

To Fill or do a Root Canal??? That's the Question

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Received: June 17, 2019; Published: July 15, 2019

DOI: 10.31080/ASDS.2019.03.0591

Abstract

Introduction: Deep carious lesion showing a thin dentinal layer on the radiograph makes the dentist wonder as to what appropriate treatment plan will work better– Indirect pulp capping or root canal treatment?

Methods: This review is based mostly on randomized control trials and a few case studies to explore the effects of different indirect pulp capping (IPC) techniques and types of pulp capping materials on deep carious lesions in permanent teeth.

Results: The information gained by this review indicates that IPC is more cost-effective as compared to unnecessary endodontic treatment. Partial caries removal (PCR) and restoration at a single visit is equally efficacious as compared to the stepwise caries removal (SWR) technique. Both PCR and SWR are better than complete caries excavation at conserving the vitality of the pulp in deep carious lesions.

Conclusion: Irrespective of the pulp capping agent utilized, indirect pulp capping procedure works best with a good final sealing restoration. In the long run CPD Courses in cariology will prevent overtreatment and benefit the patients.

Keywords: Indirect Pulp Capping (IPC); Root Canal Treatment (RCT); Permanent Teeth; Efficacy

Introduction

Most dentists' in their everyday clinical practice encounter a deep dark looking cavitation in a tooth and wonder whether they should fill the tooth or does this tooth warrant a root canal. This split second thought steers them towards taking a radiograph, which being a two dimensional image of a three dimensional structure further deepens their dilemma as a thin dentinal shadow can be seen over the pulp. A deeper radiographic investigation reveals no periapical lesion widening in most cases but not all and a subjective symptom of sensitivity on consuming cold beverages and pain on biting down on the tooth further baffles the dentist. Although this problem seems innocuous but it has implications on the treatment cost and time concern to the patient; and as for the dentist- to fill or to do a root canal???

Histologically [1] the dentin and pulp are two intimately related but separate structures where the dentin formation and nutrition is the primary task of the pulp. Dentin gets its sensory nerve innervation from the pulp and in the face of irritation- i.e. mechanical or chemical; caries assault or even coronal deep filling, the pulp which has a defensive role stimulates the odontoblasts' (the principal dentin forming layer arising from the peripheral

mesenchymal cells of the dental papilla). Or in case of injury, odontoblast - like cells which look similar to fibroblasts, react to injury. These are a pool of undifferentiated multi-potential cells in the dental papilla and are present at the base of the dentinal tubules juxtaposed to the dental pulp and in deep caries lesions they form new dentin called as secondary; irritation; reparative or hardened dentin. Although these terms are used interchangeably but actually secondary dentin develops slowly and forms at the roof or the occlusal side of the pulp; reparative dentine is formed at the pulp horn exposure area and reactionary dentin is an ageing physiological process at the floor and the mesial and distal sides of the pulp chamber². Indirect pulp capping supposedly aims at formation of secondary dentin [2].

The dentin although a hardened structure is made up of calcified tubules one micrometer wide at the dentino-enamel junction and about 3 micrometers at the dentino-pulpal interphase it also contains fluid [1]. Pathphysiologically [1], in deep carious lesions, this fluid gets contaminated by bacterial endotoxins and exotoxins causing inflammation and irritation to the pulp and the chronic carious lesion thus formed due to irritation gives rise to less permeable sclerotic dentin [1].

Furthermore a typical deep carious lesion is mostly made up of soft infected layer at the core of the lesion and an affected layer of demineralization of the dentin by acids produced by the bacteria at the periphery closer to the dento-pulpal junction. The affected layer of the cavity which is dark in colour has relatively less bacterial innervation. Infected dentin giving rise to irreversible pulpitis that differs from inflamed or affected dentin with symptoms of reversible pulpitis [3].

It has been observed that it is not only the bacteria but salivary contamination, food impaction, etching of deep dentin etc. that can penetrate the dentinal tubules and tilt the balance towards irreversible pulpitis [4]. Therefore sealing the dentin from irritants i.e. saliva, food etc. without exposing the pulp may help in healing the localized pulp abscess in a few days [1].

Different materials like Calcium hydroxide, MTA (Mineral Trioxide Aggregate), Glass Ionomer, Calcium Silicate (Biodentine) etc. are used as indirect pulp capping agents. In order to regenerate the pulp-dentin complex there are three basic IPC techniques: Selective/partial (in-complete caries removal in one step), Stepwise (incomplete caries removal in two steps) and complete caries excavation [5]. Statistics from literature [6,7] has shown that in comparison to complete caries removal, there is atleast 73% to 95% [6,7] success rate with different techniques of indirect pulp capping like step-wise removal (SWR) [8-10] of caries and partial caries removal (PCR) at a single visit [3] which has shown 82% better results as compared to SWR (62%) [6].

But do these theories regarding different materials and methods of indirect pulp capping really work on the ground or is it better to be on the safer side and perform an elective root canal in deep carious lesions- that's the question.

Methods

This study is a review of sixteen clinical studies mainly randomized control trials (thirteen), case studies (two), a prospective cohort (one) published on indirect pulp capping versus in deep carious lesions since 2009. This study is based on all patients of any age group with deep caries in permanent teeth. The primary outcome of interest is the efficacy of IPC. The secondary outcomes of concern are adverse effects, cost-effectiveness and prognosis of indirect pulp capping.

Review of the materials and methods of indirect pulp capping

93% to 97% success rate has been mooted for indirect pulp capping using MTA [11] or Medical Portland cement [6] and seventy three percent [11] to 93.6% [12] for calcium hydroxide. Calcium hydroxide has a chemical effect on the soft demineralized dentin [10]. It has an alkaline pH [13] and is abound with properties

of promoting a physiological reaction on the pulp-dentine complex as it induces sclerosis and formation of secondary dentin [14,15]. It is preferable to use calcium hydroxide as a liner in deep carious lesions less than 0.5 mm as compared to direct use of RMGIC (Resin modified glass ionomer cement) which can be used in 1mm to 1.5 mm of the remaining dentin or over calcium hydroxide to prevent injury to the odontoblasts [2,16].

A 17 year old follow up case study [9] has favored stepwise excavation – which is partial removal of the carious lesion which is then lined with Calcium hydroxide and bulk filled with Zinc oxide eugenol [10]. After 45 days the lesion is revisited and given a Glass Ionomer restoration. The tooth can finally be restored preferably with composite [9,17]. But the downside of the stepwise technique is increased risk of pulp exposure at re-entry [18]; cost [19] and microleakage [2], as zinc oxide is softer than glass ionomer cement causing failure of the IPC [2,20].

Glass Ionomer restoration is acidic in nature and has low polymerization shrinkage with an antimicrobial action on streptococcus mutans [21]. It is deemed to be a better substitute for dentin and is useful especially in deep caries [20] with undermined cusps. They release fluoride and strontium ions [22] and have similar coefficient of thermal expansion as the tooth structure [23].

A systematic review [24] has pointed towards step-wise excavation of deep carious lesions with no symptoms of irreversible pulpitis with a lining of Calcium hydroxide as well as antimicrobials and Polycarboxylate cement with tannin-fluoride preparation. This is useful in reducing the bacteria and helps in re-mineralization of the dentinal deep carious lesion.

Another study [25] has stressed on the benefits of Calcium Silicate (Biodentine) which is alkaline and has a caustic effect on the collagenous aspect of the dentine leading to porosities in the dentine diffusing calcium, hydroxyl and carbonate ions leading to increased mineral deposition/dentine bridge formation with no inflammatory pulp reaction using Transforming Growth Factor (TGF)-b1.

A randomized trial comparing a single visit partial and complete removal of caries using iRoot®BP Plus [26] as a liner which is a silica based cement with bioceramic particles less than 2 microns is a bioactive material that is effective at a low pH. and is considered better than MTA26. Good remineralization was seen with both techniques.

Outcome

The outcome of this review was stated on the basis of four parameters: efficacy, cost-effectiveness, safety and prognosis.

Efficacy

In comparison to complete caries removal, partial caries removal at a single visit has emerged as an equally efficacious technique as stepwise technique in very deep carious lesions with poor prognosis (Table 2). No statistical significant superiority has been observed with any of the reviewed materials used for IPC; if the technique and final seal are good -the IPC has a good chance of survival [13,18] Some other outcomes elicited are- CBCT [12,25,27] and higher magnification [27] are better predictors of detection of baseline lesions therefore giving rise to improved prognosis of 38% healed lesions after IPC.

Cost effectiveness

A study [19] has shown that the selective caries removal was less costly and a more effective alternative especially in high risk group [19] i.e. the mean lifetime treatment cost per posterior tooth was 26.91 Euro as compared to 27.80 Euro for complete excavation and stepwise - 28 .02 euro. [19]. The authors, personal clinical experience has shown that IPC is 70% more cost-effective as there is a 70% risk reduction for pulpal exposure and an unnecessary root canal treatment.

Safety

In a deep cavity, resin dental adhesives yield more toxicity [2,28-30] in the form severe or moderate inflammation of dilated blood vessels throughout the pulp as compared to a more favorable response with Calcium hydroxide, Zinc oxide eugenol or conventional Glass Ionomer [28]. Direct application of resins in deep carious lesions has a cytotoxic effect on the fibroblasts in the pulp due to the uncured monomers [31,32] Conventional Glass Ionomers are deemed better than RMGIC in very deep carious lesions as the HEMA and TEGDMA polymerized monomers leach from the resin modified materials resulting in toxicity to the pulp [2,30].

Prognosis

Most of the studies elicited in this review have shown a success rate of atleast seventy percent with IPC. The chances of pulp exposure in complete caries removal are 13% [33] or 16.7% [17] as compared to partial caries removal [33]. A ten year study [34] done on 32 permanent teeth on 27 subjects as a prospective single arm study using Calcium hydroxide and ZnOE (Zinc Oxide Eugenol) as a stepwise technique ultimately restored with composite showed 97 percent success in the first years and reducing to 63% by the tenth year especially in multiple surface ones as compared to single surface (p=0.01). The lowest recorded survival of IPC is 57.9% in 36 months especially in multiple surface fillings (HR -3.22 [CI -1.49; 6.97]) [17]. (Table 2)

Discussion

The results of this review advocate step wise partial caries removal [26] or selective caries removal [17] as the more favorable technique. Although, generally, for the authors'- complete caries

removal has worked well in the past where the soft carious tissue is removed till hard dentinal tissue is encountered [35] and then covered with Calcium hydroxide liner and Glass Ionomer at a single visit followed by Composite layer on the same visit or subsequent visit.

In Southern Brazil 71.1% [36]; 62% US [36] and 82.5% Saudi Arabian dentists preferred complete caries removal [36]. This practice of complete caries removal also seems to be similar to > 66% French and German dental practitioners mostly male and in private practice as the perception that sealed bacteria can harm the pulp. On the other hand it has been observed that 84% Norwegian dentist prefer stepwise excavation [37].

The authors' working as private practitioners in India are aligned to these other dentists' attitude of complete caries removal because most patient's perception of private dentistry in India is a costly matter and if the IPC does not work the additional cost of the root canal is not well tolerated by them and reduces patients compliance to treatment. Therefore most dentists tend to be on the safe side prefer to follow a complete caries excavation ritual.

But the authors' current practice may not be factual and deemed as "over-treatment" [18,35] as new research on cariology [18,35] has refuted our myth and we like the 80% dentists as compared to 8.8 [35] believed in total excavation and the study [35] reflects on encouraging more dentists to take up cariology CPD courses as literature supports selective/ partial caries removal being definitely better than complete caries removal to prevent a pulp exposure [38,43] and unnecessary endodontic treatment [39]. The need to incorporate evidenced based dentistry via CPD courses and reading peer reviewed journals is important to educate ourselves in using less invasive strategies to treat deep carious lesions and not allow just our beliefs of the past gained through didactic methods, influence better decision making in our dental practices.

The IPC technique is basically judicious non-invasive caries removal from the periphery of the lesion and the IPC technique is important only for preparing the cavitated lesion for placement of appropriate subsequent restoration according to the size of the and depth of the cavity and to prevent pulp exposure [18].

A good coronal seal is the most important aspect of IPC [10,13,18,32,40] irrespective of the lining material or filling technique. But there is the issue of bonding composite to demineralized enamel and dentin in deep carious lesions which is not as good as bonding to healthy enamel and dentin [41-48]. Therefore more research is needed in this direction.

Conclusion

Irrespective of the pulp capping agent utilized, indirect pulp capping procedure works best with a good final sealing restoration. In the long run CPD Courses in cariology will prevent overtreatment and benefit the patients.

Reference	First Author	Year	Study Design	Features	No. of patients	Age (Years)	Material for IPC	Males	Females	Observation period	Black Class
26	Bjørndal	2010	RCT- two arm	Parallel group comparison between stepwise and direct complete excavation	314	Adults	-	-	-	1 year	-
12	Lima	2010	Case Study	Stepwise technique; second visit 45 days	1	-	Calcium hydroxide, ZOE, RMGIC and Composite	-	√	17 years	Class 1
4	Petrou	2014	RCT- three arm	Parallel group, step-wise incomplete caries removal one, comparison between MTA, Ca(OH) ₂ , Medical Portland cement and re-entry after 6.3 months-stepwise technique	86	17±13.8	MTA, Calcium hydroxide, Medical Portland Cement	51.00%	49%	6.3 months	-
5	Fagundes	2009	Case Study	No periodontal ligament widening and no spontaneous pain detected before treatment, Step-wise technique used-Ca(OH) ₂ and RMGIC was used for the first step followed by composite after 60 days in the second step	1	16	Calcium hydroxide; RMGIC and Composite	√	-	4 years	Class 1
6	Hashem	2015	RCT- two arm, single blinded, patients of the dental teaching institution	Parallel group comparison, 72 restorations (mostly molars) were compared (36 -Biodentine vs. 36 Fuji IX at baseline T0 and after T12 months Stepwise technique	53	18 -76	Calcium silicate (Biodentine); Glass Ionomer (Fuji IX)	60.40%	39.60%	1 year	All Black Classes
7	Vural	2017	RCT- two arm, not operator blinded/ single blinded, patients of the dental teaching institution	Parallel group comparison, MTA test (n=51) and Ca(OH) ₂ control (n=49), 100 restorations (both molars -62% and premolars) at 6 months, 12 months and 24 months by direct complete caries removal	73	-	MTA and Calcium hydroxide; RMGIC ; Composite	64.40%	35.60%	2 years	not mentioned specifically
30	Maltz	2017	RCT- two arm, single blinded, patients of two locations at Public Health service units or Public universities	The randomization unit was the tooth. Parallel group comparison, control group was stepwise caries removal (n=147-42) and test was partial caries removal (n=152), restorations (both molars -299) at 18 months, three years and 5 years. 121 teeth examined after 5 years contributed to the data analysis	229	20-23	Ca(OH) ₂ , ZOE-IRM, Amalgam and Glass Ionomer and composite	85	144	5 years	1,2 or more surfaces
37	Ali	2018	RCT- two arm, single blinded; teaching institution	Parallel group comparison, Experimental group removal carious tissue using Carisolv and hand instrumentation under operating microscope and Control was no magnification removal of leathery dentin using rotary burs; single visit; 101 restorations- Molars(74/101) and premolars (27/101); 55 control and 46 experimental; single visit; CBCT and conventional x-ray at baseline and twelve months	86	37.6yrs (mean age)	MTA/ GIC/composite	47.20%	52.80%	1years	1,2 or >2 walls

17	Harahap	2018	Prospective RCT-two arm, single blinded; teaching institution	Parallel group comparison, in group I infected dentin was partially removed and in group II infected dentin was completely removed. Lined with iRoot @BP Plus and pixel grey value of intraoral radiograph was the unit of randomization compared at baseline and after 4 weeks.	10	-	iRoot @BP Plus and Glass ionomer	-	-	4 weeks	Class I and II
38	Mathur	2016	Longitudinal interventional RCT at AIIMS, New Delhi, India	Parallel group comparison of calcium hydroxide, glass ionomer and MTA. Single visit; CBCT examination 8 weeks, six months and 1 year. 109 teeth with 52 permanent molars	94	7-12	calcium hydroxide, glass ionomer and MTA	-	-	1 year	not mentioned specifically
29	Khokar	2018	Randomized control trial-two arm; single blinded; teaching institution, India	Parallel group comparison between PCR – partial caries removal and complete caries removal CCR	143	14-54	Composite and RMGIC as base.	40 –CCR 44-PCR	29 CCR/23 PCR	18 months	not mentioned specifically
39	Bitello-Firmino	2018	Randomized control trial; two arm double blinded;	Parallel group complete caries removal -CCR (control) vs. (test) selective caries removal SCR	34	9-31	Ca(oh)2 Dycal and Glass ionomer (Vitromolar)	-	-	3 months	-
40	Oz	2019	Prospective clinical cohort study	Parallel group comparison between SWR, CCR, DPC	214	-	Ca(oh)2, Glass ionomer, amalgam, composite	171	110	62 months	-
25	Casagrande	2017	Retrospective; university based study	Comparison CCR vs. SCR; clinical data was analyzed for 477 restorations	297	9 to ± 1.7	Composite resin and RMGIC	-	-	36 months	Single/multiple surface
42	Hashem	2018	Randomized control (control trial); Institutional	Comparing dentin-pulp response to calcium silicate (Biodentine) test and GI IX as control. 72 restorations Tooth and cavity size as unit of randomization.	53	18 and over	Calcium silicate (biodentine), Glass ionomer (Fuji xi) and composite resin veneer restoration	-	-	24 months	Single/multiple surfaces
41	Corralo	2013	Prospective, double blinded placebo controlled. Three arm parallel RCT. University clinic,	Convenience sampling. 60 teeth permanent teeth. Partial caries removal, stepwise, reopened after 3-4 months. Unit of randomization colour and consistency of the dentin, dentin organization and bacterial infection.	44	11-35	Ca (oh)2,GIC, Sterile wax as placebo restored with zinc oxide eugenol for 3-4 months. Permanent restoration LC composite	-	-	1 year	Class 1,2

Table 1: Features of the studies.

Reference	First Author	Year	Survival or Success rate %	Failure rate %	Efficacy
26	Bjørndal	2010	A difference of 11.7 % -CI (0.5; 22.5) better with step-wise excavation than direct complete excavation	-	Stepwise excavation has fewer pulp exposures as compared to direct excavation. Step wise excavation is recommended over direct complete excavation in deep carious lesions.
12	Lima	2010	100%	none	Stepwise excavation was successful and is recommended.
4	Petrou	2014	IPC has 90.3% (p value=0.72) success rate regardless of the material used.		Step-wise was successful preferably with MTA and Portland cement. The arrested lesions showed sclerotic dentin formation (p<0.05) and reduction in bacterial count (lactobacillus - p<0.01 and Strep. Mutans < 0.07)
5	Fagundes	2009	100%	none	Stepwise excavation was successful Indirect pulp capping maintains the vitality of the pulp and function of the permanent molar.
6	Hashem	2015	83.3% success with both the materials	Fuji IX had less healed lesions as compared to Biodentine	No statistically significant difference in the clinical efficacy of either Biodentine or GI. But CBCT could detect initial lesions more efficiently than PA lesions and most healed lesions had significantly received Biodentine. Stepwise technique
7	Vural	2017	The success rates for Ca (oh)2- 91.7% and 96.01% for MTA- Not statistically significant.	Failure in 4 teeth with ca(oh)2 and 2 with MTA needed endodontic treatment	Both materials are clinically acceptable as IPC agents after 24 months. Single visit direct complete caries removal
30	Maltz	2017	80 percent in partial caries removal compared to 56% in stepwise	Failure was associated with the region from which the patient presented themselves and the type of treatment (PCR vs. SW)	PCR with a single visit technique significantly reduces the occurrence of pulp necrosis when compared to SW Patients from the South compared to the Midwest region failed to show up for SW visits.
37	Ali	2018	Success with 73.3% control (rotary burs) and 90% experimental (carisolv and/operating microscope)	33.3% failure in premolars vs. 14molars	Statistically significant PCR at a single visit HR=0.38 CI (0.23-0.63) GEE modeling showed excavation protocol and tooth type significant predictors. Teeth treated with experimental-magnification and self-limiting protocol had higher probability of success (OR-4.33, CI 1.2-15.6; visit=0.025). CBCT detects lesions better than PA x-rays at the baseline; there was no significant difference in the excavation techniques that is without magnification in decreasing bacterial concentration in deep lesions
17	Harahap	2018	There was a statistically significant difference in both the groups before and after i-Root® BP Plus application	-	i-Root® BP Plus should good results in both the groups with significant remineralization irrespective of complete or partial caries removal. Single visit i-Root® BP Plus application with Glass ionomer proved good after 4 weeks
38	Mathur	2016	The clinical and radiographic success rate at 1 year in Ca(oh)2 was 93.6%; GIC Type VII-97% and MTA 100%	-	The size of the dentin barrier formation was the same in all the three materials. More radiodensity was visible with GIC and MTA as compared to Ca(oh)2 at six months but not statistically significant. Single visit
29	Khokar	2018	The overall success rate for both the techniques was 95.12%	13% pulp exposure in CCR as compared to none in PCR	In deep carious lesions PCR is preferred method of IPC.

39	Bitello-Firmino	2018	There was no statistical difference in the microbial count in the CCR and SCR before sealing with respect to total viable microorganism, streptococcus series and s. mutans but not lactobacillus. After sealing SCR reported a major fall in all these microorganisms except s.mutans.		SWR is as effective as CCR in the dentin bacterial load reduction after three months
40	Oz	2019	SWR (110teeth)-85.7% success, CCR (80 teeth) = 90.9%, and DPC (40 teeth) = 59.7%		There was no significant difference in the type of restorative material used amalgam (86.6%) and composite (83%). SWR has the most acceptable result for deep carious lesions as compared to CCR OR DPC
25	Casagrande	2017	Survival of restorations reached 57.9% up to 36 months. There was no statistically significant difference in the longevity of CCR or SCR	16.7% more in CCR the failure was significantly higher; multisurface the failure was higher (HR 3.22 CI-1.49;6.97); RMGIC < Composite (HR 4.11 CI1.91-8.81); Gingivitis high failure (HR 2.88 CI1.33-6.24)	Regardless of the caries removal the adhesive restorations performance in high risk group had limited survival. Risk factors-multiple surface RMGIC, and poor oral hygiene.
42	Hashem	2018	Overall 72 % success rate significant for both IPC materials.77.8% Biodentine vs. 66.7% Fuji IX but not statistically significant	15 teeth (6 biodentine vs. 9 Fuji) = failed to maintain vitality	Both Biodentine and Fuji XI are effective IPC materials At one month after baseline. Resin composite veneer restoration as a closed sandwich technique.
41	Corralo	2013	At baseline and after the dentin colour was similar but the dentin consistency the hardness was lower in the GIC group at baseline. The colour after sealing was darker with Ca(oh)2 and sterile wax. Dentin hardening was similar after sealing period.	-	Dentin samples showed better organization after sealing after PCR especially with GIC (P<0.05) with total or partial obliteration of tubules, decreased bacterial numbers irrespective of the liner used.

Table 2: Outcomes of the featured studies.

Bibliography

- Ingle JI, et al. Ingles Endodontics 6. Hamilton, ON: BC Decker Maidenhead : McGraw-Hill Education [distributor], © (2008).
- Tuculina MJ, et al. "Indirect pulp capping in young patients: immunohistological study of pulp dentin complex". *Romanian Journal of Morphology and Embryology* 54.4 (2013): 1081-1086.
- Massler M and Pawlak J. "The affected and infected pulp". *Oral Surgery, Oral Medicine, Oral Pathology* 43.6 (1977): 929-947.
- Canby CP and Burnett GW. "Clinical management of deep carious lesion". *Oral Surgery, Oral Medicine, Oral Pathology* 16.8 (1963): 999-1011.
- Schwendicke F, et al. "Cost-effectiveness of caries excavations in different risk groups-a micro-simulation study". *BMC Oral Health* 14 (2014): 153.
- Petrou MA, et al. "A randomized clinical trial on the use of medical Portland cement, MTA and calcium hydroxide in indirect pulp treatment". *Clinical Oral Investigations* 18.5 (2014): 1383-1389.
- Fagundes TC, et al. "Indirect Pulp Treatment in a Permanent Molar: Case Report a 4 year follow-up". *Journal of Applied Oral Science* 17.1 (2009): 70-74.
- Bjørndal L, et al. "Treatment of deep caries lesions in adults: randomized clinical trials comparing stepwise vs. direct complete excavation, and direct pulp capping vs. partial pulpotomy". *European Journal of Oral Sciences* 118.3 (2010): 290-297.
- Lima FF, et al. "Stepwise excavation in a Permanent Molar: 17-year Follow-up". *Operative Dentistry* 35.4 (2010): 482-486.
- Leksell E, et al. "Pulp exposure after stepwise versus direct excavation of deep carious lesions in young posterior permanent teeth". *Endodontics and Dental Traumatology* 12.4 (1996): 192-196.

11. Gaye Ndiaye F., *et al.* "Evaluation of mineral trioxide aggregate (MTA) versus calcium hydroxide cement (Dycal (®) in the formation of a dentine bridge: a randomised controlled trial". *International Dental Journal* 62.1 (2012): 33-39.
12. Mathur VP., *et al.* "Evaluation of indirect pulp capping using three different materials: A randomized control trial using cone beam computed tomography". *Indian Journal of Dental Research* 27.6 (2016): 623-629.
13. Ghoddusi J., *et al.* "New Approaches in Vital Pulp Therapy in Permanent Teeth". *Iranian Endodontic Journal* 9.1 (2014): 15-22.
14. Maltz M., *et al.* "A clinical, microbiological and radiographic study of deep carious lesions after incomplete carious removal". *Quintessence International* 33.2 (2002): 151-159.
15. Warfinge J., *et al.* "Effect of calcium hydroxide treated dentin on pulp responses". *International Endodontic Journal* 20.4 (1987): 183-193.
16. Cortés., *et al.* "Biocompatibility Evaluation of Four Dentin Adhesives". *Acta stomatologica Croatica* 51.2 (2017): 113-121.
17. Casagrande L., *et al.* "Longevity and associated risk factors in adhesive restorations of young permanent teeth after complete and selective caries removal: a retrospective study". *Clinical Oral Investigations* 21.3 (2017): 847-855.
18. Schwendicke F. "Contemporary Concepts in Carious Tissue removal: A Review". *Journal of Esthetic and Restorative Dentistry* 29.6 (2017): 403-408.
19. Schwendicke F., *et al.* "Cost-effectiveness of caries excavations in different risk groups-a micro-simulation study". *BMC Oral Health* 14 (2014): 153.
20. Lillo OC., *et al.* "Microleakage of Glass Ionomers Temporary Restorations in Indirect Pulp Treatment: An *in-vitro* Study". *Open Journal of Dentistry and Oral Medicine* 6.1 (2018): 1-6.
21. Bonecker M., *et al.* "Mutanas streptococci, lactobaccili in carious dentine before Atraumatic Restorative Treatment". *Journal of Dentistry* 31.6 (2003): 423-428.
22. Ngo HC., *et al.* "Chemical exchange between glass ionmer restorations and residual carious dentine in permanent molars: an *in-vivo* study". *Journal of Dentistry* 34.8 (2006): 608-613.
23. Weigand A., *et al.* "Review on fluoride- releasing restorative materials- fluoride release and uptake characteristics, anti-bacterial activity and influence on carious formation". *Dental Materials* 23.3 (2007): 343-362.
24. Hayashi M., *et al.* "Ways of enhancing pulp preservation by stepwise excavation--a systematic review". *Journal of Dentistry* 39.2 (2011): 95-107.
25. Hashem D., *et al.* "Clinical and Radiographic assessment of the Efficacy of Calcium Silicate Indirect Pulp Capping: A Randomized Controlled Trial". *Journal of Dental Research* 94.4 (2015): 562-568.
26. Harahap NU., *et al.* "Affected dentin remineralization after partial caries excavation (*in vivo*): the effect of iRoot® BP Plus application". *Journal of Physics: Conference Series* 1073 052003 (2018).
27. Ali AH., *et al.* "Self-Limiting versus Conventional Caries Removal: A Randomized Clinical Trial". *Journal of Dental Research* 97.11 (2018): 1-7.
28. Arandi NZ. "Calcium hydroxide liners: a literature review". *Clinical, Cosmetic and Investigational Dentistry* 9 (2017): 67-72.
29. Gerzina T and Hume WR. "Diffusion of monomers from bonding resin-resin composite combinations through dentin *in vitro*". *Journal of Dentistry* 24.1-2 (1996):125-128.
30. Hilton TJ. "Keys to Clinical Success with Pulp Capping: A Review of the Literature". *Operative Dentistry* 34.5 (2009): 615-625.
31. Büyükgüral B and Cehreli ZC. "Effect of different adhesive protocols vs calcium hydroxide on primary tooth pulp with different remaining dentin thicknesses: 24-month results". *Clinical Oral Investigations* 12.1 (2008): 91-96.
32. Falster CA., *et al.* "Indirect pulp treatment: *in vivo* outcomes of an adhesive resin system vs calcium hydroxide for protection of the dentin-pulp complex". *Pediatric Dentistry* 24.3 (2002): 241-248.
33. Khokar M and Tewari S. "Outcomes of Partial and Complete Caries Excavation in Permanent Teeth: An 18 Month Clinical Study". *Contemporary Clinical Dentistry* 9.3 (2018): 468-473.
34. Maltz M., *et al.* "Incomplete caries removal in deep lesions: A ten year prospective study". *American Journal of Dentistry* 24.4 (2011): 211-214.
35. Crespo-Gallardo I., *et al.* "Criteria and treatment decisions in the management of deep caries lesions: Is there endodontic overtreatment?" *Journal of Clinical and Experimental Dentistry* 10.8 (2018): e751-e760.
36. Alnahwi TH., *et al.* "Management preferences of deep caries in permanent teeth among dentists in Saudi Arabia". *European Journal of Dentistry* 12.2 (2018): 300-304.

37. Schwendicke F, *et al.* "Dentists' attitudes and behaviour regarding deep carious lesion management: a multi-national survey". *Clinical Oral Investigations* 21.1 (2017): 191-198.
38. Thompson V, *et al.* "Treatment of deep carious lesions by complete excavations or partial removal". *JADA* 139.6 (2008): 705-712.
39. Karin Cristina da Silva Modena, *et al.* "Cytotoxicity and Biocompatibility of Direct and Indirect Pulp Capping Materials". *Journal of Applied Oral Science* 17.6 (2009): 544-554.
40. Marchi JJ, *et al.* "Indirect pulp capping in the primary dentition: a 4 year follow-up study". *Journal of Clinical Pediatric Dentistry* 31.2 (2006): 68-71.
41. Pres CW, *et al.* "Bonding of universal adhesive system to enamel surrounding real-life carious cavities". *Brazilian Oral Research* 33 (2019): e038.
42. Nakajima M, *et al.* "Bonding to caries-affected dentin". *Japanese Dental Science Review* 47.2 (2011): 102-114.
43. Vural UK, *et al.* "Randomized Clinical Trial to evaluate MTA Indirect Pulp Capping in Deep Caries Lesion after 24 – months". *Operative dentistry* 42.5 (2017): 470-477.
44. Maltz M, *et al.* "Partial caries removal in deep caries lesion: a 5-year multicenter randomized control trial". *Clinical Oral Investigations* 22.3 (2017): 1337-1343.
45. Luciana Bitello-Firmino, *et al.* "Microbial Load After Selective and Complete Caries Removal in Permanent Molars: a Randomized Clinical Trial". *Brazilian Dental Journal* 29.3 (2018): 290-295.
46. Oz F D, *et al.* "Long-term survival of different deep dentin caries treatments: A 5-year clinical study". *Nigerian Journal of Clinical Practice* 22.1 (2019): 117-124.
47. Hashem D, *et al.* "Evaluation of efficacy of calcium silicate vs. glass ionomer cement indirect pulp capping and restoration assessment criteria: a randomised controlled trial-2 year results". *Clinical Oral Investigations* 23.4 (2018): 1931-1939.
48. Corralo DJ and Maltz M. "Clinical and Ultrastructural Effects of Different Liners/ Restorative Materials on Deep Carious Dentin: A Randomized Clinical Trial". *Caries Research* 47.3 (2013): 243-250.

Volume 3 Issue 8 August 2019

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