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CLINICAL OUTCOME OF HERBAL VERSUS BIO-INDUCTIVE PULP CAPPING MATERIAL IN VITAL PULP THERAPY

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ABSTRACT

Aim: To clinically and radiographically assess the effectiveness of Aloe vera compared to Mineral Trioxide Aggregate (MTA) as a direct pulp-capping material.

Materials and methods: Forty patients, aged 14–30 years, who had immediate mechanical pulp exposure in their mandibular first permanent molars during class I cavity preparation were gathered from the Restorative Dentistry Department Clinic, Faculty of Dentistry, Tanta University. They were randomly divided into two groups of equal size (n = 20) based on the pulp-capping material used: Group I: pulp exposures were capped using Aloe Vera, and Group II (control): pulp exposures were capped using MTA. In both groups, the remaining part of the cavity was filled with composite resin restoration. The treated teeth were assessed clinically and radiographically at different intervals (baseline, 3, 6 months postoperatively). Data from both groups were statistically analyzed at a 95 % significance level at different study intervals.

Results: Both groups initially had clinical, radiographic, and overall success rates of 100%. These rates decreased to 94.7% at the 3-month follow-up for both groups except the clinical success for group I and 94.1% at the 6-month follow-up for group I while group II rerecorded 100%. The final clinical, radiographic, and overall success rates were 94.1%, 88.2%, and 88.2%, respectively, for group I and 94.4% for group II. There were no significant statistical differences between the two groups ($p > 0.05$).

Conclusion: Aloe vera was as effective as MTA as a direct pulp capping material, despite MTA offering superior clinical and radiographic success.

KEYWORDS: Vital pulp therapy, Aloe vera, MTA, Direct pulp capping.

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INTRODUCTION

Vital pulp therapy maintains the pulp's vitality when exposed to iatrogenic errors or trauma [1]. Creating a dentine bridge is the gold standard for pulpal exposure treatment that has succeeded. Consequently, the pulp's healing capacity and the promotion of dentin bridge creation provide an argument for applying pulp dressing material [2].

Therefore, utilizing biocompatible materials to create a favorable environment for healing pulp is a significant area of interest[2]. Over the years, various materials have been applied for pulp capping, although the ideal direct pulp capping material is still up for dispute. While calcium hydroxide has been the go-to material for pulp capping, it has numerous drawbacks, such as dissolution over time, inadequate dentin adhesion, and the development of various tunnel defects within the dentin bridge [3].

Mineral trioxide aggregate (MTA) is advocated as an alternative to calcium hydroxide because it stimulates dentin-bridge development faster, permitting pulp healing, and has shown superior clinical procedure success rates [4]. MTA is an antibacterial, bioactive, biocompatible material with excellent stability and sealing capabilities. Nevertheless, its poor handling properties, prolonged setting time, high price, and potential for discoloration are still challenges for practitioners [5].

There is growing interest in the use of natural materials in dentistry. Aloe vera, a tropical vegetation belonging to the family Liliaceae, is frequently applied for its moisturizing and pain-relieving properties in dermatology, particularly for skin burns and wounds. Additionally, it exhibits strong antiviral, antibacterial, antifungal, antioxidative, and anti-inflammatory properties [6].

Acemannan is a polysaccharide derived from Aloe vera gel. Research shows that when it comes into contact with pulp tissue, it stimulates dentin creation by promoting the proliferation and differentiation of pulp cells into odontoblast-like cells in addition to mineral deposition. As a result, it creates a dentine barrier onto the pulp tissue that has been exposed [7].

It is crucial to assess the effectiveness and efficiency of this product, as it is becoming increasingly popular in dentistry. Hence, Aloe vera could be a promising biological and cost-effective substitute to MTA for DPC. This study is designed to verify the effectiveness of Aloe vera as a direct pulp-capping material by contrasting its influence with MTA in mandibular first permanent molars. The hypothesis was that the clinical outcome of Aloe vera and MTA as DPC materials would be similar at different study intervals.

MATERIALS AND METHODS

Study design

This study was conducted as a randomized controlled clinical trial at the Clinic of the Restorative Dentistry Department, Faculty of Dentistry, Tanta University.

Ethical considerations

The study's objectives were explained to the patients, and their informed consent was obtained using the research ethics guidelines approved by the Research Ethics Committee, Faculty of Dentistry, Tanta University. Patients could choose not to participate in the study and leave it at any point.

Patients' selection

Patients of both genders aged 14 to 30 have immediate mechanical pulp exposure during class I cavity preparation in mandibular first permanent molars participated in this study. To qualify, they must meet the clinical and radiographic criteria described below.

The clinical inclusion criteria comprise teeth with normal or reversible pulpitis, with a small exposure size of less than 1mm in diameter (a pinpoint exposure). Bleeding should be controllable under pres-

sure; the patient should be in good general health without any relevant diseases, maintain good oral hygiene, have good periodontal condition, and receive proper isolation with a rubber dam. The clinical exclusion criteria include teeth with irreversible pulpitis, pulp necrosis, showing clinical signs of periodontitis, uncontrolled and excessive bleeding at the site of pulpal exposure, any uncontrolled systemic disease, pregnancy, or lactation, and any patient unable to attend follow-up visits [8].

The radiographic inclusion criteria comprise an intact lamina dura, no evidence of the periodontal ligament space expanding, radiolucency free at the furcation and periapical area, neither externally nor internally resorbing roots and neither calcification nor eradication of pulp and root canal. The radiographic exclusion criteria include the presence of external or internal root resorption, pathological periapical changes with an endodontic origin, pulp calcification, discontinuation of lamina dura, or widening of periodontal ligament space [8].

Sample size

A power calculation was conducted to determine the study sample size, which indicated that we needed 20 patients in each group. This calculation was based on previous sample size calculations from a similarly designed study [9]. The analysis was performed with a power of 84%, a confidence limit of 95%, and an accepted error of 5%, using Epi-Info software, a statistical package created by the World Health Organization and the Centers for Disease Control and Prevention in Atlanta, Georgia, USA (version 2002).

Study grouping:

Forty patients, consisting of 21 males and 19 females, were haphazardly assigned equally into two groups based on the direct pulp-capping material, with each group consisting of 20 patients:

Group I: pulp exposures were covered using Aloe vera.

Group II (control): pulp exposures were covered using MTA.

Preparation of Aloe vera:

Following Ahmed et al. [10], aloe vera was made in the labs of the Pharmacology department, Faculty of Pharmacy, Tanta University. In short, a healthy Aloe barbadensis leaf was immersed for an hour in distilled water after it was washed with 70% ethyl alcohol. After that, the green outer layer was extracted, and the gel from the aloe vera was scooped up using a spatula. By combining the extracted aloe vera gel with agar (a thickening agent) and preservatives including sorbitol, potassium sorbate, and sodium metabisulfite, a 70% aloe vera mucilage was created and kept in sterile containers.

Pulp capping procedure:

The teeth to be treated were locally anesthetized (Artinibsa, insiba, Spain) using a single-block injection. A rubber dam (Pure Latex. Health Co International, Inc., Boston, U.S.A) was placed to prevent salivary contamination and to make the restoration procedure accurate. The tooth surfaces were disinfected by rubbing them with a cotton pellet soaked in 2% chlorhexidine (Kempetro, ARE) and 75% isopropyl alcohol [11]. Pulp bleeding at the exposed area was stopped by gently applying a saline-soaked cotton pellet (Fipco, Borg El Arab, Egypt) for 5 minutes [9]. If bleeding continued, the teeth were excluded from the study otherwise, teeth were haphazardly allocated to one of two groups.

After hemostasis, in group I, a 3 mm thick Aloe vera was applied to the exposed area using a sterile amalgam carrier (Buffalo Dental Manufacturing Co., Inc. USA). Care was taken to apply the Aloe vera without putting pressure on the site. In group II, the MTA mixture (Cerkamed, Stalowa Wola, Poland) was prepared using the manufacturer's recommended ratio of 3 parts powder to 1 part water on a paper pad with a cement spatula for 30 seconds until it reached a putty-like consistency. Then, it was placed on the exposed area using a sterile amalgam

carrier and gently compacted with a wet cotton pellet. A cotton pellet soaked in saline was placed on the top of MTA to allow it to be appropriately set before removing it for cavity restoration.

Both groups' cavities were restored in a single session using a resin-modified glass ionomer liner (Ionoseal RMGIC VOCO Gmbh, Cuxhaven, Germany) and a composite resin filling material (Filtek nanohybrid bulk fill composite 3M ESPE, St. Paul, MN, USA) following the directions provided by the manufacturer. A liner was placed on the pulp-capping agent and light-cured for 20 seconds using an LED curing unit (Blue phase, Ivoclar Vivadent) with 1200 mW/cm^2 power density followed by composite resin placement that light-cured for 20 seconds. Patients did not receive any postoperative medications and were instructed to contact the operator if they experienced any pain or had any unfavorable treatment-related responses within the first week after the procedure.

Treatment assessments

Treatment assessments were conducted clinically and radiographically preoperative, immediately after treatment, 3- and 6-months postoperative. Clinical assessment involved asking patients about their symptoms and any pain they were experiencing. It also included a clinical examination and an evaluation for any draining sinuses presence. Additionally, a percussion test was accomplished by vertically tapping the tooth cusps with the end of a metal mirror handle. A thermal pulp vitality test was carried out using ice sticks frozen in an anesthetic needle cover. Ice sticks were utilized to the gingival one-third of the buccal surface, and the pulp response was evaluated as usual, pronounced, or non-existent. Pulp response was compared between the tested tooth and a control tooth.

The radiographic assessment involved taking digital periapical and bitewing radiographs with a paralleling technique using a digital radiograph device (New Life Radiology Srl, Rome, Italy) set at 60kV and 7mA. A disposable sleeve was used to protect the number 2 digital sensor. For bitewing radiographs, a Uni-Grip XCP device (Dentsply Sirona, Woodbridge, Canada) was employed, while a Troll byte plus (Troll byte plus, Dr Suni, Sweden) was used for periapical radiographs. These devices ensured standardized positioning and distance from the X-ray cone during the study.

Two experienced endodontists, who were not involved in the study, independently assessed the treated teeth at different intervals. They were not informed about the capping material used in each case. They received training before this study to determine the assessment criteria. In the event of any disagreements, they discussed with each other and came to a consensus.

The clinical assessment criteria include aberrant tooth mobility, edema or abscess, soreness to percussion, the presence or absence of spontaneous discomfort, and pulp response to the vitality test. The radiographic assessment criteria include widening the periodontal ligament space, a discontinuity in lamina dura, furcation or periapical radiolucent areas, and pathologically externally or internally resorbed root. In the successful cases, neither adverse clinical findings nor radiographic pathology were observed. In cases where one or more unfavorable clinical findings or radiographic pathology with or without negative clinical findings were observed, considered a failure, and endodontic treatment was prescribed.

Statistical analysis

Clinical and radiographic data of both groups at different intervals were collected, tabulated, and statistically analyzed at a 95 % significance level using Statistical Package for Social Sciences (SPSS Inc, Chicago, IL, US) Version 26. At different study intervals and after a 6-month follow-up, differences in clinical, radiographic, or overall success rates between the Aloe vera and MTA-treated groups were analyzed using Chi-square tests. Values of $p \leq 0.05$ were considered statistically significant.

RESULTS

In this study, 40 patients with immediate mechanical pulp exposure in mandibular first permanent molars were randomly assigned to the Aloe vera group (group I) or the MTA group (group II). After one day of treatment, three patients in the Aloe vera group and two in the MTA group experienced mild pain. After being prescribed analgesics for pain relief, none of these patients reported any further pain or adverse effects. At the 3-month follow-up, 19 patients from each group were assessed. At the 6-month follow-up, 17 patients from the Aloe vera and 18 from the MTA groups were reassessed. Five patients (three from the Aloe vera group and two from the MTA group) were lost to follow-up. 15 out of 17 patients in the Aloe vera group were successful (Figure 1). In the MTA group, 17 out of 18 patients were successful (Figure 2).

At baseline, both groups had clinical, radiographic, and overall success rates of 100% (20/20). One patient in the Aloe vera group had no symptoms at the three-month follow-up. Nonetheless, the radiographic assessment revealed periapical radiolucency and widening of periodontal ligament space. One patient in the MTA group had severe pain with percussion clinically and widening in periodontal ligament space radiographically and was recognized by irreversible pulpitis. Endodontic treatments were performed for these patients. The clinical, radiographic, and overall success rates in the Aloe vera group were 100% (19/19), 94.7% (18/19), and 94.7 % (18/19), respectively. The MTA group's clinical, radiographic, and overall success rates were 94.7% (18/19) for all rates. The chi-square test revealed no significant difference ($p > 0.05$) between the two groups in the clinical, radiographic, and overall success rates as presented in Table 1.

At 6 months post-treatment (from 3 to 6 months), one patient in the Aloe vera group was diagnosed with irreversible pulpitis due to sharp pain with percussion clinically and a radiolucent periapical area radiographically. This patient underwent endodontic treatments. The clinical, radiographic, and overall success rates of Aloe vera and MTA groups were 94.1% (16/17) and 100% (18/18) respectively for all rates. There was no significant difference ($p > 0.05$) between the two groups in the clinical, radiographic, and overall success rates as determined by the chi-square test and presented in Table 1.

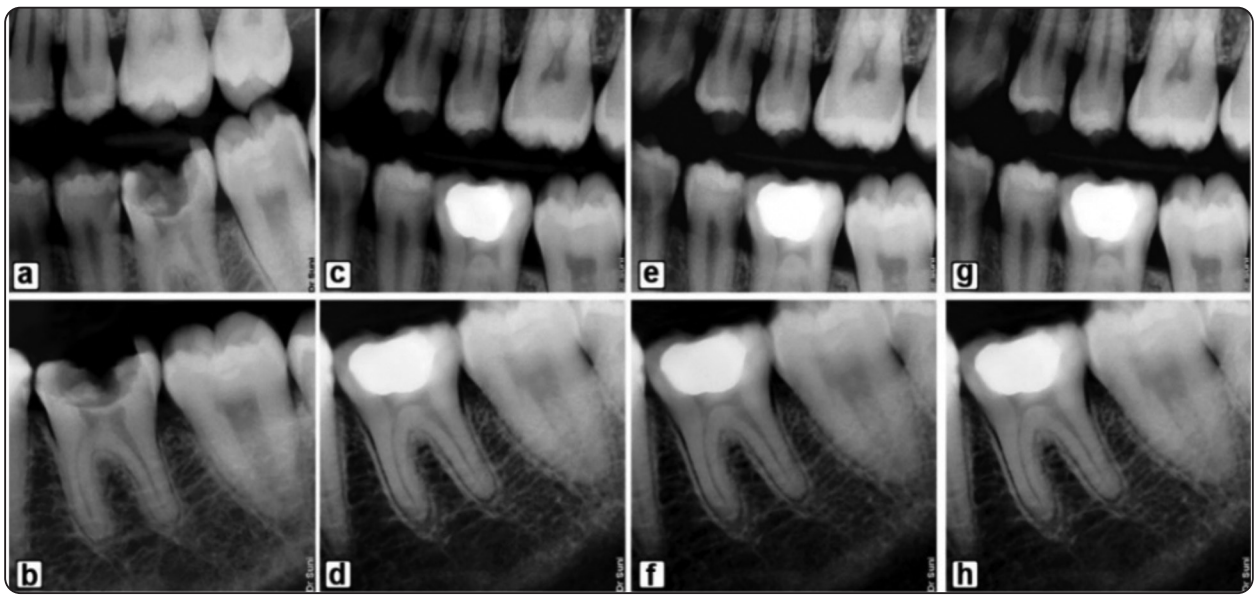

Fig. (1) Bitewing and periapical digital radiograph of the mandibular first permanent molar in the Aloe vera-treated group: (a, b) Preoperative. (c, d) Immediate postoperative. (e, f) 3 months postoperative. (g, h) 6 months postoperative.

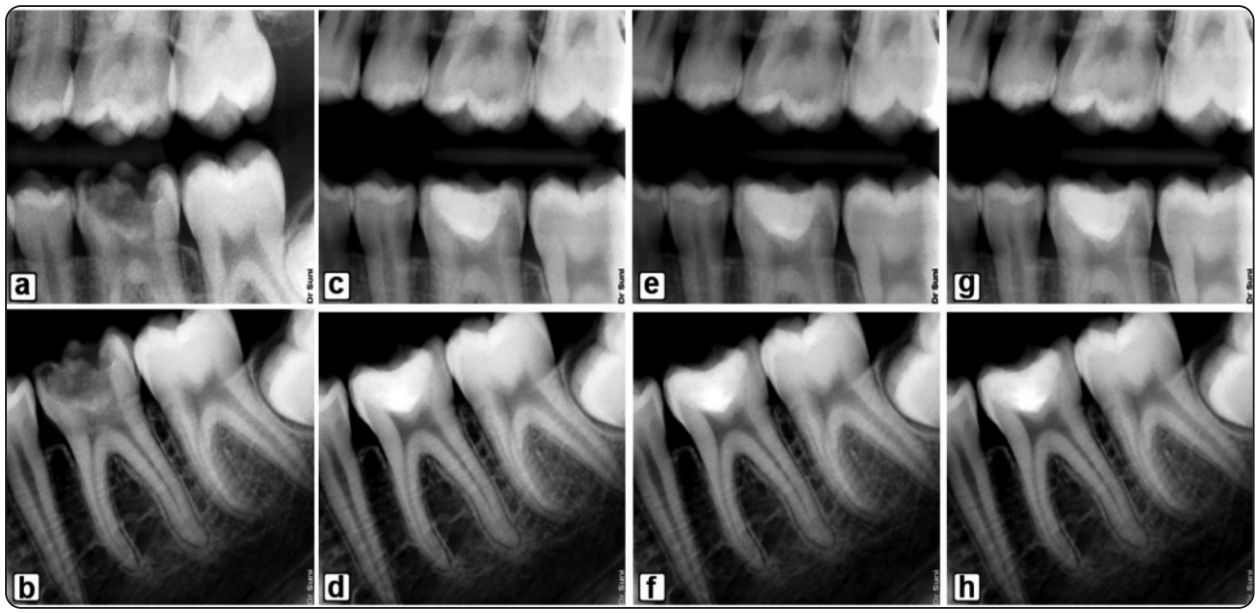

Fig. (2) Bitewing and periapical digital radiograph of the mandibular first permanent molar in the MTA-treated group: (a, b) Preoperative. (c, d) Immediate postoperative. (e, f) 3 months postoperative. (g, h) 6 months postoperative.

TABLE (1) The groups' clinical, radiographic, and overall success/failure at different study intervals.

Duration	Group	Group I (Aloe vera)		Group II (MTA)		X^2	P-value
		N	%	N	%		
At baseline	**Clinical Success**	20	100	20	100	-	-
	Clinical Failure	0	0	0	0		
	Radiographic Success	20	100	20	100	-	-
	Radiographic Failure	0	0	0	0		
	Overall success	20	100	20	100	-	-
	Overall Failure	0	0	0	0		
After 3 months	**Clinical Success**	19	100	18	94.7	1.032	0.311
	Clinical Failure	0	0	1	5.3		
	Radiographic Success	18	94.7	18	94.7	0.0	1.0
	Radiographic Failure	1	5.3	1	5.3		
	Overall success	18	94.7	18	94.7	0.0	1.0
	Overall Failure	1	5.3	1	5.3		
After 6 months	**Clinical Success**	16	94.1	18	100	0.234	0.891
	Clinical Failure	1	5.9	0	0		
	Radiographic Success	16	94.1	18	100	1.087	0.296
	Radiographic Failure	1	5.9	0	0		
	Overall success	16	94.1	18	100	1.087	0.296
	Overall Failure	1	5.9	0	0		

The final clinical, radiographic, and overall success rates in the Aloe vera group from baseline to the 6-month follow-up were 94.1% (16/17), 88.2% (15/17), and 88.2% (15/17), respectively. While in the MTA group, these rates were 94.4% (17/18). There were no significant differences in the final clinical, radiographic, and overall success rates between the two groups ($p > 0.05$), as indicated by the chi-square test and presented in Table 2 and Figures 3, and 4. This finding denotes that "Aloe vera was effective as MTA when used as a DPC material."

TABLE (2) The groups' final clinical, radiographic, and overall success/failure after 6-month follow-up

Final success		Group I (Aloe vera)		Group II (MTA)		X2	P-value
		N	%	N	%		
Clinical success	**Success**	16	94.1	17	94.4	0.012	0.967
	Failure	1	5.9	1	5.6		
Radiographic success	**Success**	15	88.2	17	94.4	0.432	0.512
	Failure	2	11.8	1	5.6		
Overall success	**Success**	15	88.2	17	94.4	0.432	0.512
	Failure	2	11.8	1	5.6		

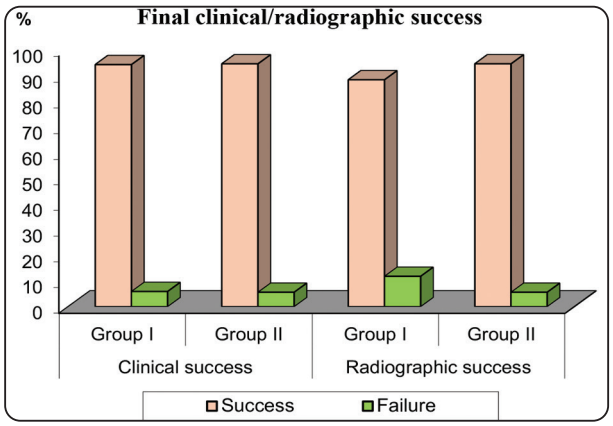

Fig. (3) Bar chart showing final clinical and radiographic success/failure of both groups after 6-month follow-up

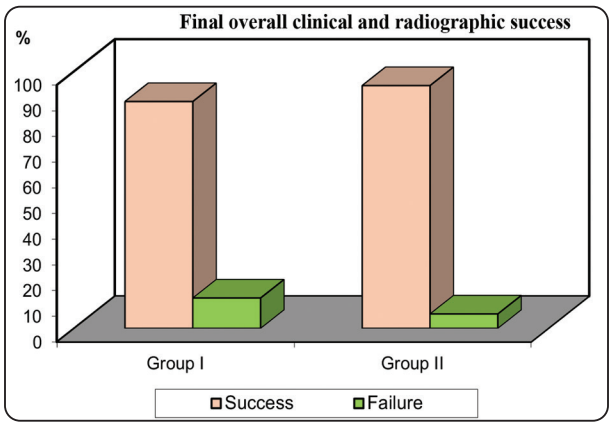

Fig. (4) Bar chart showing final overall success/failure of both groups after 6-month follow-up

DISCUSSION

The DPC procedure aims to heal the reversibly destroyed pulp by encouraging the development of a dentine bridge that restores the pulp-dentin complex's structure and functionality [12]. The formation of the dentine bridge is crucial for complete recovery and sustained success. It prevents oral bacteria from reattaching the exposed pulps, which could otherwise lead to pulp degeneration, atrophy, and shrinkage [13].

MTA is a preferable option for DPC to the continued use of calcium hydroxide as the gold standard material for pulp capping procedures. MTA, the first calcium silicate material introduced, has a few drawbacks, including extended setting time, handling challenges, and tooth discoloration [14-16].

Attempting to address the existing dental biomaterials shortcomings, the application of herbal compounds in dentistry has grown recently, with various plant-based products evaluated for their effects [17]. Aloe vera, scientifically known as Aloe barbadensis miller, has long been used as a natural remedy for treating soft tissue injuries such as burns and wounds. Acemannan, a polysaccharide extracted from Aloe barbadensis gel, is recognized for its compatibility with living cells and ability to promote wound healing [18].

Therefore, this study compared the clinical and radiographic effectiveness of Aloe vera as a direct pulp-capping agent with the current gold standard—mineral trioxide aggregate (MTA) in mandibular first permanent molar with immediate mechanical pulp exposure at various intervals (baseline, 3, 6 months postoperative).

Mandibular first molars were chosen for this study because they are the most prevalent teeth necessitating vital pulp therapy, as caries often develop shortly after the molars erupt into the oral cavity [19]. The occlusal surfaces of these molars are more prone to dental caries due to incomplete maturation after erupting, fewer minerals in the enamel, and the narrow, deep grooves on the occlusal surfaces that harbor bacteria and institute the caries process [20].

Pulp capping's effectiveness in Class I restorations might be attributed to the marginal seal's influence and the subsequent reduction or avoidance of microleakage [21,22]. The margin length of the tooth-restoration interface may explain this influence, as a more extended margin is associated with a greater risk of microbial invasion from the oral cavity to the pulp chamber [23].

The pulp exposure type impacts the success rate of DPC procedures. If the pulp exposure results from mechanical reasons, the long-term success rate is almost 100%. However, if the pulp exposure is due to caries and becomes contaminated with bacteria, it is assumed to result in inflammation and has a lower chance of success [24]. So, the mechanical pulp exposure during class I cavity preparation was selected in the present study.

The patient's age may also affect the survival rate after DPC. Most of the patients in this study were between 14 and 30 years old. DPC is known to be more successful in young individuals, as they have a high cell population in the pulp, which offers the best conditions for healing [25-27]. Many studies have noted a higher success rate in patients younger than 40 than older patients [24, 28, 29]. Nevertheless, other studies failed to support the idea that age affects whether pulp-capped teeth succeed or fail [26,30].

The rubber dam was applied during pulp capping procedures to avoid microbial contamination of the pulp tissue. Preventing microorganisms from entering the pulp is crucial for successful direct capping [31]. Permanent restorations were used in DPC procedures as they had a higher success rate than temporary restorations [32]. Using adhesive restorative materials as definitive restorations minimizes tooth reduction, promotes anatomic preservation, and provides better pulpal protection and repair potential [33].

It's unknown how long is required for sufficient postoperative follow-up. Matsuo et al. [30] reported that a three-month interval was suitable for a tentative prognosis because the group's success rates with postoperative follow-up periods ranging from three to eighteen months were comparable. Moreover, previous studies [11,34,35] experienced less than four-month postoperative follow-up periods. Additionally, Jang et al. [28] proposed that most failures develop in the first three months despite their study's six-month recall time. Consequently, the short follow-up duration noted in our study was adequate for making a tentative prognosis.

Based on our findings of clinical and radiographic assessment, the null hypothesis of this study cannot be rejected since the Aloe-vera-treated group showed a success rate comparable to that of the MTA-treated group, with no statistically significant

differences between groups at different study intervals. This could be explained by the capacity of these materials to form a reparative dentin which protects the underlying pulp tissues and preserves their vitality when applied as a DPC agent [18,36].

The Aloe vera-treated group showed 88.2% success rate. This success rate may be due to Aloe vera's biocompatibility and strong antibacterial and anti-inflammatory qualities that help in reparative dentin creation. Treatment of human papillary cells with aloe vera can result in the expression of dentin saliva protein, vascular endothelial growth factor, type I collagen, alkaline phosphatase, BMP-2, BMP-4, dental pulp cells proliferating, and mineralization [18, 37, 38].

Other studies by Songsiripradubboon et al. [39] and Elhag et al.[9] revealed a less direct pulp capping success rate with Aloe vera than ours. Their success rates were 72.73% and 77.8% respectively. This disparity in results could be attributed to the variation in the type of pulp exposure in their studies. They investigated teeth with pathological pulp exposure, whereas the teeth in our investigation had traumatic pulp exposure.

On the other hand, the MTA-treated group had a success rate of 94.4%. This high success rate could be due to MTA's capacity to encourage dentin bridge production, antibacterial characteristics, and superior sealing capacity, which are essential to the DPC procedure's success [40]. MTA also enables human osteoblasts to adhere well to the material and increases their production of cytokines, therefore actively contributing to the production of dentin bridges [41].

Additionally, MTA has approvingly physiochemical characteristics that promote the production of reparative dentin by attracting and activating cells that form hard tissues, aiding in matrix formation and mineralization [42]. Additionally, MTA can decrease pulp inflammation, hyperemia, and necrosis levels. It can also dissolve bioactive proteins that play a role in tooth repair [27, 43, 44]. Other studies by Kermanshah et al.[45], and Hegde et al.[46] showed 93% and 91.7% success rates of MTA as a direct pulp capping respectively. These rates were approximately agreed with our study.

We suggest that the failed cases in both groups (11.8% and 5.6% respectively) may be due to previous inflammation in these cases before treatment without any discernible clinical symptoms of such inflammation. The postoperative pain is probably an indication that this inflammation aggravates after treatment as explained by Caicedo et al [8]. Other causes of this failure may be due to microleakage, and poor sealing [47].

A meager failure rate for both groups in this study indicated that both materials were effective for DPC. Aloe vera could be a cost-effective alternative to MTA for vital pulp therapy. However, additional clinical research is still required to affirm the biocompatibility and efficiency of Aloe vera as a pulp-capping material over a longer period.

CONCLUSIONS

Aloe vera and MTA are favorable materials for DPC and could preserve the dental pulp vitality. Aloe vera is a promising pulp-capping material that offers good clinical outcomes compared to MTA, despite MTA offering superior clinical and radiographic outcomes.

REFERENCES

1. Parirokh M, Asgary S, Eghbal MJ, Kakoei S, Samiee M. A comparative study of using a combination of calcium chloride and mineral trioxide aggregate as the pulp-capping agent on dogs' teeth. J Endod 2011; 37:786-788.

2. Fuks AB, Guelmann M, Kupietzky A. Pulp therapy for the primary dentition. In: al C, editor. Pediatric dentistry infancy through adolescence. St Louis, Missouri: Elsevier Saunders 2013; 3:333-351.

3. Seltzer S, Bender IB, Ziontz M. The dynamics of pulp inflammation: Correlations between diagnostic data and actual histologic findings in the pulp. Oral Surg Oral Med Oral Pathol 1963; 16: 969-977.

4. Eskandarizadeh A, Shahpasandzadeh MH, Shahpasandzadeh M, Torabi M, Parirokh M. A comparative study on dental pulp response to calcium hydroxide, white and grey mineral trioxide aggregate as pulp capping agents. J Conserv Dent 2011; 14: 351-355.
5. Parirokh M, Torabinejad M. Mineral trioxide aggregate: A comprehensive literature review – Part I: Chemical, physical, and antibacterial properties. J Endod 2010; 36:16-27.
6. Mangaiyarkarasi SP, Manigandan T, Elumalai M, et al. Benefits of Aloe vera in dentistry. J Pharm Bioallied Sci 2015; 7: S255-S259.
7. Abirami K, Ramkumar H, Senthil D. Clinical and Radiographic Assessment of the Efficacy of Formocresol, Allium sativum Oil, and Aloe barbadensis Gel as Pulpotomy Medicaments in Primary Molars: A Randomized Controlled Trial. Int. J Clin Pediatr Dent. 2020; 13: 518-522.
8. Caicedo R, Abbott PV, Alongi DJ, Alarcon MY. Clinical, radiographic, and histological analysis of the effects of mineral trioxide aggregate used in direct pulp capping and pulpotomies of primary teeth. Aust Dent J. 2006; 51: 297-305.
9. Elhag AM, El-Bayoumy SY, Eisa AA. Clinical and radio, graphic evaluation of acemannan as direct pulp capping material in young permanent teeth. AJDS 2020; 23: 415-421.
10. Ahmed SS, Gadalla LM, Elmeadawy SH and Badria F. The Efficacy of Aloe vera Gel in Treatment of Oral Lichen Planus. Int. dent. med. j. adv. res. 2018; 4: 1–6.
11. Song M, Kang M, Kim HC, Kim E. A randomized controlled study of the use of ProRoot mineral trioxide aggregate and Endocem as direct pulp capping materials. J Endod 2015; 41:11-15.
12. Parolia A, Kundabala M, Rao NN, Acharya SR, Agrawal P, Mohan M, et al. A comparative histological analysis of human pulp following direct pulp capping with propolis, mineral trioxide aggregates, and Dycal. Aust Dent J 2010; 55: 59-64.
13. Stanley HR. Criteria for standardizing and increasing credibility of direct pulp capping studies. Am J Dent 1998; 11: S17-S34.
14. Valles M, Mercade M, Duran-Sindreu F, et al. Influence of light and oxygen on the color stability of five calcium silicate-based materials. J Endod 2013; 39: 525–528.
15. Valles M, Mercade M, Duran-Sindreu F, et al. Color stability of white mineral trioxide aggregate. Clin Oral Investig 2013; 17: 1155–1159.
16. Marciano MA, Costa RM, Camilleri J, et al. Assessment of color stability of white mineral trioxide aggregate angelus and bismuth oxide in contact with tooth structure. J Endod 2014; 40: 1235–1240.
17. Ghasemi N, Behnezhad M, Asgharzadeh M, Zeinalzadeh E, Kafil HS. Antibacterial Properties of Aloe vera on Intracanal Medicaments against Enterococcus faecalis Biofilmat Different Stages of Development. Int J Dent. 2020; 2020: 8855277.
18. Jittapiromsak N, Sahawat D, Banlunara W, et al. Acemannan, an extracted product from Aloe Vera, stimulates dental pulp cell proliferation, differentiation, mineralization, and dentin formation. Tissue Eng Part A 2010; 16: 1997–2006.
19. Ferreira Zandoná A, Santiago E, Eckert G, Katz B, Pereira de Oliveira S, Capin O, *et al*. The natural history of dental caries lesions: a 4-year observational study. J Dent Res 2012; 91:841–846.
20. Carvalho JC, Van Nieuwenhuysen JP, D'hoore W. The decline in dental caries among Belgian children between 1983 and 1998. Community Dent Oral Epidemiol 2001; 29: 55-61.
21. Al-Hiyasat AS, Barrieshi-Nusair KM, Al-Omari MA. The radiographic outcomes of direct pulp-capping procedures performed by dental students: a retrospective study. J Am Dent Assoc (1939) 2006; 137:1699-1705.
22. Sitaru A, Monea M, Monea A. Clinical and Radiographic Evaluation of Direct Pulp Capping Procedures in Permanent Teeth. Acta Med Marisiensis 2011;57: 244-246.
23. Horsted P, Sandergaard B, Thylstrup A, El Attar K, Fejerskov O. A retrospective study of direct pulp capping with calcium hydroxide compounds. Endod Dent Traumatol 1985; 1:29-34.
24. Cho SY, Seo DG, Lee SJ, Lee J, Lee SJ, Jung I-Y. Prognostic factors for clinical outcomes according to time after direct pulp capping. J Endod 2013; 39: 327-331.
25. Barthel CR, Rosenkranz B, Leuenberg A, Roulet JF. Pulp capping of carious exposures: treatment outcome after 5 and 10 years: a retrospective study. J Endod 2000; 26: 525-528.
26. Mente J, Hufnagel S, Leo M, Michel A, Gehrig H, Panagidis D, et al. Treatment outcome of mineral trioxide aggregate or calcium hydroxide direct pulp capping: long-term results. J Endod 2014; 40: 1746-1751.
27. Marques MS, Wesselink PR, Shemesh H. Outcome of direct pulp capping with mineral trioxide aggregate: a prospective study. J Endod 2015; 41: 1026-1031.

28. Jang Y, Song M, Yoo IS, Song Y, Roh BD, Kim E. A Randomized Controlled Study of the Use of ProRoot Mineral Trioxide Aggregate and Endocem as Direct Pulp Capping Materials: 3-month versus 1-year Outcomes. J Endod 2015; 41: 1201-1206.

29. Lipski M, Nowicka A, Kot K, Postek-Stefanska L, Wysoczanska- Jankowicz I, Borkowski L, et al. Factors affecting the outcomes of direct pulp capping using Biodentine. Clin Oral investig 2018; 22: 2021-2029.

30. Matsuo T, Nakanishi T, Shimizu H, Ebisu S. A clinical study of direct pulp capping applied to carious-exposed pulps. J Endod 1996; 22: 551-556.

31. Dammaschke T. A new bioactive cement for direct pulp capping. Int Dent-Aust ed. 2012; 7: 52-58.

32. Pashley DH. Dynamics of the pulpo-dentin complex. Crit Rev Oral Biol Med 1996; 7: 104-133.

33. Gwinnett AJ, Tay FR, Pang KM, Wei SH. Quantitative contribution of the collagen network in dentin hybridization. Am J Dent 1996; 9: 140-144.

34. Moritz A, Schoop U, Goharkhay K, Sperr W. Advantages of a pulsed CO2 laser in direct pulp capping: a long-term in vivo study. Lasers Surg Med 1998; 22: 288-293.

35. Accorinte Mde L, Holland R, Reis A, Bortoluzzi MC, Murata SS, Dezan E, Jr., et al. Evaluation of mineral trioxide aggregate and calcium hydroxide cement as pulp-capping agents in human teeth. J Endod 2008;34 :1-6.

36. Min KS, Park HJ, Lee SK, et al. Effect of mineral trioxide aggregate on dentin bridge formation and expression of dentin sialoprotein and heme oxygenase-1 in human dental pulp. J Endod2008; 34: 666–6670.

37. Boonyagul S, Banlunara W, Sangvanich P, Thunyakitpisal P. Effect of acemannan, an extracted polysaccharide from Aloe vera, on BMSCs proliferation, differentiation, extracellular matrix synthesis, mineralization, and bone formation in a tooth extraction model. Odontology. 2014; 102: 310-317.

38. Songsiripradubboon S, Kladkaew S, Trairatvorakul C, Sangvanich P, Soontornvipart K, Banlunara W, et al. Stimulation of Dentin Regeneration by Using Acemannan in Teeth with Lipopolysaccharide-induced Pulp Inflammation. Journal of Endodontics. 2017; 43: 1097-1103.

39. Songsiripradubboon S, Banlunara W, Sangvanich P, Trairatvorakul C, Thunyakitpisal P. Clinical, radiographic, and histologic analysis of the effects of acemannan used in direct pulp capping of human primary teeth: short-term outcomes. Odontology. 2016; 104: 329-337.

40. Koh ET, McDonald F, Pitt Ford TR, Torabinejad M. Cellular response to mineral trioxide aggregate. J Endod 1998; 24: 543-547.

41. Grech L, Mallia B, Camilleri J. Investigation of the physical properties of tricalcium silicate cement-based root-end filling materials. Dent Mater 2013; 29: e20-e28.

42. Okiji T, Yoshiba K. Reparative dentinogenesis induced by mineral trioxide aggregate: a review from the biological and physicochemical points of view. Int J Dent 2009; 2009: 464280.

43. Nair PNR, Duncan HF, Pitt Ford TR, Luder HU. Histological, ultrastructural and quantitative investigations on the response of healthy human pulps to experimental capping with mineral trioxide aggregate: a randomized controlled trial. Int Endod J 2008;2008(41):128–150.

44. Tomson PL, Grover LM, Lumley PJ, Sloan AJ, Smith AJ, Cooper PR. Dissolution of bio-active dentine matrix components by mineral trioxide aggregate. J Dent 2007; 35:636–642.

45. Kermanshah H, Ranjbar Omrani L, Ghabraei S, Fekrazad R, Daneshparvar N, Bagheri P. Direct Pulp Capping With ProRoot MTA Alone and in Combination With Er:YAG Laser Irradiation: A Clinical Trial. J Lasers Med Sci. 2020;11: S60-S66.

46. Hegde S, Sowmya B, Mathew S, Bhandi SH, Nagaraja S, Dinesh K. Clinical evaluation of mineral trioxide aggregate and biodentine as direct pulp capping agents in carious teeth. J Conserv Dent. 2017; 20: 91-95.

47. Trope M. Root resorption due to dental trauma. Endodontic topics. 2002; 1: 79-100.