Minimally Invasive Clinical Approach in Indirect Pulp Therapy and Healing of Deep Carious Lesions

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Indirect pulp treatment is a conservative vital pulp procedure performed in deep carious lesion approximating the pulp, but without signs or symptoms of pulp degeneration. Removing the carious biomass along with sealing the residual caries from extrinsic substrate and oral bacteria makes residual caries after the first excavation less active. This allows time for pulpo dentinal complex to form tertiary dentine so that at the second excavation, there is less likelihood of pulpal exposure. It has also been suggested that by changing the cavity environment from an active lesion into a more slowly progressing lesion, will be accompanied by more regular tubular tertiary dentin formation. The success of this approach has been demonstrated by various randomized controlled studies comparing conventional treatment of such lesions with stepwise excavation. These results are echoed at clinical, radiographic, macroscopic, microscopic and ultrastructural level during follow up visits. This study reviews promising concepts and rationale of minimally invasive indirect pulp therapy technique where conventional wisdom of caries removal is challenged.

Keywords*: Stepwise Excavation, Partial Caries removal, Ultrastructural, indirect pulp capping, systematic review.*

INTRODUCTION

Conventional treatment of deep dentinal carious lesions is based on the aggressive approach of complete caries removal. However complete removal of dentin does not adhere to today's challenges of maximum preservation. Leksell and colleagues observed 40% failure rate in treatment of deep carious lesion by direct complete excavation as compared to a 17.5% failure rate in stepwise excavation with a 1 year follow-up period.[1] Minimal intervention *via* stepwise excavation adopts a philosophy that integrates prevention, remineralization and minimal intervention for the placement of restorations. This change towards minimal invasion and maximum preservation focuses on indirect pulp therapy techniques. Hume stated that dentists should modify their 200 year old philosophy, that caries should be treated like gangrene by extracting or excavating and filling. He advocated a treatment-based approach on the structure and behavior of caries lesion. He further noted that carious lesion in dentin and cementum are reversible to some degree and recommends that the clinician include non-surgical healing of these lesions in a treatment plan.[2]

The ultimate aim of indirect pulp therapy lies in maintaining the vitality of the pulp. The rationale behind conservative pulp treatment strategies is based on the healing capacity of young dental pulps and primary teeth, which is enhanced due to increased vascularity. It has also been observed that bacteria can invade dentinal tubules, and bacterial products can diffuse across dentin to elicit pulpal reactions. Dentin undergoes an increase in mineral content with age caused by filling of the tubule lumens and in some instances, total obliteration of the tubules takes place.[3,4] Tubules that are sclerotic or obliterated can physically impede bacterial invasion and delay the pulpal response and give the pulp a chance to heal.[5] A careful diagnosis of the preoperative pulp status is essential for the success of any treatment. However in pediatric dentistry, it is difficult to elicit true information related to symptoms. The clinician's decision must be guided by carious dentins macroscopic quality, remaining dentin thickness, the radiographic extent of the lesion assessment and the ability to elicit clinical symptoms from the child for the success of the treatment.

A large numbers of practitioners still believe in an aggressive approach towards treating deep dentinal caries by complete carious removal followed by an endodontic intervention and minority of practitioners follow the ideology of partial caries removal.[6,7] Conservative management of the dentin- pulp complex for deep dentinal caries lesion needs evidence. We reviewed various studies to assess the microbiological, radiographic and clinical successes with the recent ultra-structural concept in assessing indirect pulp treatment, partial caries removal and sealing carious lesions.

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In children dentin tubules have a larger diameter and a broader pulp chamber, thus the progression of the carious lesion is faster, and the risk of accidentally hitting the pulp during carious tissue removal is higher.[8] Due to rapid lesion progression in young teeth which are recommended for the indirect pulp therapy technique, the diagnosis of pulp condition is essential for the success of this treatment, as it is necessary for the pulp to present normal or with reversible inflammation, in order to obtain a potential healing response. There is no gold standard to assess the pulp vitality thus we must rely on experience and clinical judgment.

Casagrande *et al* [9] in their study associated the success of indirect pulp therapy to correct selection of cases. They stated " Indirect Pulp Therapy does not directly intervene into the pulp tissue, the information about pain or sensitivity associated with clinical and radiographic signs, are essential to achieve the correct pulp condition diagnosis.[9] Similar observation was reported by Falster *et al*,[10] ,= Pinto *et al,*[11] Rosenberg *et al.*[12]

Follow-up is essential because of possibility of development of degenerative pulpal changes over a period of time as yet more evidence is needed to confirm the success of therapy. Post-treatment signs and symptoms such as sensitivity, pain, or swelling should be checked. There should be no radiographic evidence of pathologic external or internal root resorption or other pathologic changes. Vitality of the teeth needs to be confirmed at each follow-up.

Techniques

Several treatment modalities have been considered in indirect pulp therapy technique:

- Partial/Incomplete caries removal
- Step-wise Excavation

In Partial caries removal, demineralized carious tissue is excavated and a layer of carious dentin lying over the pulp is allowed to remain. A lining material is applied and the tooth is permanently sealed. Oliveirea *et al*,[13] Duque *et al*,[14] Gruythysen *et al* [15] in their study followed partial caries removal in one session, which avoids pulp exposure and preserves the tooth structure.

Bjorndal *et al*,[16] Leksell *et al*,[1] Maltz *et al*,[17] in their study followed an alternative of stepwise excavation technique. In stepwise treatment, the carious tissue is partially removed, a layer of carious dentin is left over the pulp, and the tooth is temporarily sealed. The tooth is then reopened, residual caries removed and then permanently sealed.

However, incomplete removal of carious lesion is not only limited to Indirect pulp capping procedures. In the early 1990s, the international dental federation proposed a new strategy called ART. The carious dentin is partially removed by hand instruments; its removal is limited by patient's sensitivity to pain or by the risk of pulpal exposure. Frencken *et al* [18] found the durability of art restorations to be 85.3% after 3 years.

Halls Technique is the other technique in practice. In this technique, primary molar teeth with carious lesions affecting two or more surfaces are restored with a preformed stainless steel crown. Unlike the traditionally taught techniques, no caries removal takes place and no tooth preparation is performed. The study performed by Innes *et al* [19] with control restorations being conventionally placed fillings observed at end of 2 years that only 2% of teeth with pulpal pathology in the Hall group compared with 15% in the conventionally restored group. Loss of restoration or caries lesion progression occurred in 5% of the Hall group but in 46% in the control group. When children and caregivers were asked at placement which technique they preferred, the Hall technique was favored by most.

Promoting Pulpal Defense

The rapid progression of active caries lesion hinders the defense mechanism of tubular sclerosis. Tubular sclerosis is an important factor in the dentins resistance to caries progression, which occurs in the presence of reduced stimulus.[20,21] As it was observed in all the studies that we have reviewed, the first step of any indirect pulp therapy aims at removing the initial demineralized microbial degenerative mass of dentin. The basis of removing superficial dentin is that it promotes physiological reactions in the pulp dentin organ. Removal of cariogenic microbial biomass modifies the acid profile and the pH of the lesions, or even interrupts the proteolytic destruction of the organic material. This contributes to the formation of tertiary dentin and sclerosis of dentinal tubules, thus limiting the progress of carious process.[22,23]

However, the most likely mechanism of formation of reactionary dentin to advancing lesions involves the solubilization of growth factors and bioactive molecules sequestered within the dentine matrix, which diffuse through the dentinal tubules to the odontoblastic cell.[24] The odontoblastic cells respond to these growth factors by increasing the rate of secretion of dentin matrix, resulting in the appearance of reactionary dentin. The presence of bacteria may exacerbate release of growth factors from the matrix through their acidogenic activity.[25]

Reactionary dentin formation in indirect pulp therapy techniques can be observed non invasively by radiographic studies indicating an increase in radiopacity and the decrease in the radiolucent zone as observed by Oliveira *et al*,[13] Maltz *et al.*[26]

Thus, the pulp is capable of defending itself by biological mechanisms. Massler[27] studied the pulp reactions to dental caries and concluded: "in all cases, except when the pulp is actually invaded by instrumentation or microorganisms, the response of the pulp is productive and not degenerative. Sclerosis of the underlying dentine and reparative dentine is the rule-not exception

REMAINING DENTAL THICKNESS

Remaining dentin thickness and tubular permeability are important determining factors of the pulpal inflammatory response.[28] Although bacteria or their cell-wall components such as LPS are capable of passing through tubules to induce inflammatory responses in the dental pulp .Not only does it affect microbial invasion of its toxic products but also the cytotoxic effects of components leached from the lining materials.[29,30] RDT and invasion are inversely related to each other, thus pulp tissue gets time to react to aggressions and for the inflammatory process to be retarded in presence of favorable environment. Odontoblast survival and reactionary dentin secretion are the two responses most sensitive to RDT. Reactionary dentin is secreted by pre-existing odontoblasts, and reparative dentin is secreted by newly differentiated odontoblastoidcells.[31]

McLachlan *et al* [32] observed less expression of PMN-associated genes in inflamed pulps when the remaining dentin thickness was 2 mm. However, Reeves and Stanley[33] showed that if the advancing

front of the lesion was about 1 mm from the pulp then no significant disturbance occurred. However, once within 0.5 mm of the pulp more pathological changes occur, but it was only when the reactionary dentine itself was involved that 'pathosis of real consequence' was seen.

Murray *et al* [25] concluded that maximal reactionary dentin appeared to be beneath cavities with an a RDT between 0.5-0.25 mm. Odontoblast numbers were maintained beneath cavities with a RDT above 0.25 mm, cavities placed closer to the pulp appeared to injure underlying odontoblasts, reducing their numbers.

It appears that 0.25-0.50 of sound dentin provides a safeguard for a speedy recovery of the dental pulp to health.

MICROBIOTA OF DEEP CARIOUS LESION

The microflora in dental caries is highly complex and varies between individual lesions. The ecological plaque hypothesis suggests that caries is a result of a shift in the balance of the resident microflora driven by changes in local environmental conditions. Mutans group streptococci, such as *Streptococcus mutans* and *Streptococcus sobrinus*, and lactobacilli are important in the initiation and progression of caries.[34] These microorganisms are acidogenic and also aciduric which gives them a competitive survival advantage. As the lesion progresses deeper into the dentin, a transition from predominantly facultative, Gram-positive bacteria in shallow caries to deep dentinal caries dominated with lactobacilli and/or anaerobic bacteria takes place.[35,36] Chhour *et al* [37] used real-time polymerase chain reaction (PCR) to assess the total bacterial load of deep carious lesions and categorized the lesions into high-Lactobacillus, mid-Lactobacillus/Prevotella, high-Prevotella, and low-Lactobacillus/ Prevotella lesions. Hoshino *et al* [35] observed predominantly anaerobic Gram-positive bacteria and Gram-negative rods in deep dentinal caries, among which *Pseudo ramibacteralactolyticus* was the predominant isolate.

The application of strict anaerobic sampling and cultivation gives higher recoveries of bacteria, implying that the environment of deep carious lesions is dominated by obligatory anaerobic conditions. Species of *propionibacterium,eubacterium* and bifidobacterium dominate the microflora of deep carious dentin with actinomyces, lactobacillus and some streptococci but rarely S mutans being present.[38]

FATE OF SEALED CARIES

Clinical identification of infected/disorganized dentine is carried out by tactile procedures, since such procedures are operator dependent, as they do not correlate with complete removal of infected carious dentin.[39] Thus in regular practice carious microbiota are sealed in a restorative treatment and we bestow the success of treatment by accepting such cavities to be visually free of bacteria. Maltz *et al*,[17] Lula *et al* [40] reported that number of microorganisms is reduced after incomplete caries removal compared with complete carious dentine removal. Maltz and colleagues observed that significantly lower number of anaerobic microorganism and mutans streptococci was observed in incomplete caries removal group as compared to complete caries removal. Similar results were reported by Lula and colleagues who reported an increase in mutans streptococci and lactobacillus in complete caries removal group as compared to 11-99% reduction in partial caries removal group after the sealing period.

During treatment interval, there is substantial bacterial reduction and the remaining carious dentine exhibits the characteristics of inactive lesion. The dentin macroscopically appears to be drier, harder and darker in consistency. These findings are in correlation with studies conducted by Bjorndal *et al,*[16] Maltz *et al*,[26] Lula *et al*.[41] Fusayama[42] investigated the relationship between dentin softening, discoloration and bacterial infection and found that softening preceded discoloration which in turn preceded bacterial invasion. During the carious process, the acids released from bacterial biofilm diffuse through the dental tissues and dissolve the enamel and dentin matrix. The dentin matrix has biologically active molecules that have the capacity of influencing the cell events in the dentino-pulpal complex, and a number of factors influence the rate at which this occurs. These are namely the concentration of bacterial by-products, the permeability of the dentin and the pulpal fluid pressure.[43]

The studies reviewed show that by depriving the organisms within lesions of the intra-oral substrate they require to survive, both the number and diversity of organisms decline, with only those able to metabolize pulpal serum proteins surviving. These organisms are not associated with active carious lesions, and even pulpal nutrients will decline with time because of pulp-dentin complex reactions of tubular sclerosis and reactionary dentin formation.[44]

Lining Material

Some important factors influence the reduction of residual bacteria.

Bjorndal *et al* [16] had observed in their study that insufficient sealing during the 6-12 month treatment interval of a tooth was associated with a high level of cultivable flora before the final excavation. Thus sealing a cavity is essential to arrest the activity of the biofilm. Literature has shown that large number of failures in indirect pulp therapy occurs due to inadequate final seal and maintenance of carious active profile of the patient.[45,46,47,48]

AAPD guidelines[49] state that a biocompatible material should be used as a liner, including dentin bonding agent ,RMGI, Calcium Hydroxide, Zinc oxide/ eugenol, or glass ionomer cement. Lining Materials such as calcium hydroxide and glass ionomer due to their initial low pH setting have superficial solubilizing effect on dentine immediately after the application on cavity floor.[50,51] As a result, bioactive molecules such as transforming growth factor could be released from the dentine matrix, bacteria and activated to induce odontoblasts cells to produce intratubular and reactionary dentine in order to decrease dentine permeability and to pose a barrier against bacterial invasion via dentinal tubules.[51]

Falster *et al* [10] demonstrated clinical effectiveness of indirect pulp therapy excavation independent of lining material. They performed indirect pulp therapy in forty eight primary molars and after 2 years clinical and radiographic success was observed in 83% of teeth treated with calcium hydroxide and 96% of teeth treated with only the adhesive resin system and concluded that lining material is not a determinant of successful outcome of technique. Marchii *et al*,[52] Duque *et al*,[14] Casagrande *et al* [9] also observed similar results. The onus lies on proper sealing which not only inhibits the nutrient supply but create a microenvironment favorable for remineralization.[53]

Authors	Year	Teeth considered	Duration of study	Clinical Procedure	Method of study, analysis		Results	Capping material used	Coronal seal
Leksell et al[1]	1996	134 Posterior permanent teeth	8-24 weeks	Stepwise caries remov-al;direct complete excavation	Clinical	y	40% pulp exposure in DCE as compared to 17.5% in SW	SW- Calcium Hydroxide DCE- Calcium Hydroxide base	SW-ZOE DCE-GIC, Amalgam
					Macroscopic	-	-		
					Radiographic	y	Successful. Teeth with immature roots at the time of treatment exhibited a complete root development		
					Microbiological		-		
L. Bjornadal et al[16]	1997	31 Permanent Teeth (15 molars,14 premlars and 2 canines)	6-12 months	Stepwise Excavation	Clinical	y	No failure	Calcium Hydroxide	Not mentioned
					Macroscopic	y	darker, drier ,harder dentin after sealing		
					Radiographic	-	-		
					Microbiological	y	Reduction in microorganism		
Maltz et al[26]	2002	32 permanent teeth	6-7 months	Incomplete caries removal	Clinical	y	2 failure;	Calcium Hydroxide	Modified ZOE
					Macroscopic	y	darker, drier ,harder dentin after sealing		
					Radiographic	y	Increase in radioopacity		
					Microbiological	y	Decrease in microorganism		
Oliveira et al[13]	2006	32 posterior permanent teeth	14-18 month	Incomplete caries removal	Clinical	y	2 failures in 6-7 month No failures 6-18 months	Calcium Hydroxide	Modified ZOE
					Macroscopic	-	-		
					Radiographic	y	initial mineral increase over a 6-7 month period followed by remineralization of residual sealed decalcified dentine		
					Microbiological	-	-		
Marchii et al[52]	2006	27 primary molars	4 year	Incomplete caries removal	Clinical	y	88.8% success in Calcium liner group and 93% success in Glass ionomer liner.	Calcium Hydrox-ide;Glass Ionomer	Composite in Calcium hydroxide liner;
					Macroscopic	-			
					Radiographic	-			
					Microbiological	-			
Maltz et al[56]	2007	32 permanent teeth	40 month	Incomplete caries removal	Clinical	-	-	Calcium Hydroxide	Modified ZOE
					Macroscopic	-	-		
					Radiographic	y	significant increase in the radioopacity decreased radioloucent zone depth ; deposition of tertiary dentine		
					Microbiological	-	-		
Casagrande et al[9]	2008	40 primary molars	24 months	Incomplete caries removal	Clinical	y	87% success rate for traetment	Self etching adhesive; Calcium Hydroxide	Resin compositte
					Macroscopic	-			
					Radiographic	y			
					Microbiological	-			
Duque et al[14]	2009	30 Primary Deciduous molars	3 months	Incomplete dentine caries	Clinical	y	No failure	RMGIC; Calcium Hydroxide	ZOE
					Macroscopic	-	-		
					Radiographic	-	-		
					Microbiological	y	Reduction in microorganism		

SW- Stepwise excavation DCE- Direct complete excavation

Authors	Year	Teeth considered	Duration of study	Clinical Procedure	Method of study, analysis		Results	Capping material used	Coronal seal
Lula et al[40]	2009	36 deciduous molars	3-6 months	Complete caries removal group and incomplete caries removal group	Clinical	y	No failure; 4 pulp exposures on removal of carious tissue	Calcium hydroxide	Resin composite
					Macroscopic	-	-		
					Radiographic	-	-		
					Microbiological	y	Increase in microbial count in complete caries removal ; partial caries removal showed a reduction in microbial count.		
Gruythuysen et al[68]	2010	125 primary molars; 45 permanent teeth	3 years	Incomplete caries removal	Clinical	y	No failure	RMGI	Adhesive filling material; SSC
					Macroscopic	-	-		
					Radiographic	y	primary molars had 96% and permanent teeth had 93% success		
					Microbiological	-	-		
Bjorndal et al	2010	314 permanent teeth	I year	Stepwise caries remov-al;direct complete excavation	Clinical	y	74.1%success for stepwise excavation direct complete excavation had 62.4% success	SW-Calcium Hydroxide DCE-Calcium Hydroxide base	Glass ionomer
					Macroscopic	-	-		
					Radiographic	y	89.8% retained pulp vitality without apical radiolucency following stepwise vs 87.7% after direct complete excavation		
					Microbiological	-	-		
Lula et al[41]	2011	16 Deciduous teeth	3-6 months	Partial caries removal	Clinical	-	-	Calcium Hydroxide	Resin composite
					Macroscopic	y	darker, drier ,harder dentin after sealing		
					Radiographic	-	-		
					Microbiological	y	Reduction in microorganism		
Maltz et a[l17]	2012	90 Posterior Permanent	6-7 month	Complete caries removal group and incomplete caries removal group	Clinical	-	-	Calcium Hydroxide	Modified ZOE
					Macroscopic	-	-		
					Radiographic	-	-		
					Microbiological	y	Reduction in microorganism Significantly less micro-organism growth d after incomplete caries removal as compared to complete caries removal.		
Maltz et al[67]	2012	299 permanent molars	3 years	partial caries removal and stepwise excavation	Clinical	Y	91% and 69% success rate for PCR and SW	PCR-RMGI SW-CAL-CIUM HYDROXIDE	PCR-COM-POSITE/ AMALGAM SW-ZOE

PCR-Partial caries removal

ADHESION TO CARIOUS DENTIN

Partial removal of caries from deep lesions usually involves complete removal of carious tissue from cavity walls but limited removal from the pulpal floor and axial wall, which are sites of reduced bond strength. The bond strength of adhesives to carious dentin has been reported to be inversely proportional to the degree of caries progression, with caries-infected dentin presenting the lowest bond strength. The lower bonding effectiveness to caries-infected dentin is related to its extremely low cohesive strength, due to its low degree of mineralization and the collagen-matrix disorganization.[54] In resin-based composite restoration polymerization shrinkage can result in retraction of the bonding agent from the pulpal floor or axial wall of sound dentin. The resultant gap can result in invasion of the toxic substances by microbiota.[55] On the basis of these findings, one might suggest that infected dentin be removed completely from preparation walls but selectively from the pulpal floor or axial wall. Thus stepwise excavation may be acceptable, as after second step of removal, it will limit the further progression of caries and reduce the chances of failure due to the marginal gap created.

A Study by Maltz *et al* [56] showed failures of indirect pulp capped restorations due to fracture after 40 months, indicating that the fracture strength of such restorations may be compromised.[55] Similar results were also obtained by Zayer *et al*.[57] Higher bond strengths are achieved when a restoration material is bonded to sound instead of carious dentin.[58,59] Carious dentin is softer and has a lower Young's Modulus than sound dentin.[60,61] Both factors may result in larger deformation of the tooth-restoration complex, leading to higher marginal stresses and increased susceptibility to fatigue failure. Thus, when soft carious tissue is left in the cavity before the tooth is restored, the fracture strength of the tooth-restoration complex may be reduced as observed by Hevinga *et al*.[62] Thus the need to study the amount of carious tissue to be left behind without affecting the fracture strength of the teeth is important.

In light of this research, stepwise excavation is acceptable, as the second step of complete excavation of residual caries will increase the strength of final tooth restoration complex. In terms of adhesion to carious dentin as well as fracture strength of restorations stepwise excavation is a preferred treatment approach as compared to partial caries removal as discussed.

The presence of microorganisms invasion in the dentin of arrested non-cavitated lesion has been reported in literature demonstrating that the presence of bacteria inside the dental tissues does not impede caries arrest process.[63,64,65] The mechanical procedure used in the reopening of the cavity and removal of remaining decayed dentine may injure the pulp and increase the risk of pulp exposure submitting the patient to additional appointment. Various studies reported pulp involvement on reopening excavation in otherwise clinically asymptomatic tooth.[40,56,66] Maltz *et al* compared partial caries removal and stepwise excavation and observed 91% and 69% success rate respectively. Gruythysen *et al* [68] sealed caries in both primary and permanent teeth and observed a high clinical success of 96% for primary molars and 93% for permanent teeth evaluated for a period of three years. Thus allowing the carious lesion to remain may be considered acceptable if the patient ensures to be on a follow up to confirm absence of periapical changes and calcific degeneration by severe inflammation.[69,9] We can consider partial caries removal as recommended by recent studies[13,17, 26,56,70] also in primary teeth where the biological cycle is defined this technique can be considered a definitive approach.[9,52]

ADVANTAGES

Various authors indicate the use of less aggressive techniques for maintaining the vitality of pulp and giving the pulp a chance to heal.[1,13,15,71] A healthy vital tooth has a longer chance of survival in the oral cavity further The procedure is less invasive, cost effective and the child is more comfortable and acceptable to the treatment as compared to various complex endodontic treatment.

DISADVANTAGES OF IPC

Indirect pulp therapy technique with age the pulp gradually becomes more fibrous with a reduction in volume due to the physiological production of dentin and reduction in blood supply and regeneration capacity. That is why these techniques is recommended more for young patients, whose pulp chamber is still broad, or even in teeth with incomplete apexes, because they have a better supply of nutrients and a greater potential for repair.[72] This together with the evolution of new dental materials, demand further research into this subject, particularly where older more compromised teeth are concerned.

Stepwise treatment technique may require 2 sessions for treatment completion as *per* treatment, resulting in additional costs and discomfort to the patient, further there is a probability of pulp exposure during the second procedure as compared to partial caries removal.[1,26,] Jardim *et al* [73] showed that partial caries removal as compared to stepwise excavation reduced the cost by 45.24%. Certain authors argue that lining materials may leach into the dentinal tubules and be cytotoxic to pulp with time result in severe pulpal inflammation and calcification of canal.[74,75]

Recent Concept of Assessing Remineralization in Deep Carious Lesion-Ultrastructural Analysis

Ultrastructural analysis is beneficial to assess the changes at dentinal tubule level. The formation of tertiary dentin denoting mineralization can be confirmed over a short interval of time which by any another analysis may take a longer time to be observed. Thus we are also at a better position to understand the reaction of pulp at the microstructural level and dentin reorganization in teeth. Wambier *et al* [76] analyzed stepwise excavation of dentin samples lined by resin modified glass ionomer cement by scanning electron microscope after a 60 day observing a better tissue organization with more compact collagen fibers and narrower dentinal tubules. Pinheiro *et al* [77] assessed the effect of sealing material on repairing collagen in dentin carious lesion and observed calcium hydroxide and glass ionomer cement can be used for the treatment of affected and infected dentin respectively.

Limitations of our study

The studies selected in our review are heterogeneous with different time period of studies chosen but it gives us an insight into the early pulpal healing of tissues and the long term effect of the treatment as well. Such studies always suffer from the problem of patient dropout, and it is quite possible those patients who fail to attend follow up visits can provide us with useful information, which may influence our treatment strategy.

CONCLUSION

The basis for a biological approach to indirect pulp therapy is to identify and attempt to reduce pulpal exposure in deep carious lesions in clinical practice and also aid in potentiating inherent dentino-pulpal repair capacity of young dental tissue. Thus a proper case selection, adequate cavity sealing and biocompatible lining material all together is critical for success of indirect pulp therapy.

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