The Phenomenon of Postoperative Sensitivity and Composite Restorations - A Review

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The number of composite restorations delivered to patients is on the rise. Despite the improvement in mechanical properties of modern composites, the task of providing a functional restoration is at times compromised due to the problem of postoperative sensitivity associated with these restorations. An understanding of the potential causes of postoperative sensitivity will enable clinicians to adopt a technique which minimizes the risk of development of postoperative sensitivity and subsequently ensure restoration longevity. This article reviews the literature to explain the common reasons for development of this phenomenon. The continuous development and introduction of newer materials in the market creates a lack of long term clinical data pertaining to a particular type of composite and adhesive system. Although the newly developed materials have shown promising results in terms of reduced postoperative sensitivity, a systematic review and meta-analysis is required for evaluating the findings from the recently conducted clinical studies on the subject of postoperative sensitivity.

INTRODUCTION

Composite resins have become a popular restorative material substituting amalgam, with longitudinal studies showing comparable results in terms of long term clinical performance.[1] However, cross sectional studies have observed a disparity in the clinical performance of these two materials which can be explained in part by the lack of undergraduate training for composite restorations when compared with amalgam.[2] Among the different reasons for the failure of composite restorations, postoperative sensitivity is a very common phenomenon, whereby the clinician has to deal with an embarrassing situation while trying to reassure a suffering patient.[3] Studies have reported the frequency of postoperative sensitivity to be as low as 5% and as high as 30%.[4,5,6] In order to avoid such instances it is important to understand the reasons for development of postoperative sensitivity following placement of composite restorations. This article reviews the reasons for development of postoperative sensitivity as identified in the literature.

The literature has theorized various causes of postoperative sensitivity, for example:
1. Polymerization shrinkage
2. Marginal gaps
3. Suboptimal adhesion
4. Inadequate polymerization
5. Unfavourable C-factor and residual dentin thickness
6. Pre-existing tooth related factors, such as cracks

Polymerization shrinkage

Many of the problems associated with composite resins stem from their inherent tendency to undergo shrinkage. Resin based materials like composites set by a polymerization reaction, which results in a shrinkage of varying degree.[7] This polymerization shrinkage can either, generate stress at the bonding interface, transfer stress to the adjacent tooth structure or generate residual stress in the final set material.[8] Stresses at the interface can potentially weaken the bond, particularly in cases where cavosurface margins exist entirely in dentin.[9] Depending on the compliance of the remaining tooth structure, varying degrees of cuspal deflection has been observed and this may lead to enamel crazes or fracture lines.[8,10,11] Cracks may increase flexure of tooth structure under occlusal loading or become an avenue for bacterial ingress. Moreover, movement of dentinal fluid in association with the cuspal deflection can potentially induce postoperative sensitivity depending on the rate and direction of fluid movement.[12,13]

There have been numerous improvements in material formulation of composite resins to improve clinical performance. In clinical dentistry two most notable areas of

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improvement have been the minimization of the amount of polymerization shrinkage and reduction in the development of shrinkage stress. The development of silorane based composites with the advantage of reduced polymerization shrinkage of about 1% have provided hope for minimizing the detrimental effects like postoperative sensitivity. However, a recent systematic review and meta analysis of the available clinical studies on siloranes concluded that silorane based composites are not better than conventional methacrylate based composites in terms of the observed clinical performance in class I and class II restoration of permanent posterior teeth.[14] Table 1 summarizes the results of different clinical studies on silorane based composites and postoperative sensitivity.[15-25]

Bulkfill composites with shrinkage stress relievers and polymerization modulators have been introduced to counter the development of shrinkage stress and in vitro studies have shown these materials exhibit less shrinkage stress than conventional composite resins.[26] The results of clinical studies evaluating the postoperative sensitivity associated with the use of bulkfill composites are shown in Table 1. A recent double blind randomized clinical trial while investigating the effect of filling technique on occurrence and intensity of postoperative sensitivity concluded that the risk and intensity of postoperative

Table 1: Summary of clinical studies that evaluated postoperative sensitivity in relation to different types of composites and adhesive strategy

Authors	Publication year	Observation period	Study design	Sample size	Materials/ adhesive strategy	Post operative sensitivity
Baracco B and others[15]	2012	1 year	Randomized Control trial	75	Filtek silorane vs Filtek Z250 (3M ESPE, St Paul, MN, USA)/ Adper Scotchbond 1 XT vs Adper Scotchbond SE (3M ESPE, St Paul, MN, USA)	0 %
Mahmoud SH and others[16]	2014	3 years	Randomized control trial	156	Filtek P90 (3M ESPE, St Paul, MN, USA) vs Quixfil (Dentsply DeTrey; York, PA, USA)/ Filtek P90 adhesive (3M/ESPE; Seefeld, Germany) vs Prime & bond NT (Dentsply DeTrey)	3%
Van Dijkin JW and others[17]	2014	3 years	Randomized control trial	104	SDR (Dentsply DeTrey; Konstanz, Germany) vs Ceram X mono (Dentsply DeTrey) / XenoV (Dentsply DeTrey; Konstanz, Germany)	< 1 %
Yaman and others[18]	2014	3 years	Randomized control trial	121	Filtek silorane (3M ESPE AG, St Paul, MN, USA) vs Ceram X mono (Dentsply DeTrey, Konstanz, Germany)/ Clearfil SE (Kurraray America, NY) vs XP Bond (Dentsply DeTrey, Konstanz, Germany)	0 %
Van Dijkin JW and others[19]	2015	15 years	Randomized control trial	91	InTen-S (IvoclarVivadent, Schaan,Liechtenstein) vs Point 4 (Kerr, West Collins Orange, CA, USA) / Excite (IvoclarVivadent, Schaan,Liechtenstein) vs Optibond Solo Plus (Kerr, West Collins Orange, CA, USA)	< 2 %
Van Dijkin JW and others[20]	2016	5 years	Randomized control trial	183	SDR (Dentsply DeTrey; Konstanz, Germany) vs Ceram X mono+ (Dentsply DeTrey) / Xeno V+ (Dentsply DeTrey; Konstanz, Germany)	0 %
Öztürk-Bozkurt F and others[21]	2016	3 years	Randomized control trial	58	Filtek silorane (3M ESPE AG, St Paul, MN, USA) vs Filtek Z550 (3M ESPE AG)/ Silorane Primer and Bond (3M ESPE AG, St Paul, MN, USA) vs Adper Single bond 2 (3M ESPE AG)	3.45 %
Yazici AR and others[22]	2017	3 years	Split mouth design	81	Tetric EvoCeram Bulkfill (Ivoclar Vivadent, Schaan, Liechtenstein) vs Filtek Ultimate (3M ESPE, St Paul, MN, USA)/ Excite F (Ivoclor Vivadent) vs Adper Single Bond 2 (3M ESPE)	0 %
Ayar MK[23]	2017	-	Retrospective	72	Filtek Bulk fill (3M ESPE, St. Paul, MN, USA) vs Filtek Z250 (3M ESPE, St. Paul, MN, USA)/ Single bond universal (3M ESPE, St. Paul, MN, USA)	25% vs 30.5%
Costa T and others[24]	2017	48 hours- 1 week	Double blind randomized control trial	236	Tetric EvoCeram bulkfill (Ivoclar Vivadent, Schaan, Liechtenstein) Incremental vs bulkfill/ Tetric N bond (Ivoclar Vivadent, Schaan, Liechtenstein) vs Tetric N bond SE (Ivoclar Vivadent, Schaan, Liechtenstein)	20.3 %
Heck K and others[25]	2018	10 years	Randomized control trial	56	Quix fill (Dentsply DeTrey, Konstanz, Germany) vs Tetric Ceram (Vivadent, Schaan, Liechtenstein) / Xeno III (Dentsply DeTrey, Konstanz, Germany) vs Syntac classic (Vivadent, Schaan, Liechtenstein)	1.7 %

sensitivity was not associated with the filling technique.[24]

Marginal gap

The polymerization shrinkage stresses have the potential to create a marginal gap in areas deficient in enamel. It has been proposed that a gap at the tooth- restorative margin is a potential site for bacterial ingress as well as portal for fluid exchange leading to a movement of dentinal fluid in the tubules and subsequent postoperative sensitivity.[27,28] Clinical situations with an extension of the cavity margin to dentin, like a deep class II and class V, create a challenge for the placement and adaptation of the composite to the dentinal margin. The formation of a gap along this cavosurface margin can potentially invite postoperative sensitivity,[5] microleakage and secondary caries in the long run.[2]

However, the results from clinical studies have not been able to establish an unequivocal link between marginal gap and postoperative sensitivity.[29,30] A systematic analysis of the literature found a lack of correlation between the percentages of margins with gaps and clinical outcomes; moreover, a correlation between microleakage and secondary caries, hypersensitivity and marginal discoloration could not be demonstrated.[31]

Additionally, the adaptation of the composite has been to shown to be affected by the c- factor and compliance of the cavity; with both bulk fills and conventional composites demonstrating inferior adaptation in such clinical situations.[32] The findings from different in vitro studies concluded that bulkfill composites do not ensure an improvement in marginal adaptation in class II situations, rather the presence or absence of enamel at the restorative margin is a more important predictor of marginal adaptation.[33,34,35,36] A recent systematic review also concluded that application of flowable composites cannot improve microleakage.[37]

Despite the improvement in adhesives, enamel still remains the most favorable substrate for bonding. Although reasonable bond strength can be achieved when bonding to dentin alone, the long term bond longevity is questionable due to the hydrolytic degradation of the hybrid layer components.[9]

Suboptimal adhesion

The technique sensitive nature of the adhesive procedure for composite restoration demands meticulous attention to detail by the clinician, failing to do so often results in postoperative sensitivity and restoration failure.[4]

A common mechanism for persistent postoperative sensitivity is when a gap forms beneath the restoration and fills with dentinal fluid. When cold or hot stimuli cause contraction or expansion of fluid in this gap, the consequent sudden movement of fluid in the dentinal tubules causes

pain.[28] This gap formation beneath the restoration could be either from a void in the composite material being placed on the floor of the cavity, the pulling away of composite from pulpal floor due to shrinkage stress[38] or it could be a gap in the hybrid layer due to insufficient resin infiltration resulting in the formation of a "hybridoid layer".[39]

Moreover, even the use of bulk fill flowable composites has not been able to eradicate the formation of gaps over the internal walls of the restored cavity,[40] while the use of the traditional incremental technique with conventional composite has demonstrated a better internal adaptation.[41] The research on the benefits of applying a flowable composite over the pulpal floor for the sake of eliminating postoperative sensitivity has shown conflicting results. However, a recent Cochrane review of the literature has deemed the evidence "low quality" and discredited the notion of perceived benefit of using flowable liners under composite restorations.[42] It has been identified that the inadequate permeation of the demineralized dentin during the restorative procedure is a significant contributor to postoperative sensitivity. The risk of postoperative sensitivity and development of "hybridoid layer" has been regarded higher with etch and rinse adhesives as compared to self-etch adhesives due to the elimination of the smear layer in the former and the simultaneous demineralization and resin infiltration in the latter.[43] The results of clinical trials investigating the role of adhesive strategy in causing postoperative sensitivity have shown mixed results with some studies[24,43,44,45] claiming no association between the two while others[46,47] have reported a statistically significant difference in the postoperative sensitivity and adhesive approach. However, meta-analysis and systematic reviews have found no significant association of bonding strategy with the risk and intensity of postoperative sensitivity.[48,49] The details of different clinical studies comparing adhesive strategies in relation of postoperative sensitivity are summarized in Table 2.

Irrespective of the adhesion strategy used, the presence of a collagen matrix without any resin support is vulnerable to accelerated aging and degradation.[9,50] Quality of substrate available for adhesion varies across the prepared tooth surface, with areas of caries affected dentin, sclerosis and high tubular density present an adhesive challenge due to a difference in water and mineral content.[9] Presence of caries affected dentin at the marginal interface of the restoration makes it an unsuitable substrate for predictable adhesion and marginal adaptation contributing to postoperative sensitivity.[5,9]

Inadequate polymerization

Even the stiffest composites are relatively flexible in comparison to the stiffness of tooth enamel, as evident by

the difference in the modulus of elasticity.[51] The flexure of composite restoration in relation to the tooth can produce pressure changes in the dentinal tubular fluid and a subsequent fluid movement can in turn provoke pain on chewing.[52] However, composites applied in sufficient bulk rarely exhibit flexure of this magnitude to induce sensitivity on biting unless the degree of polymerization of the material was not in the acceptable limits, leading to a "soggy bottom" phenomenon.[53]

Clinical situations often require placement of composite in deep cavities where if adequate intensity of the curing light is not provided then the in situ polymerization of the adhesive resins and formation of the hybrid layer is jeopardized leading to a premature bond failure and postoperative sensitivity.[54] The placement and subsequent curing of conventional composites in bulk can result in a similar situation, whereby complete polymerization of the material to the entire depth is not achieved. However, modern bulkfill composites have demonstrated a promising degree of polymerization in relation to conventional composites[55,56] and clinical studies on comparison between bulk and incremental filling show no significant difference in the occurrence of reported postoperative sensitivity.[22,23,24,25]

In terms of the biological properties of the composite resins, the process of polymerization is not complete in the set material; 25-50% of the monomer double bonds remain unreacted and this monomer has the potential to irritate the

Table 2: Summary of clinical studies that evaluated postoperative sensitivity in relation to different adhesive strategies and adhesive systems

Authors	Observation period	Materials tested	Adhesive strategy	No. of restorations evaluated	Conclusion
Costa T et al[24]	48 hours- 1 week	Tetric N bond (Ivoclar Vivadent, Schaan, Liechtenstein) vs Tetric N bond SE (Ivoclar Vivadent, Schaan, Liechtenstein)	2 step etch and rinse vs 1 step self etch	236	No statistically significant difference at 1 week
Perdigao J et al[43]	6 months	Clearfil Se Bond (Kurraray America, NY) vs Prime & Bond NT (Dentsply Caulk, Milford, Del.)	2 step self etch vs 2 step etch and rinse	66	No statistically significant difference at 6 months
Scotti N et al[44]	1 week	All bond 3 (Bisco Schaumburg, IL, USA.) vs Clearfil protect bond (Kurraray, Osaka, Japan)	3 step etch and rinse vs 2 step self etch	204	No statistically significant difference
Browning Wd et al[45]	13 weeks	Single bond (3M ESPE Dental Products, St Paul, MN, USA) vs Adper prompt (3M ESPE Dental Products, St Paul, MN, USA)	2 step etch and rinse vs 1 step self etch	209	No statistically significant difference
Yousaf A et al[46]	1 week	Eco-etch (Ivoclar Vivadent, Schaan, Liechtenstein) vs Adhese One (Ivoclar Vivadent, Schaan, Liechtenstein)	2 step etch and rinse vs 1 step self etch	70	Less postoperative sensitivity with self etch at 1 week
Amin M et al[47]	1 week	Prime bond NT (Dentsply Caulk, Milford, Del.) vs L-Pop (3M ESPE Dental Products, St Paul, MN, USA)	2 step etch and rinse Vs self etch	80	Less postoperative sensitivity with Etch and rinse at 4 days

Table 3: Summary of clinical studies on postoperative sensitivity in relation to cavity type

Authors	Observation period	Cavity type	Postoperative Sensitivity
Bhatti UA et al[4]	2 days	Class I	13%
Briso ALF et al[5]	90 days	Class I, Class II (MO/DO), Class II (MOD),	5%, 15%, 26% respectively
Ayar KM[23]	30 days	Class II	28.6%
Opdam NJ et al[29]	49 days	Class I	14%
Auschill TM et al[53]	14 days	All types	6%
Unemori M et al[63]	-	All types	11%

pulp.[57] Monomer elution from the set composites has been investigated under different conditions and it may take place either due to incomplete polymerization and/or material degradation, thus highlighting the importance of adequate polymerization to minimize the adverse effects from residual

monomer like pulpal irritation and postoperative sensitivity. However, we cannot prevent material degradation in the oral environment and the eluted monomer can produce ill effects in the pulp. Luckily, the detrimental effects of the residual monomer are inversely proportional to the residual dentin thickness.[58]

Unfavourable C-factor and residual dentin thickness

The occurrence of postoperative sensitivity can be theorized to occur more frequently in the posterior teeth than the anterior. This can be explained by the difference in configuration of the cavities prepared on anterior and posterior teeth. The C-factor (ratio of bonded to unbonded surfaces) influences the ability of the unpolymerized portion of the composite to compensate for the shrinkage stresses.[59] As understood the greater C-factor of the cavities prepared in the posterior teeth results in reduced compensation for shrinkage stress and leads to greater stress accumulation at the bonding interface, initiating the sequel of microleakage and sensitivity.[60] The relatively large size of the cavities made in the posterior teeth require a larger bulk of the composite to restore them, the added bulk also contributes to an increased polymerization shrinkage and shrinkage stress.[61] However, clinical studies fail to demonstrate this association of C-factor or cavity type with postoperative sensitivity.[24,52] The frequency of postoperative sensitivity as reported in different clinical studies in relation to the type of cavity is shown in Table 3.[4,5,23,29,52,62]

Another possible reason for postoperative sensitivity could be the increased cavity depth or reduced thickness of residual dentin. As the cavity preparation depth increases the tubular density is also increased making it more challenging to control dentin wetness and ensure optimal adhesion.[9] The application of the etchant in such deep cavities as part of the etch and rinse approach removes the smear layer and increases the dentin permeability making the tooth vulnerable to postoperative sensitivity if adequate sealing of tubules is not achieved by hybridization. Initially it was believed that the use of acid etchants on the dentin can irritate the pulp but Fusayama's total etch procedure eventually helped alleviate any concerns pertaining to acid etching of dentin.[63] The higher percentage of postoperative sensitivity reported in multi surface restorations as seen in Table 3 could be explained by the greater removal of tooth structure and reduction in residual dentin thickness.[24]

The placement of composite restorations in close proximity to the pulp without an appropriate bonded liner/base would increase the risk of postoperative sensitivity in case of a compromised adhesion resulting from a failure in the hybridization process. Clinical studies on the other hand observed that a reduction of the residual dentin thickness in

deep cavities was found to be associated with greater postoperative sensitivity irrespective of the presence or absence of a cavity liner.[23,62] Although, the literature in the past has been split over the use of a resin modified glass ionomer (RMGI) base/ liner beneath composite restorations; in deep cavities with questionable bonding substrates placement of a RMGI base/liner has been regarded as a prudent practice.[62,64] However, a recent Cochrane review concluded that the evidence regarding the use of liners in class I and II is inconsistent and low quality.[65]

Pre-existing tooth related factors

Prior to delivering a restoration to any tooth, thorough investigation should be carried out to exclude the presence of any pre-existing cracks or pulpal inflammation. Cracks can develop in the tooth due to masticatory insults over a period of time and can create a diagnostic puzzle.[66] Restoring cavities with an intercuspal width exceeding one quarter are at an increased risk of crack development.[67] Following cavity preparation any visible crack should be identified and the patient informed accordingly, as symptoms arising from a cracked tooth can mimic reversible pulpitis[68] but may not be resolved with composite restoration. A clinical study evaluating the resolution of symptomatic cracked teeth following adhesive composite restorations with or without cuspal coverage reported only 50% teeth to be symptom free on clinical examination.[69] Hence, restoration of a tooth with an unidentified crack can even result in symptoms that can be confused with postoperative sensitivity.[70]

CONCLUSION

The development of modern adhesives combined with the improvement in handling of composites by the clinicians has resulted in a marked reduction of postoperative sensitivity. However, the occurrence of postoperative sensitivity is still a threat to the survival of the composite restorations along with bulk fracture, secondary caries and surface wear.[43] In this article, following the review of literature, various reasons were explained for the phenomenon of postoperative sensitivity associated with composite restorations. An understanding of these reasons is important for the dental practitioner to avoid the development of postoperative sensitivity in the delivered restorations so they can survive and provide service to the patient.

The perpetual development of new composite resin materials creates a scarcity of long term clinical data on a particular type of material. A systematic review and meta-analysis is required for understanding the clinical implications of the results from the plethora of clinical studies on the

subject of postoperative sensitivity.

CONFLICT OF INTEREST/ FINANCIAL DISCLOSURE

The author denies any plausible conflict of interest. The author denies any financial interest in the subject matter or materials discussed in this manuscript.

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