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Clinical Research

Occurrence and Causing Stimuli of Postoperative Sensitivity in Composite Restorations

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Clinical Relevance

This study enabled the dentist to analyze the individual risk of postoperative sensitivity after composite treatment and the type of pain patients may expect.

SUMMARY

Despite improvements in composite treatments over the past decade, postoperative sensitivity still remains a problem. Therefore, this clinical study evaluated the appearance of postoperative sensitivity after composite treatments and the stimuli that may have caused it. A total of 600 teeth in 231 patients was included in this study. All treatments were performed by dental students working under close supervision following standard procedures and using the bonding system Optibond FL and the nanofilled composite Ceram X. At baseline (visit 1), the restorations were grouped according to the following criteria: use of anesthesia, use of a rubber dam, indication for the restoration treatment, cavity class and clinical dimension of the cavity. After approximately two weeks (at visit 2), all the restorations were assessed and failure was defined if one of the following criteria occurred: a negative reaction to the vitality test, postoperative pain from masticatory forces or reported postoperative sensitivity by the patient. The reported postoperative sensitivity was specified with a visual analogue scale into hot/cold-sensitivity, sweet/sour-

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sensitivity, sharp/dull-sensitivity, spontaneous sensitivity and blistering/stinging-sensitivity. Failure was observed in 6% of the restorations. The statistical analysis showed that the clinical cavity depth turned out to be the only factor to have a significant influence on the appearance of postoperative sensitivity: caries profunda showed a four times higher risk of failure, while cavities with pulp exposure had a 14 times higher failure risk compared to restorations that were localized in the dentin. With regard to the type of sensitivity, no patients reported sensitivity to sweet/sour; most of them described their sensitivity as sharp/dull.

INTRODUCTION

Over the past decade, the use of resin-based dental composite fillings has increased significantly[1] and has become a well-established dental procedure for the direct restoration of anterior and posterior teeth.[2] Improvements in the materials and the decreasing acceptance of traditional amalgam by patients[3] have both contributed to the establishment of this restorative material as an amalgam alternative in many countries.[2] The demand for tooth-colored restorations[4-5] and discussion about the possible health risks associated with amalgam restorations have increasingly influenced the selection of restorative materials. With the development of improved adhesive and composite systems, resin-based composites have become predictably successful. Improvements in the clinical performance of resin-based composites were made by varying polymerization methods, filler content, particle size and particle composition.[6] Numerous promising clinical outcomes have encouraged many clinicians today to restore even relatively large cavities in posterior teeth with composites.

Despite these improvements in materials and techniques, postoperative sensitivity following composite restoration still remains a problem, especially in posterior teeth.[5,7-11] Closely connected with the problem of postoperative sensitivity is the fact that light-cured composites undergo polymerization shrinkage, which may, in turn, lead to internal stress and gap formation between the composite and tooth.[12] There are several proposals on how to handle polymerization shrinkage and postoperative sensitivity, for example, incremental curing, soft-start polymerization or lining coats under the composite. Additionally, self-etching primers have been reported to decrease the incidence of postoperative sensitivity.[12] In general, postoperative sensitivity resolves within the first few weeks after restoration placement.[13] However, in certain cases, it may persist for a longer period of time[9,14] and, therefore, may lead to restoration failure.

Although there are many clinical studies that have reported postoperative sensitivity following composite restoration,[8-11,13] a standard view regarding the treatment of this complication does not exist. Clinicians still have to rely on their subjective judgment when deciding whether to monitor, modify or replace the restoration.[5]

Therefore, this prospective clinical study evaluated the rate of postoperative sensitivity, any possible risk factors or causative stimuli and types of sensitivity as described by the patient.

METHODS AND MATERIALS

A total of 600 teeth in 231 patients (137 men and 94 women, ages 18 to 71 years) requiring composite restorations were selected for the study. The study protocol was screened and approved for ethical acceptability by the Ethics Committee of the University of Freiburg (Germany), and all patients provided informed consent to participate in the study. All treatments were performed by fourth- or fifth-year dental students working under the close supervision of four staff members of the Department of Operative Dentistry and Periodontology. Inclusion criteria were the need for a composite restoration in an anterior or posterior tooth, and all restored teeth were required to be vital. Exclusion criteria were allergies against the composite materials used, participation in another clinical study, negative reaction of the chosen tooth to the vitality test and the presence of any tooth sensitivity or pain prior to the restoration. At the screening appointment, all patients received a professional tooth cleaning and were instructed in oral hygiene.

Each treatment was performed by the same clinician following standard procedures and the manufacturers' instructions.

First, the patient decided whether or not he or she preferred local anesthesia. Following anesthesia, the shade selection was performed and the teeth were isolated with a rubber dam or cotton rolls. Removal of any previous restoration material in the case of a filling replacement or the first opening of the cavity in the case of primary caries was performed with high-speed diamond burs under abundant irrigation. The deeper carious tissue was then removed by using a low-speed round carbide bur. Shallow and medium cavities were not lined with calcium hydroxide cement. Only in the case of pulp exposure without visible pulp inflammation was this area cleaned with a chlorhexidine solution, then coated with a lining of calcium hydroxide cement (Kerr Life, KerrHawe, Abbondio, Switzerland) for pulp protection and tertiary dentin formation. Prior to the actual filling, all cavities were beveled and, when necessary, an appropriate matrix was placed and fixed with wooden wedges: a translucent matrix in anterior teeth, a contoured tofflemire metal matrix in posterior

teeth. The surface of the cavity was then etched with a 37.5% phosphoric acid gel. The acid gel was first placed on the enamel, then the dentin was conditioned during the last 15 seconds of the 30-second etching time to control the etching pattern. Then, the specimens were rinsed carefully for at least 20 seconds and gently air dried. Next, the dentin primer and bonding agents were applied (Optibond FL, KerrHawe) and light-cured for 30 seconds with a halogen curing light following the manufacturer's instructions. For the actual restorative procedure, a nanofilled composite (Ceram X, Dentsply DeTrey, Konstanz, Germany) was used. In anterior teeth, the Ceram X Duo system, with the combination of enamel-like and dentin-like shades, was preferred. In posterior teeth, Ceram X Mono was used. The restorations were built-up incrementally in oblique layers with a maximum thickness of 2 mm each. Each layer was light cured for 40 seconds. The adequate intensity of the halogen curing light was checked weekly throughout the investigation by using a curing radiometer. After the rubber dam was removed, all restorations were finished with polishing disks (Sof-Lex, 3M ESPE, Germany) for the buccal or palatal surfaces, while finishing strips (Sof-Lex) were used for the proximal areas. The occlusal surfaces were finished with water-cooled fine-grit diamond burs and a silicone-based polishing system. Finally, articulation was checked with articulating paper and the proximal contacts were assessed. Approximately two weeks later, the restorations were high-gloss polished with a Hawe Occlubrush.

Each treatment was noted on a separate study form, even if a patient received several restorations. For screening, the gender and age of the patient and the inclusion and exclusion criteria were checked and noted. Patients were interviewed regarding sensitivity of the tooth. At baseline (visit 1), the absence of sensitivity or pain and the vitality of the study tooth were checked again. During treatment, the operator noted:

1) the use of anesthesia (yes, no)
2) the use of a rubber dam (yes, no)
3) the reason for the restoration treatment (caries, restoration replacement, other)
4) the cavity class (I,II,III,IV,V)
5) the clinical dimensions of the cavity (enamel, dentin, caries profunda [inner third of dentin], pulp exposure)

Each restoration was evaluated clinically after about two weeks (visit 2) during the polishing session and was assessed for postoperative sensitivity. During the polishing appointment, the patients had to evaluate the postoperative sensitivity of the tooth by using a visual analogue scale. The patients were asked to give a score on a 10-point-scale, with 10 meaning "maximal sensitivity." Supplementally, the patients reported the circumstances under which the sensitivity occurred. The patients were asked to quantify the following details of their sensitivity with the same visual scale from 0 to 10:

- Onset of pain:
  - spontaneous sensitivity
  - stimulated sensitivity
- Cause of stimulated sensitivity:
  - hot/cold-sensitivity
  - sweet/sour-sensitivity
- Type of sensitivity:
  - sharp/dull-sensitivity
  - blistering/stinging-sensitivity

In addition, the operator tested the vitality of the tooth (positive, negative) by using a coolant spray and the absence or presence of postoperative pain to masticatory forces (tested with a cotton roll) (yes, no). For the statistical analysis, "failure" of the restoration regarding postoperative sensitivity was defined (visit 2) as:

- negative reaction to the vitality test at the polishing appointment
- postoperative pain to masticatory forces at the polishing appointment
- reported postoperative sensitivity by the patient (score >0)

The risk of postoperative sensitivity was statistically analyzed by comparing different parameters, such as age and gender of the patient, the reason for the restoration treatment, the clinical dimension of the cavity, the cavity class, the use of a rubber dam and the use of local anesthesia. The individual effects of these various factors were examined by the following statistical tests: The probability of at least one failure has been modeled using logistic regression with correlated data. Six-hundred restorations in 231 probands were considered in a marginal model.

In a marginal model, the effect of the risk factors is modeled separately from the within-proband correlation. The interpretation of the parameters is analogous to the standard logistic regression model. However, in this model, the authors adjusted for the correlation between fillings from the same proband and assumed that this correlation is identical for every two restorations from the same proband. Of course, restorations from different probands are considered to be independent.

RESULTS

A total of 600 restorations of different clinical classes, clinical dimensions and indications were placed in 231 patients. The analysis of the baseline treatment data

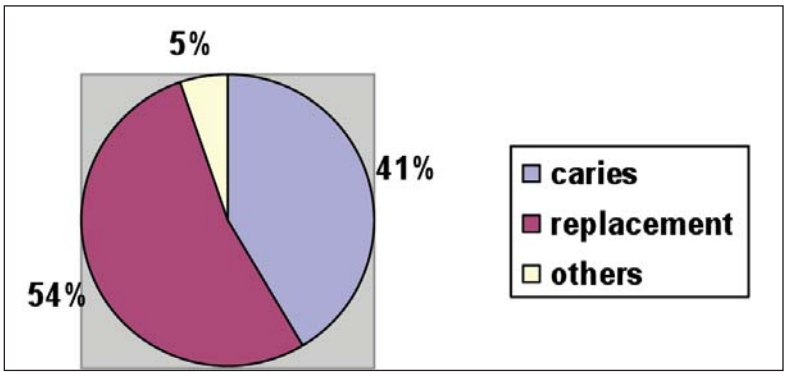

Figure 1: *Statistical distribution of the restorations with respect to indication at baseline.*

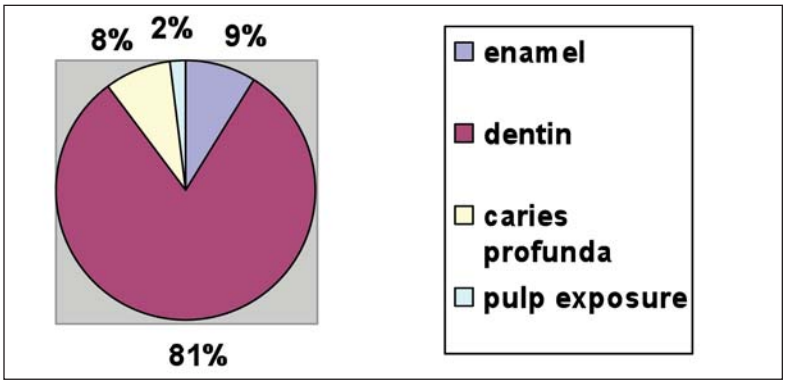

Figure 2: *Statistical distribution of the restorations with respect to clinical dimension at baseline.*

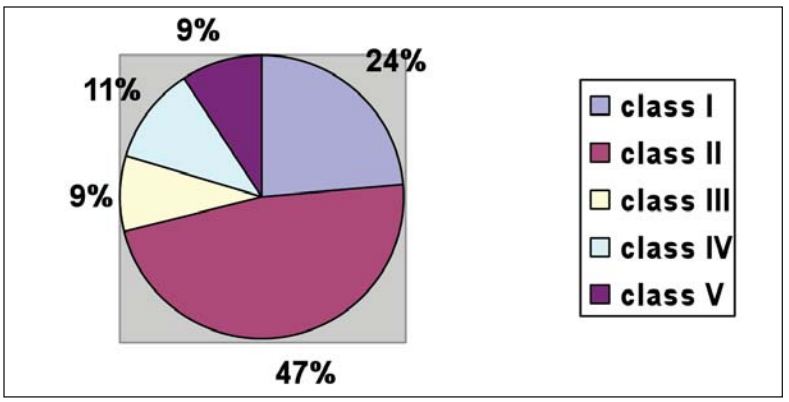

Figure 3: *Statistical distribution of the restorations with respect to clinical class at baseline.*

revealed that a rubber dam was used in 94% of the cases and cotton roll isolation was used in 6% of the cases. In 70% of the treatments, patients requested local anesthesia. Figures 1-3 show the statistical distribution of the 600 restorations with respect to indication, clinical dimension and clinical class at baseline.

All patients returned to the polishing and evaluation appointment after about two weeks (visit 2). At this point, 94% of the restorations did not show any of the defined failure criteria, such as a negative reaction to the vitality test, reported postoperative sensitivity or postoperative pain to masticatory forces. In 6% of the restorations (36 restorations), a failure of the restoration was observed. The combined appearance of the failure criteria in these restorations is shown in Table 1. Sensitivity was reported in 32 of the 36 failed restorations. The patients reported sensitivity by specifying five details (pain onset: spontaneous, cause: hot/cold, sweet/sour, type: light/dull, blistering/stinging). In two cases, the patient could not specify the tooth's sensitivity. Sweet/sour-sensitivity was not reported in any of the cases. The combined appearance of the other four sensitivity qualities is shown in Table 2.

Performing logistic regression with correlated data, the failure chance was analyzed with regard to the clinical class, the indication and the clinical dimension of the restorations and with regard to the use of local anesthesia and a rubber dam. Table 3 shows the results of the univariate analysis. A trend towards a protective effect of a rubber dam against failure was noted, whereas this trend was not significant. The use of local anesthesia did not have a notable influence on postoperative sensitivity. The analysis of the indication did not reveal any significant differences in postoperative sensitivity in the current study. Only a trend towards higher failure rates of restoration replacements compared with primary caries was noted. Concerning the clinical classes of the restorations, no significant differences in postoperative sensitivity were noted in the current study. The Class III restorations showed the lowest failure rate, but this trend was not significant. Only the clinical dimension of the cavity seems to have had an influence on the failure rate (postoperative sensitivity), as significant differences among cavity depths were evident. Whereas similar failure rates were noted in dentin and enamel cavities, caries profunda cavities showed a four times higher risk of failure. Cavities with pulp exposure showed a highly significant difference in which the failure risk was 14 times higher compared to dentin-localized restorations. Even if the sensitivity counts of the visual analogue scale could not be statistically analyzed because of the missing power of the study, the descriptive analysis of the mean counts supported the fact that cavity depth has an influence on postoperative sensitivity (mean scores of the visual analogue scale: pulp exposure: 3.25; caries profunda: 3.14; dentin: 2.75; enamel: 1).

Table 1: *Combined Appearance of the Failure Criteria (n=36 failed restorations)*

Frequency of the Combiations N=36	Vitality Test	Pain from Masticatory Forces	Sensitivity Score	Percent [%]
3	negative	no	0	8.3
1	positive	yes	0	2.8
13	positive	yes	>0	36.1
19	positive	no	>0	52.8

Table 2: *Combined Appearance of Sensitivity Characteristics (n=32 restorations with reported sensitivity)*

Frequency of the Combinations N= 32	Hot/Cold Sensitivity	Sharp/Dull Sensitivity	Spontaneous Sensitivity	Blistering/ Stinging-Sensitivity	Percent [%]
2	0	0	0	0	6.2
6	0	0	0	>0	18.8
1	0	0	>0	>0	3.1
7	0	>0	0	0	21.9
1	0	>0	>0	0	3.1
6	>0	0	0	0	18.8
3	>0	0	0	>0	9.4
3	>0	0	>0	0	9.4
1	>0	0	>0	>0	3.1
2	>0	>0	0	0	6.2

Table 3: *Univariate Analysis of the Chance of Failure with Regard to Clinical Class, Indication and Clinical Dimension of the Restorations as Well as with Regard to the Use of Local Anesthesia and Rubber Dam*

	Odds Ratio	*p*-value
Clinical Class		
Class I	(statistic reference)	<.0001
Class II	1.9019	0.1833 (ns)
Class III	0.5567	0.5677 (ns)
Class IV	1.5439	0.4937 (ns)
Class V	1.6973	0.4560 (ns)
Indication		
Caries	(statistic reference)	<.0001
Restoration replacement	1.8871	0.0678 (ns)
Other	1.0943	0.9173 (ns)
Clinical Dimension		
Dentin	(statistic reference)	<.0001
Enamel	0.4775	0.3844 (ns)
Caries profunda (inner third)	3.8789	0.0046 (*)
Pulp exposure	13.9159	<.0001 (**)
Local Anesthesia		
No	(statistic reference)	<.0001
Yes	1.0656	0.8754 (ns)
Rubber Dam		
No	(statistic reference)	0.0003
Yes	0.5074	0.2457 (ns)

DISCUSSION

In the current study, a total of 600 composite restorations were performed by dental students working under the close supervision of staff members, and they were assessed after about two weeks in terms of postoperative sensitivity and pain.

Several theories have been proposed over the years to explain the transmission of pain:[15] The first theory proposes that the dentinal tubule has a nerve running along the entire tubule length to the free surface. The second theory proposes that odontoblasts could serve as receptors. But the most widely accepted explanation of tooth sensitivity is the hydrodynamic theory.[16] According to this theory, dentin sensitivity is mediated by fluid movements within the dentinal tubules. Factors that can cause this fluid movement include dentin drying,[17] heat resulting from cavity preparation,[18] chemical agents and bacterial penetration.[14,19] Sensitivity may also result from polymerization shrinkage and deformation of the restoration under occlusal stress, which transmits hydraulic pressure to the odontoblastic processes.[8,11,20] Dentinal adhesives are able to bond the restorative material to the tooth structure and obliterate open dentinal tubules.[21] Well-sealed dentinal tubules pre-

vent invasion from outside bacteria and susceptibility to outside stimuli.[22-23] However, for many years, acid etching of vital dentin has been related to postoperative problems, such as tooth sensitivity and pulp inflammation. Dentin conditioning agents can also be harmful when their pH value is lower than 5.5 and when they approach or come in contact with pulp.[14,24-25] Polymerization shrinkage can usually provoke a gap forming between the resin composite and the hybrid layer.

In the current study, the failure rate of 6% after about two weeks is very low compared to other studies with failure rates of up to 30%.[9-10,15] This may refer to the use of the Optibond FL 3-step etch-and-rinse bonding system, which shows the best clinical performance.[26] As all treatments were performed by students in a teaching setting, it cannot be considered representative; it may not be fully applicable in routine dental practice. However, Opdam and others[9] noted that the relatively inexperienced dental student performed as well as the experienced dentist. The fact that all treatments were performed by students under the supervision of staff members may have had a positive effect towards the low rate of postoperative sensitivity. Even if the students were mostly inexperienced in restorative treatments, it is possible that the supervision guaranteed that the manufacturers' instructions were followed closely and that the restorative treatment was carefully performed. According to Sobral and others,[22] a restoration is usually successful and the incidence of postoperative sensitivity nears zero when the correct technique is used and all the cavity preparation and restoration guidelines are carefully followed.

The current study combined an objective with a subjective assessment to evaluate the intensity of postoperative sensitivity. Subjectively, the patients classified their postoperative sensitivity and the causing stimulus from each of the restored teeth by using a visual analogue scale (value 0-10). The objective assessment included the vitality test and the level of discomfort on loading.[9] Subjective methods to assess sensitivity, such as the visual analogue scale, seem to provide more effective statistical tests than the objective tests.[22] However, some patients may have difficulty responding to visual analogue scales. In the current study, the authors also concentrated on a detailed evaluation of postoperative sensitivity. Therefore, no restorative parameters were included in the failure criteria. According to the authors best knowledge, few if any studies have concentrated on a detailed description of the types of postoperative sensitivity. Most authors who performed a detailed evaluation of sensitivity concentrated on the causative stimuli. In clinical practice, it may be important for further treatment to know about both the onset of pain (spontaneous, stimulated), the causing stimuli (cold/hot, sweet/sour) and the type of sensitivity (sharp/dull, blistering/stinging) described by the patient. In the study by Gordan and others,[27] sensitivity stimuli included cold (ice cream, cold drinks), heat (coffee or tea), chewing and spontaneous sensitivity. Kuijs and others[28] asked patients under what circumstances (cold/warm, while biting, spontaneously) they had experienced sensitivity. Sobral and others[22] asked patients to record sensitivity triggered by different stimuli (cold drinks, hot drinks, sugar, dental floss). In contrast to Sobral and others,[22] none of the patients reported sensitivity to a sweet stimulus. Most patients did not report a combination of different stimuli, but rather named a single stimulus or category corresponding to their postoperative sensitivity: hot/cold stimulus (6 teeth), sharp/dull-sensitivity (7 teeth), blistering/stinging-sensitivity (6 teeth). Because cavity depth turned out to be the most important factor and showed a significant influence on postoperative sensitivity, the authors suppose that the clinical evaluation of cavity dimension, as used in this study, was an appropriate tool to standardize the different types of teeth and clinical classes. Because radiographs often do not correlate exactly with clinical cavity depth, the often proposed application of X-rays for classification was not used in the current study.[1,12,29] Another clinical classification of cavity size was proposed by Hayashi and Wilson,[5] who divided cavities into small, medium, large and extra large, according to the distance up the cuspal slopes.

In order to identify the risk factors for postoperative sensitivity in the current study, data from the 36 failed restorations was analyzed with regard to:

- anesthesia use
- rubber dam use
- the reason for restorative treatment
- clinical class of the restorations
- clinical cavity depth

With the exception of cavity depth, none of the other parameters had a significant influence on the occurrence of postoperative sensitivity.

- *Use of Anesthesia and Rubber Dam*

Neither the use of anesthesia nor the use of a rubber dam turned out to have any significant influence on postoperative sensitivity. However, a trend towards a protective effect against failure was noted for rubber dam use. As a guarantor for a low incidence of postoperative sensitivity in composite restorations,[30] rubber dam isolation was used in most studies, whereas some authors preferred to use a cotton roll for isolation.[9,28-31] In any case, both techniques need to guarantee good isolation in order to achieve optimal bonding.

- *Reason for Restorative Treatment*

The initial reason for the restorative treatment was not found to have a significant influence on sensitivity.

The results of the current study do not support the observation of an increased rate of postoperative sensitivity for replacement restorations compared to the treatment of primary caries.[1] In the current study, no significant difference between those two types of restorations was noted. Baratieri and Ritter[1] reported that replacement restorations induced more postoperative sensitivity (86%) than those placed because of primary decay (14%), despite the fact that the replacements were usually shallower preparations. According to the authors, one explanation could be that the teeth that had been previously restored had suffered cumulative stresses from the previous caries challenge, fractures or restorative procedures. These authors speculated that it is also possible that the dentin substrate on the previously restored teeth had been modified and was not as receptive to the bonding technique as the dentin in primary caries cavities.

- *Clinical Class of the Restorations*

Resin-based composites are being increasingly used for the direct restoration of posterior teeth.[1] Subsequently, postoperative sensitivity has been associated with posterior resin-based composite restorations.[5,9,32] Several factors may be responsible for postoperative sensitivity in posterior composite restorations, such as polymerization shrinkage, bulk filling technique, incomplete coating of the dentin surface with dentin adhesives and traumatic occlusion.[33] The current results did not show a significant association of postoperative sensitivity to specific clinical classes, such as Class I or II (posterior teeth). Feilzer and others[34] showed that, in occlusal cavities, the C-factor is greater than five, thereby producing higher concentration stress, because only one of the current six surfaces is free.[15] Concerning the C-factor, Class IV restorations are supposed to show the least polymerization stress, whereas the current study could not support this finding.

Even if there are less appropriate alternatives for direct restorative treatments in anterior teeth, it is important for the clinician to know whether composite restorations really provoke more postoperative sensitivity than amalgam fillings. The etching procedure and polymerization shrinkage in composite restorations lead to postoperative sensitivity, owing to the stresses generated upon curing.[1] Because of this, they are generally meant to provoke more postoperative sensitivity than amalgam fillings. On the other hand, corrosion products from dental amalgam are believed to produce a gradual reduction in postoperative sensitivity.[35] However, the authors of the current study could not show a higher postoperative sensitivity rate in comparison to Al-Omari. In the study by Al-Omari, amalgam restorations were also carried out by dental students working under the close supervision of staff members, and these dental students found a postoperative sensitivity of 8% after 30 days.

- *Cavity Depth*

Al-Omari and others[36] showed that short-term (2-30 days) postoperative sensitivity was affected by lesion depth (27% of the middle-third lesions, 58% of the inner third lesions); whereas medium-term (>30 days) postoperative sensitivity was affected neither by the method of cavity treatment nor by the depth of lesion. Although this study describes the results of amalgam treatments, its results are comparable to the results of the current study, because they describe the fact that the larger the cavity preparation, the greater the area of dentinal tubules exposed. Likewise, the deeper the cavity, the wider the dentinal tubules. These morphological factors could explain why deeper cavities had more reports of postoperative sensitivity and pain.[36] While this might also help to explain the authors' observation that Class II cavities had more postoperative sensitivity than Class I cavities, it should be noted that, in the current study, this difference was not statistically significant.

CONCLUSIONS

The current study detected individual factors that may lead to postoperative sensitivity in order to enable clinicians to define an individual risk of failure for each case and to inform patients about the type of sensitivity that they can expect.

Students performed all the restorations, and a wide variety of types and depths of restorations were analyzed.

No significant effect on sensitivity was seen based on the reason for the restoration, the clinical class of the filling, the use of anesthesia or the use of a rubber dam. Cavity depth was significantly associated with the appearance of postoperative sensitivity.

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