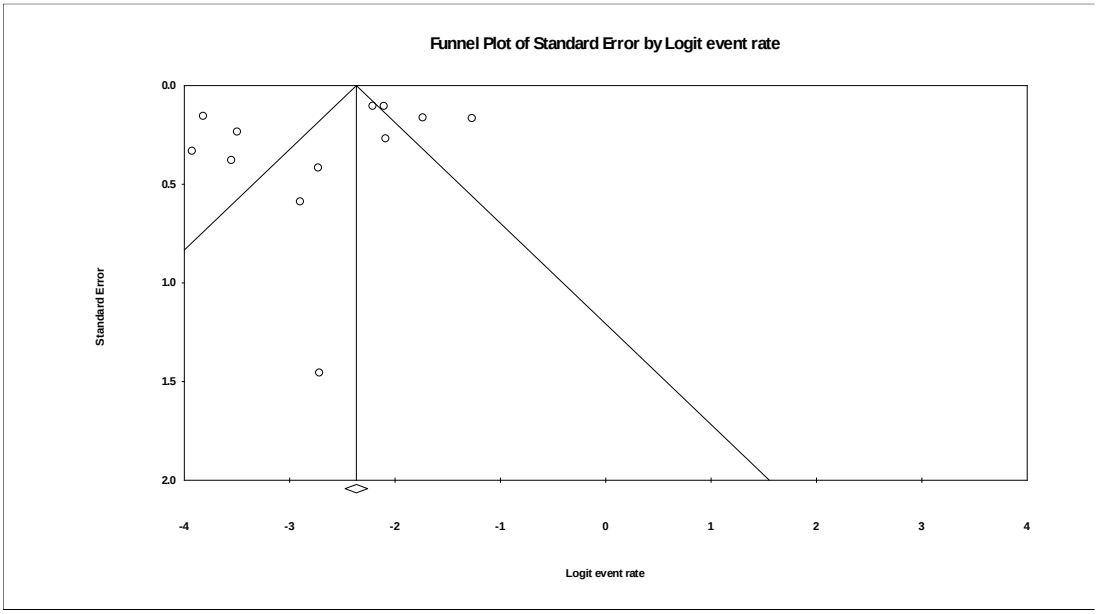


Figure 3.A: Incidence of pulp vitality loss in: Crowns

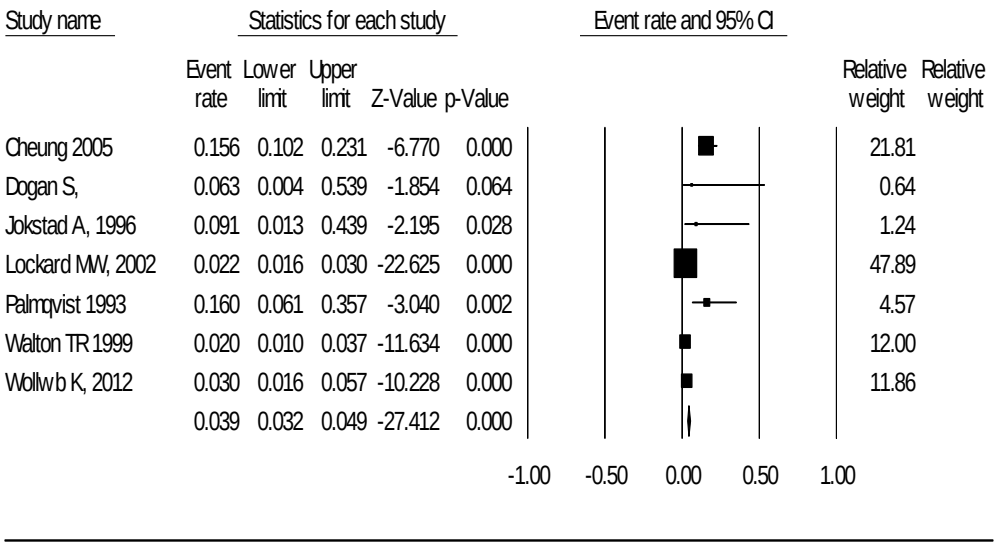


Figure 3.B: Funnel plot for incidence of pulp vitality loss: crowns

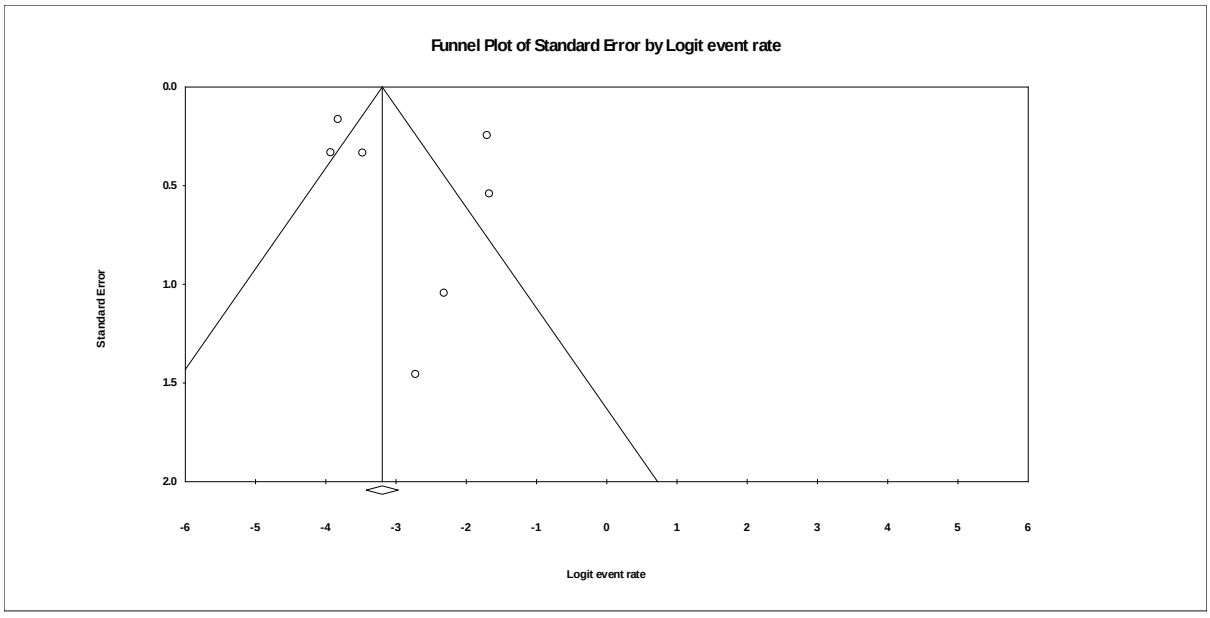


Figure 4.A: Incidence of pulp vitality loss: Abutments

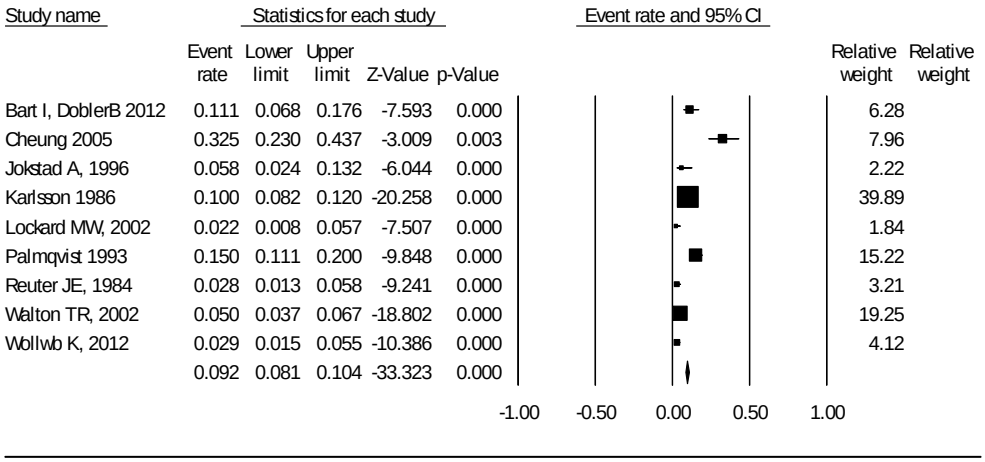


Figure 4.B: Funnel plot for incidence of pulp vitality: Abutments

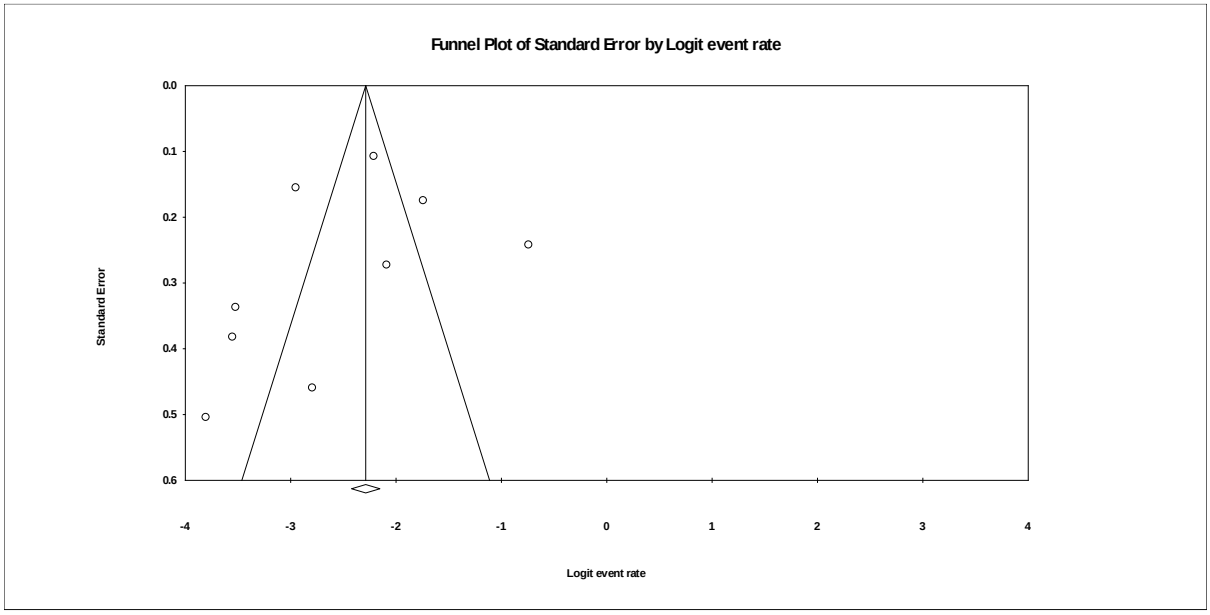
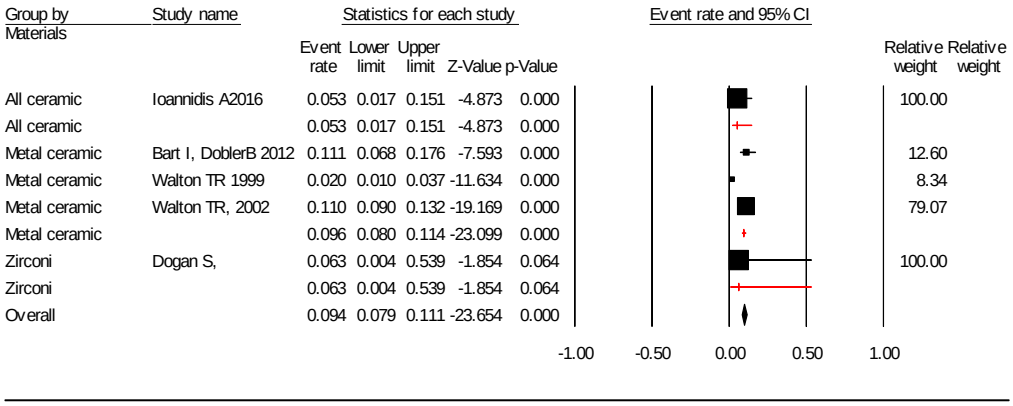


Figure 5: Incidence of pulp vitality loss overall by material



6. DISCUSSION

The aim of the current systematic review was to assess the incidence of loss of pulp vitality after full coverage indirect restoration, in either full coverage single crown or in full coverage fixed partial denture that examined clinically and appealed in radiographic examination for at least 5 years of observation period for the materials of metal, metal-ceramic, full-ceramic or zirconia.

A few studies have reported the incidence of loss of pulp vitality or endodontic complications in prosthodontics treatment, (Bergenholtz 1983; Cheung 1991a; Cheung GS 1990; Cheung GS 2005; J.Valderhauge 1997; Jackson 1992b; Karlsson 1986; Palmqvist 1993b; Walton 1999) which were 2-33.8%. These results were wide-ranging. All the studies were either prospective, retrospective cohort studies or cross-sectional studies with too many variables and no clinical randomized trails among them. Because of the variations in restoration material, observation periods, assessment methods to detect the loss of pulp vitality, and other factors like the initial restorative status of the vital teeth was not documented with pulp sensibility tests, and even in a recall review the pulp health status reported according to patient`s complaints, clinical symptoms and radiographic findings since the proper pulp sensibility tests were not possible after placing crown or bridge on the vital teeth. Thus, no clear conclusions could be drawn from these reports and that is why there is a wide range of loss of pulp vitality incidence between the studies (2-33.8%).

Twelve retrospective and prospective cohort studies are present in our systematic review with the total incidence of loss of pulp vitality 6.5% for 6046 vital teeth restored with full coverage restoration crowns/FDPs retainers for at least 5 years follow up period.

The incidence of pulp vitality loss reported in the included studies was varied from 32.6% which was the highest in (Cheung GS 2005) to 0% in (Dogan S 2017).

The studies ranged from medium to high quality using Newcastle-Ottawa scale (Table 4). Eight studies (Dogan S 2017; Ioannidis 2016a; Jokstad A 1996; Lockard 2002; Reuter JE 1984; Walton 1999; 2002; Wolleb K 2012) had standardized patient selection, pre-operative clinical examination and clinical treatment, regular follow up examination to evaluate the pulp status and other treatments complications.

In a retrospective study of (Saunders WP 1998) a full mouth periapical radiographs for 202 patients with 802 crowns, periapical lesions were found in 19% of 458 vital crowned, The incidence of loss of vitality in the mentioned study may have been underestimated because the crowned tooth could be associated with loss of pulp vitality without radiographic changes had showed yet at the time of observation. This results was in accordance with other cross sectional study where 6.3% of teeth with extra coronal restorations showed periapical lesions. (Dawson 2014) which is a cross-sectional study of 1000 panoramic radiographs, 6.3% of teeth with extra coronal restorations showed periapical lesions.

Dutta and colleagues reported 17.7% prevalence of periapical lesions in a survey of Cone-Beam Computer Tomography scans taken from 245 dentate patients (Dutta A 2014).

Radiographic absence of a periapical lesion does not mean that the pulp is sound, and loss of pulp vitality is not always associated with clinical symptoms (P L Michaelson 2002). “Painless pulpitis” (J E halser 1970) means that the dental pulp may have an inflammatory reaction leading to necrosis without pain, and some of the teeth radiographically showed normal periapical tissue at the time of crown cementation may develop undiagnosed loss of pulp vitality after a long time of crown cementation.

Restorative status of the vital tooth should be clearly identified before doing any prosthetic work, the teeth associated with preoperative caries, restorations, or crowns are considered at an eight times higher risk of loss of pulp vitality than the intact teeth according to the findings of the diagnostic clinical concept of ‘stressed pulp condition’ (Rass 1982), whereas the main

finding is that the pulp has had repeated previous injury and still survived with diminished responses and less repair potentials. The response of the pulp to restorative procedures is cumulative, each procedure adds to the response that arisen by the previous procedure (Collett 1974).

From the current meta-analysis, the loss of pulp vitality is slightly higher in group of bridge abutments 7.4% (95% CI,4.4-12), than the group of single crowns 5.4% (95%CI,2.3-12.3) and the result was statistically significant ($p>0.05$), higher incidence are probably because of the need for greater tooth structure reduction during bridge abutments preparation to align multiple abutments to allow for good path of insertion (Bergenholtz 1983), Additionally, recurrent carries or marginal leakage due to ill-fitting bridges, loss of retention, or difficult good oral hygiene techniques, all were contributing factors for loss of pulp vitality.

A previous clinical study revealed that the incidence of loss of pulp vitality occurred to abutment teeth was doubled than those in single crowns(Cheung GS 2005). In Cheung study the incidence for both groups were 32.5% (abutments) and 15.6% (single crowns) respectively. Greater number of bridge abutments developed loss of pulp vitality than the teeth restored with single crown according to the study of (Cheung GS 2005) which was a retrospective study to investigate the frequency of dental pulp complications in vital teeth, restored with metal-ceramic crowns or bridge retainers of a FPD in the mean observation period of 169 and 187 months respectively. The higher complications were found in the anterior teeth in both groups, which may be related to the need for more reduction for metal ceramic crowns than gold crowns and parallelism that required in the anterior teeth for the bridge abutments. In this study factor of practitioners skills should be considered when interpretation of the results, because the treatments were done in a teaching hospital by different levels of expertise from student to faculty, this means that treatments that were provided by students were more likely to require more time with multiple visits to finish, keeping the vital tooth covered with the provisional

restoration for a longer time to deliver the restoration which affect the pulp health later. Other factors in this study could affect the results are the patients were selected randomly from patients records and there was favoritism during patient examination to have the symptomatic cases. In the study of (Karlsson 1986) the incidence of loss of pulp vitality was 10 %, the patients were randomly selected with the pre-operative status was unknown for the assumed initially vital teeth.

Valderhaug and colleagues evaluated clinical and periapical status of the vital crowned 291 teeth for the period of 25 years at a dental school, only 10% was the loss of pulp vitality among the patients at the end of follow up period. In this study less pulp complications were showed in small bridges abutments than the larger bridges abutments, in long span bridges there is more need for preparation of the abutment teeth to allow for one path of insertion, difficulties in casting a well fitted long span bridges, more tendency for loss of retention of bridge, in addition to difficulties of achieving adequate oral hygiene can be possible reasons for this outcome.

Loss of pulp vitality regarding restoration material selected in the review (metal ceramic, all ceramic and zirconia) was more in metal-ceramic restoration than the other martials, and the result was statistically not significant at ($p < 0.05$) when talking about the incidence of loss of pulp vitality between all ceramic and metal ceramic groups only excluding Dogan`s study because of small number of sample, in a study by (Dogan S 2017) the incidence of pulp vitality was 0% for a small size of sample where the number of zirconia crowned teeth was 20 and 2 patients received 2 crowns. Because of variations in sample sizes between the included studies in this subtype of Meta-Analysis (Bart I Dobler B 2012; Dogan S 2017; Ioannidis 2016a; Walton 1999; 2002) and no significant difference was in incidence of loss of pulp vitality, no conclusion could be retrieved form this specific outcome.

Conventional metal- ceramic restorations require more reduction of tooth structure (Edelhoff 2002) . Both patients and dental practitioners are favoring esthetic and nonmetallic restorations, minimal reduction of 1.5 mm is routinely indicated for acceptable esthetic and function which at the same time affecting the biological outcome of the restorations.

In the study of Stanley and Swerdlow, the histological studies of dentinal specimens with dentin thickness greater than 2mm after preparation showed little or no pulpal response (H R Stanley 1967). However, for full crowns, literature is still supporting the porcelain-fused-to-metal crowns as the gold standard, with results of 5-year survival rates exceeding 95% , (A D Rekow 2011; Sailer I 2015).

The wide range in the incidence of loss of pulp vitality among the literatures could be also attributed to several other clinical factors: methods of pulp vitality assessment, regular follow up for the cases, oral hygiene performance of patients, and experience and technical skills of the provider which affect the treatment option selection, identifying the teeth at risk, and treatment duration as well.

Preparation of the vital tooth as part of prosthetic rehabilitation may lead to some biological complications. The dental pulp health could be affected at any stage of treatment having the risk of loss of pulp vitality at any time later after crown/bridge cementation.

More conservative treatment options should be considered like resin bonded bridges and implant-supported prosthesis to replace the missing teeth, considering taking thorough dental history with comprehensive clinical and radiographic examination before starting the prosthetic treatment.

Patient should be informed clearly about the possibility of different type of complications which may result from vital teeth preparation especially the need for future root canal therapy.

The dental practitioners should also follow all the precautions to decrease the pulp irritation

during prosthetic treatment by avoiding iatrogenic harms during tooth preparation like over-reduction or over-heating, using non-invasive impression techniques, avoiding aggressive retraction cord packing, also by paying more attention to provide excellent provisional restoration with good marginal seal and ensure the use of biocompatible martial and less invasive techniques to preserve the pulp vitality based on the scientific evidence that the vital teeth has less complications compared to non-vital teeth (Walton 1999).

Sensibility tests should be performed before starting the prosthetic treatment and before permanent cementation of the restorations to diagnose the dental pulp status, dentin should be kept wet without desiccation and should be thoroughly cleaned, occlusion should be evaluated carefully during provisional period and before cementation. In addition to have a regular recall visit to diagnose any early pulp pathology and to investigate it in a proper time to decrease the biological and technical complications, which could affect the outcome of the prosthetic treatment.

The main limitation of the present systematic review was that there was no randomized controlled trail or standardized approaches to report the endodontic complications in fixed prosthodontics work, and that the overall conclusions were based on pooled data from different studies with different variables. Additionally, the published studies were available in the English language only.

7. CONCLUSIONS

Preserving the pulp vitality after permanent cementation of crowns or bridges is important for the best treatment outcome in prosthodontics rehabilitation. Dental practitioners should be aware about the risk factors contributing to the loss of pulp vitality by providing better clinical approach to avoid endodontic complications in addition to inform the patients about the possibility for future root canal therapy.

The result was statistically significant in incidence of loss of pulp vitality between the crowns and bridges in the vital teeth, encouraging to think about and provide better treatment options for the patients. Clinical pulp testing and examination should be performed before and during the restorative work, and periodically in follow up to assess the pulp vitality.

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