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The radiographic outcomes of direct pulp–capping procedures performed by dental students

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ABSTRACT

Background. The decision between pulp capping and root canal therapy after pulp exposure is a clinical issue. The aim of the authors' study was to evaluate the outcome of direct pulp-capping procedures performed by dental students.

Methods. The authors followed the treatment outcomes of 193 patients with 204 pulp exposures with direct pulp capping. They determined the outcome of pulp capping radiographically using periapical radiographs taken at least three years after pulp exposure. The outcome was considered as successful if the tooth was present and not associated with periapical radiolucency or root canal treatment; otherwise, the outcome was considered as being a failure.

Results. Overall, the success rate of pulp capping was 59.3 percent. The success was associated more with mechanical exposure than with carious exposure (92.2 versus 33.3 percent) ($P < .001$), more with permanent restoration than with temporary restoration (80.8 versus 47.3 percent) ($P < .001$) and more with class I occlusal restoration (83.8 percent) than with proximal multiple surface restorations (Class II, 56.1 percent; Class III, 58.8 percent; mesial-occlusal-distal, 28.6 percent) ($P = .009$). Patients' age, sex, and tooth location and position had no significant effect on the outcome ($P > .05$).

Conclusion. The success rate of direct pulp capping was 92.2 percent with mechanical exposure and 33.3 percent with carious exposure.

Clinical Implications. Direct pulp capping is recommended after mechanical exposure with immediate placement of permanent restoration, while root canal therapy would be the choice of treatment if the exposure was due to caries.

Key Words. Pulp exposure; pulp capping; radiographic outcome.

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It is well-accepted that the pulp is not a doomed organ, but has the ability of initiating several defense mechanisms to protect itself, to a certain extent, from bacterial invasion to which it may be exposed.[1] Throughout the lifetime of a tooth, the vital pulp tissue contributes to the production of secondary dentin, peritubular dentin (sclerosis) and reparative dentin in response to biological and pathological stimuli.[2] Indeed, a vital functioning pulp seems to be the best barrier for protection from microorganisms that may invade the pulp tissues.[1,3]

Operative procedures may be considered the most frequent cause of pulpal injury. Trauma to the pulp during such procedures cannot always be avoided, particularly when the tooth requires extensive restoration or when inexperienced hands carry out the treatment.

Treatment of pulp exposures by pulp capping still is controversial. Clinicians are well-aware of the immediate and long-term success rates of endodontic therapy but are less certain of the success of pulp capping.[4] Berman[5] stated that pulp capping is the most misused,

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abused, unpredictable and least successful of the pulp therapy alternatives, with success rates of only 30 to 40 percent. Kakehashi and colleagues[6] showed clearly that exposed pulp heals well in the absence of bacteria, with dentin bridge formation occurring. Indeed, the success rate of pulp capping as documented in the literature has varied between the short-term and long-term follow-up. Armstrong and Hoffman[7] reported a 97.8 percent success rate after 1.5 years, while Fitzgerald and Heys[8] reported a 79 percent success rate after one year, and Haskell and colleagues[9] reported a success rate of 87.2 percent after five years. On the other hand, Barthel and colleagues[1] found a success rate of 37 percent after five years and 13 percent after 10 years for 123 pulp-capping procedures performed by dental students.

It has been reported that the curriculum time devoted to the teaching of vital-pulp therapy to undergraduate students is low compared with that designated for the teaching of formal endodontic treatments.[2] Therefore, we conducted a study to evaluate radiographically the treatment outcome of direct pulp-capping procedures performed by undergraduate dental students in teaching clinics to ascertain whether further training was in fact needed.

MATERIALS AND METHODS

We selected a random sample of 8,500 records of patients who had received treatment at Jordan University of Science and Technology's Dental Teaching Centre between 1995 and 2000. We asked the filing personnel to randomize selections from the filing storage unit by choosing every fifth file arranged in each cabinet. This yielded a total of 1,700 records, which we screened.

According to the records, 421 patients experienced 447 pulp exposures during cavity preparation at the Dental Teaching Centre's conservative dentistry clinics. Of these, we followed 193 patients with 204 pulp exposures for at least three years. We did not follow the remaining 228 patients with 243 pulp exposures because they did not return to the clinic after they had been treated and could not be contacted.

All pulp exposures occurred during the dental treatment carried out by fourth- and fifth-year undergraduate dental students at the conservative dentistry clinics. Members of senior staff at the clinics supervised all the procedures. The policy for treating pulp exposures at the school was that when pulp exposure occurred, the student should isolate the tooth with cotton rolls and remove any saliva with a saliva ejector and suction. Senior staff members then would determine if the pulp exposure was mechanical or carious, depending on the extent of caries and cleanliness of the cavity on exposure. In cases of mechanical exposure, all the walls of the cavity were clean of caries and the exposure occurred through hard dentin. In cases of caries exposure, the cavity walls were clean except for one carious spot, the removal of which resulted in exposure of the pulp. We recorded the condition of the cavity and the type (carious or mechanical) and size of exposure in the patients' records.

We considered only exposures within an estimated size of 1 square millimeter to be candidates for pulp capping. In carrying out the direct pulp-capping procedure, the students are taught to irrigate the cavity with saline, dry it with a sterile cotton pellet and then cover the site of exposure with setting calcium hydroxide ($Ca[OH]_2$) paste (Kerr Life, Kerr Italia, Scafati, Italy) using an applicator. After this, they place a temporary restoration (IRM intermediate zinc oxide eugenol restorative material, Dentsply DeTrey, Konstanz, Germany) or a permanent restoration (amalgam or resin-based composite). They ask the patient to return to the emergency clinic if he or she experiences any symptoms.

We determined the outcome of each pulp exposure procedure by reading the periapical radiographs, which had been taken at least three years after the date of the exposure. In the case of records that did not include periapical radiographs for the tooth in question, we asked the patients to report to the initial treatment unit so that their dental record could be updated; there, the radiographer took a periapical radiograph.

We considered the pulp-capping procedure to be successful if the tooth was present and not associated with periapical radiolucency or root canal treatment. We considered the procedure to have failed in teeth associated with periapical radiolucency, those that had shown root canal treatment or those that required extraction after pulp capping had been performed. Two examiners (A.S.A. and K.M.B.) assessed the radiographs independently, and when disagreement occurred, a third examiner (M.A.A.) made the final decision. We analyzed the data using SPSS for Windows Version 6.0 (SPSS, Chicago). We used χ^2 analysis to determine any significant effects on

TABLE 1

Distribution (%) of the teeth investigated in relation to age and sex of the patient, position and location of the tooth, and type of pulp exposure.*

AGE (YEARS)†	SEX‡		TOOTH POSITION§		TOOTH LOCATION¶		TYPE OF EXPOSURE#		TOTAL
	Male	Female	Anterior	Posterior	Maxillary	Mandibular	Carious	Mechanical	
10-20	25 (12.3)	23 (11.3)	5 (2.5)	43 (21.1)	21 (10.3)	27 (13.2)	27 (13.2)	21 (10.3)	**48 (23.5)**
21-30	20 (9.8)	44 (21.6)	5 (2.5)	59 (28.9)	39 (19.1)	25 (12.3)	35 (17.2)	29 (14.2)	**64 (31.4)**
31-40	26 (12.7)	33 (16.2)	6 (2.9)	53 (26.0)	31 (15.2)	28 (13.7)	35 (17.2)	24 (11.8)	**59 (28.9)**
41-50	12 (5.9)	11 (5.4)	2 (1.0)	21 (10.3)	14 (6.9)	9 (4.4)	14 (6.9)	9 (4.4)	**23 (11.3)**
51-60	4 (2.0)	4 (2.0)	3 (1.5)	5 (2.5)	7 (3.4)	1 (0.5)	2 (1.0)	6 (2.9)	**8 (3.9)**
> 60	2 (1.0)	0 (0.0)	0 (0.0)	2 (1.0)	1 (0.5)	1 (0.5)	1 (0.5)	1 (0.5)	**2 (1.0)**
TOTAL	**89 (43.6)**	**115 (56.4)**	**21 (10.3)**	**183 (89.7)**	**113 (55.4)**	**91 (44.6)**	**114 (55.9)**	**90 (44.1)**	**204 (100.0)**

* $df = 5$.
† Age of the patient at the time of exposure.
‡ $\chi^2 = 8.8$; $P = .12$.
§ $\chi^2 = 7.1$; $P = .21$.
¶ $\chi^2 = 7.3$; $P = .20$.
# $\chi^2 = 3.7$; $P = .60$.

the outcome of the treatment in relation to the patient's age, tooth location and position, type of pulp exposure, and type and class of restoration placed after the exposure. We considered a P value ≤ .05 to be statistically significant.

RESULTS

Table 1 presents the distribution of the teeth with pulp exposure in relation to the age and sex of the patients, position and location of the tooth, and the type of pulp exposure. We found no statistically significant relationships in the distribution of the teeth with pulp exposure in regard to the patients' age with the patients' sex, tooth location and position, or type of pulp exposure (Table 1).

Tables 2 through 8 show the outcome of the pulp capping for the treated teeth (success versus failure) in relation to the patient's age, the patient's sex, tooth location, tooth position, the type of pulp exposure, the type of restoration placed after pulp capping and the class of the restoration, respectively. Further analysis of the data showed that there were no significant relationships between the outcome of the pulp capping and the patients' age group ($P = .36$) (Table 2), the patients' sex ($P = .36$) (Table 3), tooth location ($P = .15$) (Table 4) or tooth position ($P = .83$) (Table 5). However, we found statistically significant relationships between the outcome of the pulp capping and the type of pulp exposure ($P < .001$) (Table 6), the type of restoration placed immediately after pulp capping ($P < .001$) (Table 7, page 1703) and the class of restoration ($P = .009$) (Table 8, page 1703). More teeth with mechanical exposure than carious exposure demonstrated successful pulp capping (92.2 and 33.3 percent, respectively), and we found a greater rate of success when a permanent rather than a temporary restoration was placed in the tooth (80.8 percent versus 47.3 percent). Furthermore, most of the teeth with a Class I

TABLE 2

Outcome of pulp capping (%) in relation to patients' age group.*

AGE (YEARS)†	OUTCOME‡		TOTAL§
	Success	Failure	
10-20	33 (68.8)	15 (31.3)	**48 (23.5)**
21-30	39 (60.9)	25 (39.1)	**64 (31.4)**
31-40	30 (50.8)	29 (49.2)	**59 (28.9)**
41-50	12 (52.2)	11 (47.8)	**23 (11.3)**
51-60	5 (62.5)	3 (37.5)	**8 (3.9)**
> 60	2 (100.0)	0 (0.0)	**2 (1.0)**
TOTAL§	**121 (59.3)**	**83 (40.7)**	**204 (100.0)**

* $\chi^2 = 5.5$; $df = 5$; $P = .36$.
† Age of the patient at the time of exposure.
‡ Percentage distribution (%) within each age group of patients.
§ Percentage distribution (%) within the total number of teeth that underwent pulp capping.

TABLE 3

Outcome of pulp capping (%) in relation to patients' sex.*

SEX	OUTCOME†		TOTAL‡
	Success	Failure	
Male	56 (62.9)	33 (37.1)	89 (43.6)
Female	65 (56.5)	50 (43.5)	115 (56.4)
TOTAL‡	121 (59.3)	83 (40.7)	204 (100.0)

* $\chi^2 = 0.85$; $df = 1$; $P = .36$.
† Percentage distribution (%) within each sex group.
‡ Percentage distribution (%) within the total number of teeth that underwent pulp capping.

TABLE 4

Outcome of pulp capping (%) in relation to the tooth location (maxillary versus mandibular).*

TOOTH LOCATION	OUTCOME†		TOTAL‡
	Success	Failure	
Maxillary	62 (54.9)	51 (45.1)	113 (62.9)
Mandibular	59 (64.8)	32 (35.2)	91 (56.5)
TOTAL‡	121 (59.3)	83 (40.7)	204 (100.0)

* $\chi^2 = 2.1$, $df = 1$; $P = .15$.
† Percentage distribution (%) within each tooth location (each jaw).
‡ Percentage distribution (%) within the total number of teeth that underwent pulp capping.

TABLE 5

Outcome of pulp capping (%) in relation to the tooth position (anterior versus posterior).*

TOOTH POSITION	OUTCOME†		TOTAL‡
	Success	Failure	
Anterior	12 (57.1)	9 (42.9)	21 (10.3)
Posterior	109 (59.6)	74 (40.4)	183 (89.7)
TOTAL†	121 (59.3)	83 (40.7)	204 (100.0)

* $\chi^2 = 0.05$; $df = 1$; $P = .83$.
† Percentage distribution (%) within each tooth position group.
‡ Percentage distribution (%) within the total number of teeth that underwent pulp capping.

TABLE 6

Outcome of pulp capping (%) in relation to the type of pulp exposure.*

PULP EXPOSURE	OUTCOME†		TOTAL‡
	Success	Failure	
Carious	38 (33.3)	76 (66.7)	114 (55.9)
Mechanical	83 (92.2)	7 (7.8)	90 (44.1)
TOTAL‡	121 (59.3)	83 (40.7)	204 (100.0)

* $\chi^2 = 72.3$; $df = 1$; $P < .001$.
† Percentage distribution (%) within each type of pulp exposure.
‡ Percentage distribution (%) within the total number of teeth that underwent pulp capping.

occlusal restoration showed successful pulp capping (83.8 percent), while most of the teeth with mesial-occlusal-distal (MOD) restoration did not (71.4 percent rate of failure) (Table 8).

DISCUSSION

Most of the teeth we assessed were from patients aged 21 through 40 years, and most of them were posterior teeth. This appears to be related to the fact that the patients who came to the conservative dentistry clinic were mostly in that age group (21-40 years); it also may reflect the fact that posterior teeth usually need operative treatment more than do anterior teeth. In fact, at our school, we have noticed that it is difficult to find a sufficient number of anterior teeth with Class III or IV caries to satisfy the curriculum requirements for students' operative dentistry training.

Overall, the success rate of the pulp-capping procedures in our study was 59.3 percent. This value is much lower than the 97.8 percent success rate reported by Armstrong and Hoffman,[7] in whose study the lack of clinical symptomology after 1.5 years was the criterion for success of the pulp capping. On the other hand, our success rate is higher than that reported by Barthel and colleagues,[1] in whose study the criterion of success was a good response to sensitivity testing and absence of clinical symptomology and signs of radiolucency after five years (37 percent success rate) and 10 years (13 percent success rate) of follow-up. However, the success rate of the pulp-capping procedure in our study was similar to that reported by Heyduck and Wegner,[10] who assessed the outcome of pulp capping after five years and based their

results on the sensitivity of the pulp and the radiological assessment (61.4 percent success rate). The criterion we used was radiographic assessment only, which we believe may be more reliable than clinical symptomology or pulp sensitivity. The latter two are subjective and depend on the response of the patient; therefore, false readings may occur. A combination of all of these may be considered to be more realistic—but it also may lead to questionable results if some criteria indicate success and others indicate failure for the same tooth, as reported in the study by Barthel and colleagues.[1]

The isolation and management of the teeth that had pulp exposure was controlled and managed by the student after he or she informed the academic staff in the clinic. This may affect the outcome of pulp capping negatively, because of the time elapsed before initiation of the pulp-capping procedure. This also means that there may be a greater degree of exposure to oral fluids (we did not use rubber dams in our study). Furthermore, it was generally observed that when the exposure occurred, the student started to panic and lose confidence, which may have further affected the management of the case. Indeed, a qualified and experienced dentist may manage the case in a shorter time and with greater confidence. Baume and Holz[11] stated that the operator's skill seems to be one factor that influences the outcome of pulp-capping procedures. However, previous reports indicate that pulp contamination by the oral environment for 24 hours or less had little if any effect on pulp healing and hard-tissue formation after pulp-capping procedures.[12]

The results of our study showed that the age of the patient did not have an influence on the success or failure of pulp capping, a finding that is in agreement with those of previous studies.[1,9,13]

TABLE 7

Outcome of pulp capping (%) in relation to the type of restoration placed immediately after pulp capping.*

TYPE OF RESTORATION	OUTCOME†		TOTAL‡
	Success	Failure	
Temporary	62 (47.3)	69 (52.7)	131 (64.2)
Permanent	59 (80.8)	14 (19.2)	73 (35.8)
TOTAL‡	121 (59.3)	83 (40.7)	204 (100.0)

* $\chi^2 = 72.3$; $df = 1$; $P < .001$.
† Percentage distribution (%) within each type of restoration.
‡ Percentage distribution (%) within the total number of teeth that underwent pulp capping.

TABLE 8

Outcome of pulp capping (%) in relation to the class of restoration placed immediately after pulp capping.*

RESTORATION CLASS	OUTCOME†		TOTAL‡
	Success	Failure	
Class I	31 (83.8)	6 (16.2)	37 (18.1)
Class II	74 (56.1)	58 (43.9)	132 (64.7)
Class III	10 (58.8)	7 (41.2)	17 (8.3)
Class IV	1 (50.0)	1 (50.0)	2 (1.0)
Class V	1 (50.0)	1 (50.0)	2 (1.0)
Mesial-Occlusal-Distal	4 (28.6)	10 (71.4)	14 (6.9)
TOTAL‡	121 (59.3)	83 (40.7)	204 (100.0)

* $\chi^2 = 15.4$; $df = 5$; $P = .009$.
† Percentage distribution (%) within each class of restoration.
‡ Percentage distribution (%) within the total number of teeth that underwent pulp capping.

Only 10 patients were older than 50 years and only two of these patients were older than 60 years, which may minimize the influence of other factors that may lead to tooth loss, such as periodontal disease. In fact, of a total of 83 failures, only 13 cases were due to tooth loss. However, the insignificant effect of age on the outcome of pulp capping in our study should be interpreted with caution due to the low number of patients older than 50 years. The patient's sex also did not influence the outcome of treatment. Furthermore, neither the tooth location (maxillary versus mandibular) nor the tooth position (anterior versus posterior) had any significant effect on the success or failure of the pulp capping, a finding that also is in agreement with those in previous reports.[1,13] However, Horsted and colleagues[14]

observed after a five-year follow-up of pulps capped with $Ca(OH)_2$ that teeth of older patients had lower success rates than those of younger patients, and the molars had better success rates than did anterior teeth and premolars.

Horsted and colleagues[14] found no significant differences between mechanical exposure and carious exposure in terms of the success of pulp capping and stated that additional clinical factors may obscure the true cause of failure when long observation periods are used. In contrast, our study showed that the type of pulp exposure (carious versus mechanical) had a significant effect on the outcome of the pulp capping. Indeed, the failure rates we observed were 66.7 percent with carious exposure and only 7.8 percent with mechanical exposure. This could be related to the presence of infected dentin in teeth with carious exposure since, despite the clinical caries excavation before pulp capping, remnant microorganisms remain in the surrounding dentin even after the tooth has been restored. Thus, these leftover microorganisms would have the chance to penetrate the pulp space and cause pulp necrosis, resulting in an infected root canal system with apical pathosis.[1] Furthermore, the status of the pulp before and at the time of exposure may influence the outcome of the pulp-capping procedure. In carious exposure, bacteria penetrate the pulp space, and the inflammatory response extends deeper into the pulp tissue relative to the superficial inflammation in mechanical exposure.[4,15]

The adverse effect of microorganisms on the outcome of pulp capping also could explain the significantly higher success rate of pulp capping when a permanent rather than a temporary restoration was placed immediately after pulp capping. This may be because permanent restorations seal the margin between the restoration and the tooth structure more effectively than does a temporary restoration, thus preventing or reducing the microleakage that may occur through the restoration–tooth structure interface. Indeed, all initial temporary restorations in our study were replaced with permanent ones within one to eight weeks, except in three patients who still had temporary restorations at the time of their last follow-up visit. Furthermore, the possible additional mechanical and bacterial contamination that could occur when the temporary restoration is replaced with a permanent restoration may affect the success rate of pulp exposure in those teeth. The significant effect of the restoration on the healing and success rate of the pulp-capping procedure has been reported in other studies.[1,12] The influence of the marginal seal and, subsequently, the prevention or reduction in the microleakage may reflect the higher success rate of pulp capping in Class I restorations relative to that in the Class II, III, IV and V and MOD restorations in our study. This significant influence may be considered to be due to the length of the margin between the tooth structure and the restoration interface, in that the longer the margin, the greater incidence of microbial microleakage that could reach the pulp space. The latter could be clearly observed in the lower success rate of pulp capping in the teeth with MOD restorations versus the rate in those with the other classes of restorations.

The other factor that also could be linked with the success of the pulp-capping procedure is the accessibility of the teeth to cleansing and brushing. The interproximal surfaces of the teeth are not as accessible as is the occlusal surface, and caries or a restoration in the proximal surfaces of the teeth usually is closer to the entire coronal pulp. In our study, the success rate of pulp capping in teeth with Class IV and V restorations was 50 percent, but only two teeth from each class were involved.

Barthel and colleagues[1] stated that the site of exposure (occlusal versus cervical) theoretically could be of influence: "an inflammation that originates in a cervical wound might involve the entire coronal pulp because of obstacle on the access road for vessels, etc., to the coronal pulp. This could lead to increased pulp death in cases of cervical exposure." However, these authors reported that this was not the case in their study. They found no difference in the pulp-capping outcome between cervical or occlusal exposure. Pereira and Stanley[16] did not detect any difference in pulp-capping outcome related to the site of exposure in dog pulp. In their opinion, the length of the margin would have a greater influence on the outcome of the pulp capping than would the site of the exposure.

Cox and colleagues[17] re-emphasized the need to provide a long-term clinical seal against microleakage following direct pulp capping with $Ca(OH)_2$. To date, numerous materials have been developed as an alternative to $Ca(OH)_2$ as pulp-capping materials in an attempt to improve both the durability and the sealing capacity of the material, as well as the pulp's reaction to it.[18-23]

Adhesive resin systems have been reported not to have results comparable with those of $Ca(OH)_2$; the latter was found to have better results in dentin bridge formation.[24-28] Resin-modified glass-ionomer cement was reported to have a comparably good result.[19,21] Various calcium phosphate cements and mineral trioxide aggregate also have been promoted as direct pulp-capping materials with promising results.[22,23,29,30]

Finally, it could be stated that the microorganisms are the key issue in the success or failure of the pulp-capping procedure and that, on the basis of the results of our study, pulp capping for carious exposure should be avoided. However, in the case of relatively small mechanical exposures, conserving the vital pulp by direct pulp capping should be considered, with immediate placement of a permanent restoration. Therefore, the undergraduate dental curriculum should be reviewed and more time should be assigned in teaching students how to conserve the vital pulp before moving toward endodontic therapy.

CONCLUSION

Overall, the success rate of direct pulp capping performed by dental students was 59.3 percent. The teeth with mechanical exposure had a 92.2 percent success rate, and those with carious exposure had a 33.3 percent success rate. Therefore, the findings of this study would lead us to recommend performing direct pulp capping after mechanical exposure with immediate placement of permanent restoration materials to conserve the vital pulp. If the exposure is due to caries, endodontic therapy would be the choice of treatment. The endodontic curriculum of the undergraduate dental student should be reviewed to include more training in conservation of the vital pulp after exposure. ■

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