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ORIGINAL ARTICLE

A Prospective-Randomized Study: The Impact of Four Different Caries Removal Method on Pain and Clinical Evaluations

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ABSTRACT

Objective: There are many different methods for removing caries. In this study, to evaluate four caries removal methods in terms of patient comfort and to evaluate the clinical success of restorations according to modified-USPHS criteria. **Methods:** In 31 patients with at least 4 Class II caries in their posterior teeth, 4 teeth were randomly divided into four groups and 4 different methods (conventional method, Carisolv, Papacarie, Er-Cr:YSGG Laser) were used for caries removal. Pain formation during caries removal was determined by FACE Pain Scale questionnaire. The restorations were controlled with Modified-USPHS criteria in 3-6-12 months period. Mann-Whitney U test for two-group comparisons, Kruskal Wallis H test for comparison of three or more groups, Wilcoxon Sign test was used to examine the changes according to time ($p < 0.05$). **Results:** A significant difference was found between conventional methods and alternative methods in terms of pain tolerance. In the 1-year clinical evaluation of the restorations, there was a significant decrease in the postoperative sensitivity in all groups. A significant difference was detected in Carisolv and laser groups between 6-months and 12-months for marginal coloration. A significant difference was found between the conventional and laser groups between 6-months and 12-months in terms of color match. **Conclusion:** The success of restorations, efficacy and efficiency of the methods used in the evaluation of all groups were found to be successful. In terms of patient comfort, all alternative methods gave positive results.

Key words: caries removal, carisolv, Er-Cr:YSGG laser, FACE Pain Scale, papacarie

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INTRODUCTION

Caries is one of the most common chronic diseases that patients often avoid or delay treatment because it is thought to be frightening to treat. Rotary instrument is generally used for caries removal. However, these instruments are uncomfortable by patients, they also require local anesthesia to control pain. And they have adverse effects on the pulp caused by the heat and pressure they create.[1] Dentin caries can be divided into two distinct layers. The outer layer is contaminated by bacteria causing a non-remineralisable necrotic collagen matrix. In the inner layer, bacteria are much less frequently observed and the collagen has been reversibly denatured, but retains the crossbanded ultrastructure.[2] With conventional burs or sharp hand instruments, it is often difficult to differentiate accurately between these two layers, and mechanical caries excavation may have the disadvantage of leaving residual caries or over-excavation of sound tooth structure.[3] Therefore, alternative caries removal methods have been developed to eliminate the negative effects of conventional methods. Some of these methods; hand excavation, air-abrasion, air-polishing, ultrasonication, sonoabrasion, lasers, and chemomechanical methods.[4]

The agents used in caries removal by chemomechanical method are divided into two as sodium hypochlorite and enzyme based.[5] One of the major advantages of chemomechanical methods is undesirable removal of sound dentin is avoided and the need for local anesthesia is less.[5] In 1998, Mediteam in Sweden introduced Carisolv system which consists of a gel with amino acids (lysine, leucine and glutamic acid) and sodium hypochlorite, and special hand instruments.[5] Papacarie, another chemomechanical caries removal (CMCR) reagent was introduced in Brazil in 2003. Papacarie Duo was developed in 2011 with the improvement of Papacarie shelf life, viscosity, and

absence of cold chain. It contains papain, the basic component of Papacarie Duo, is responsible for its bactericidal, bacteriostatic and anti-inflammatory properties. Ease of application and no need for special devices is the added advantage.[6]

The Er,Cr:YSGG laser can be used for caries removal, when its wavelength (2.78 μm) coincides with the peak of water absorption and hydroxyl radicals of hydroxyapatite. This promotes the effective ablation of the carious tissue via microexplosions from the evaporation of the water contained in the mineralized tissue.[7] The Er,Cr:YSGG laser provides a conservative treatment in caries removal because of the high absorption in the moist caries tissue.[8] Moreover, Erbium lasers have a bactericidal effect on caries tissue with their thermal effects.[9]

The null hypotheses of this study were as follows: (1) the evaluated caries removal methods are not different when compared in terms of patient comfort; (2) the restorations performed with the evaluated caries removal methods are not different in terms of clinical success.

There were conflicting results about the efficacy of the removal methods in the literature. However, no differences were reported in efficacy in Carisolv versus conventional and conventional versus Er, Cr: YSGG laser, discomfort rate was significantly higher in Er, Cr: YSGG laser. On the other hand, to the best of our knowledge, the comparison of four removal methods was not reported before.[10] This study aims to evaluate four different methods (Carisolv, Papacarie Duo, Er,Cr:YSGG laser, and the conventional method) in terms of patient comfort and to determine the clinical success of restorations performed according to the modified United States Public Health Service (USPHS) criteria.

METHODS

This was a prospective, open, randomised and controlled study. Consecutive patients at the Faculty of Dentistry, Kırıkkale University, who are between the ages of 18-40 and presented at least four active proximal carious lesion in a vital tooth at the routine examination were asked to enter the study. Informed consent was obtained prior to the start. The study had been approved by the Ethics Committee at Kırıkkale University (No:03/04).

The pretreatment examination involved a medical history, a clinical examination with a dental mirror, and explorer and radiographs.

The steps of the study were as follows: a pre-treatment examination, informed consent, randomization, caries removal, cavity inspection, restoration, and a patient interview. All treatments were performed by the main investigator (M.A.). In the study, 124 teeth, 31 patients and 4 teeth in each patient were evaluated. Teeth included in the study which with contralateral teeth were present and without amalgam, glass ionomer or composite resin restoration. Morever, in radiological examination, premolar and molar teeth that were distance from 1 mm to the pulp are included in the study. Teeth were excluded if they clinically presented tooth pain, spontaneous sensitivity or if periapical radiolucencies, increased periodontal space or internal/ external dental reabsorption. After the teeth were identified, they were distributed to 4 groups.

Caries removal

Group 1 (Carisolv): Carisolv gel (MediTeam Dental AB, Gothenburg, Sweden) was used for the process of caries removal. Before the treatment, no rubber dam was used. Isolation was done with cotton rolls. To reach the carious dentine, the enamel tissue on it was removed by the conventional method. Then, the dentin caries was first covered with the Carisolv gel. After 30 s, the carious dentin was gently scraped with hand instruments to remove softened carious tissue. A special hand instrument (MediTeam Dental AB, Gothenburg, Sweden) fit for the dimension and availability of the cavity was chosen and the softened carious dentin on the surface was scraped. When the gel becomes heavily contaminated with debris, it was removed with cotton pellets and more fresh gel was applied. The procedure was repeated until the gel was no longer contaminated with debris. After complete caries removal, the remaining gel was removed with wet and dry cotton pellets.

Group 2 (Papacarie Duo): To reach the carious dentine, the enamel tissue on it was removed by the conventional method. The carious cavity was first filled with papain gel Papacarie Duo® (Fórmula and Ação (F and A), São Paulo (SP) –Brazil). After 30 to 40 sec, softened decayed dentin was scraped using opposite side of the excavator. The procedure was repeated until a light color was observed but the cavity was not washed between the gel applications. At the end of the procedure, the remaining gel was removed with a cotton-pellet soaked in water.

Group 3 (Er,Cr:YSGG Laser): An Er,Cr:YSGG laser (Waterlase, Biolase, USA) was used for cavity preparation. The laser parameters were: wavelength 2.78 μm, pulse frequency 20 Hz, pulse duration 140 μs, sapphire fibre diameter 400 μm, tip to target distance 1.5 to 2 mm. For enamel and dentine cutting, the manufacturer's recommended settings were used, namely, for enamel 5.5 W power, 275 mJ/ pulse, 95% air flow, 80% water flow, and for dentine 3.5 W power, 175 mJ/pulse, 75% air flow, and 65% water flow. During laser irradiation, the operators and assistants wore protective eyeglasses.

Group 4 (Conventional Method): In the control group, the caries removal was performed using spherical steel drills ISO No:12-14-16, which were compatible with the cavity size, mounted in low-speed turbines under water cooling. When necessary, access to the carious lesion (removal of the cavosurface enamel) was performed using spherical diamond burs ISO No:001/010 which were also compatible with the cavity and which were mounted in high-speed turbines.

Evaluation of caries excavation

Irrespective of the removal method used, each cavity was checked by the operator for remaining caries by using an explorer. The completeness of the clinical caries removal was assessed based on the following clinical criteria: the explorer should not stick to the dentin, no tug-back sensation must be observed, and the cavity must be stain-free. If carious dentin is still present, the procedure was repeated. In addition, the postoperative DIAGNOdent pen value was obtained, a procedure that served as an adjunct method. The post-operative cut-off value for a sound tissue was set at 30.[11,12]

Evaluation of pain

Patients were asked to choose a score from the FACES Pain Assessment Scale in order to describe their pain levels after caries removal with the evaluated methods among groups. Their scores were requested after the treatment of each tooth. The options included "no pain," "little pain," "some pain," "pronounced pain," "serious pain," and "unbearable pain." It was also recorded whether the patient requested local anesthesia during caries removal.

Restoration

To restore the cavity, a composite system using dentine bonding (Clearfil SE Bond, Kuraray, Japan) and the application of composite (Clearfil Majesty Posterior, Kuraray, Japan) was used, according to the manufacturer's instructions.

Evaluation of restoration

The status of the restorations at 3, 6 and 12 months was independently examined by two calibrated authors (M.A. and E.KT) using the modified United States Public Health Service (USPHS) criteria.[13] The inter-examiner reproducibility was measured and expressed as kappa = 0.91.

Statistical analysis

In the comparison of quantitative data, it was observed that Kolmogorov-Smirnov test was not suitable for normal distribution, and nonparametric tests were carried out since parametric conditions were not provided. Mann-Whitney U test was used in two-group comparisons, the Kruskal Wallis H test was used to compare three or more groups, and the Wilcoxon Sign test was used to look for changes over time. Statistical analysis was performed using SPSS software for Windows, version 24.0 (SPSS Inc., Chicago, IL, USA).

Table 1. Materials used in the study.

Material	Material Composition
Carisolv	Glutamic acid, leucine, lysine, carboxymethylcellulose, erythrosine, sodium hypochloride, sodium chloride/ sodium hydroxide
Papacarie Duo	Papain, chloramine, toluidine blue, preservatives, salts, stabilizers, thickener, deionised water
Clearfill Majesty Posterior	Organic matrix: Bis-GMA, TEGDMA, Hydrophobic aromatic dimethacrylate, camphoroquinone, accelerators Fillers: Silanated glass ceramics, Surface treated alumina microfillers
Clearfill SE Bond	Primer:10-Metakriloksidesildihidrojen fosfat (MDP), 2-Hidroksietil metakrilat (HEMA), dl-kamforokinon, hidrofilik dimetakrilat, su, N,N-dietanol-p-tolidin (pH=1,9) Bond: Metakriloksidesildihidrojenfosfat (MDP), 2-Hidroksietil metakrilat (HEMA), Bisfenol A diglisidil metakrilat (Bis-GMA), Hidrofobikdimetakrilat, dl kamforokinon, N,N-dietanol-p-tolidin, Silanlanmış kolloidal silika

RESULTS

The FACES Pain Assessment Scale was applied to measure the pain sensation of patients during caries removal. Conditions that required local anesthesia were scored with 5 points. Considering all groups, it was found that the method causing the least pain was the laser method, while the most pain was caused by the conventional method (Table 2). Evaluating the degree of pain among the groups, a significant difference was found in terms of pain tolerance for all three other groups compared to the conventional method. No significant difference was found between the other groups as a result of binary comparisons (Table 3).

Individuals participating in the study were invited to control examinations 3, 6, and 12 months later to evaluate the performed restorations. These control examinations were performed by two experienced dentists, calibrated with each other (Cohen kappa index = 0.91). The McNemar test was used to measure the compatibility between the examiners and no differences were found between the examiners for all control criteria. Analyses were conducted using the highest scores among the two examiners' results. The modified USPHS criteria were used to evaluate the restorations (Table 4).

Table 2. Distribution of patients' responses to the FACES Pain Assessment.

Score	Conventional	Carisolv	Papacarie Duo	Laser
No Pain	0	6	7	1
Little Pain	1	9	11	21
Some Pain	2	10	8	5
Pronounced Pain	11	3	3	3
Serious Pain	10	0	0	0
Unbearable Pain	17	3	2	1

Table 3. Intergroup comparison of FACES Pain Assessment score.

Comparison of methods	p	Comparison of methods	p
Carisolv-Conventional	0.000*	Papacarie Duo - Carisolv	0.507
Papacarie Duo - Conventional	0.000*	Laser - Carisolv	0.469
Laser - Conventional	0.000*	Laser - Papacarie Duo	0.903

p-values by Wilcoxon matched-pairs signed-rank test for multiple group comparisons

None of the restorations were lost due to retention**.** Retention rates of all groups were determined as 100% in 12-month controls. According to the data at all control times, there was no statistically significant inter-group and in-group difference in terms of retention criteria depending on the time ($p > 0.05$).

When evaluated clinically in terms of marginal discoloration, there was no significant difference between time in conventional and Papacarie Duo groups. In the Carisolv and Laser groups, there was no significant difference in the first 6-month period, but at the end of 1 year, a significant difference was found in terms of marginal discoloration. However, this difference is due to Bravo scores that are clinically successful (Table 6).

According to the 3-month data, there was a significant difference between only the Papacarie Duo and laser groups in the evaluation between the groups in terms of marginal discoloration. ($p = 0.040$) There was no statistically significant difference between the groups in terms of marginal discoloration at 6 months. In 12 months, in terms of marginal discoloration, a significant difference was found between conventional and laser ($p = 0.048$) and Papacarie Duo and laser groups (0.021) (Table 6).

Table 4. Modified USPHS criteria.

Category	Score	Criteria
Retention	Alfa (A)	Without loss of restorative material
	Charlie (C)	With loss of restorative material
Marginal discoloration	Alfa (A)	There is no discoloration anywhere on the margin between the restoration and the tooth structure
	Bravo (B)	Discoloration is present but has not penetrated along the margin in a pulpal direction
	Charlie (C)	Discoloration has penetrated along the margin in a pulpal direction
Marginal adaptation	Alfa (A)	There is no visible evidence of a crevice along the margin into which the explorer will penetrate
	Bravo (B)	There is visible evidence of a crevice along the margin into which the explorer will penetrate or catch
	Charlie (C)	The explorer penetrates the crevice, and dentin or base is exposed
Color match	Alfa (A)	Restoration matches adjacent tooth structure in color, shade, or, translucency
	Bravo (B)	There is a mismatch in color, shade, or translucency but within the normal range of adjacent tooth structure
	Charlie (C)	There is a mismatch in color, shade, or translucency outside of the normal range of adjacent tooth structure
Seconder Caries	Alfa (A)	No caries is present at the margin of the restoration, as evidenced by softness, opacity, or etching at the margin
	Charlie (C)	There is evidence of caries at the margin of the restoration
Post-Operative Sensitivity	Alfa (A)	No post-operative sensitivity
	Bravo (B)	There is mild and temporary postoperative sensitivity
	Charlie (C)	There is a strong and intolerable postoperative sensitivity
Anatomic form	Alfa (A)	The restoration is continuous with existing anatomic form
	Bravo (B)	The restoration is discontinuous with existing anatomic form, but missing materials are not sufficient to expose dentin or base
	Charlie (C)	Sufficient restorative material is missing to expose the dentin or base

Table 5. Status of Modified USPHS criteria values of caries removal methods.

Criteria	time	Conventional			Carisolv			Papacarie Duo			Laser		
		A	B	C	A	B	C	A	B	C	A	B	C
Retention	3	31	-	-	31	-	-	31	-	-	31	-	-
	6	31	-	-	31	-	-	31	-	-	31	-	-
	12	31	-	-	31	-	-	31	-	-	31	-	-
Marginal discoloration	3	28	3	-	24	7	-	29	2	-	23	8	-
	6	26	5	-	21	10	-	27	4	-	21	10	-
	12	26	5	-	20	11	-	27	4	-	19	12	-
Marginal adaptation	3	31	-	-	31	-	-	31	-	-	31	-	-
	6	31	-	-	30	-	1	31	-	-	31	-	-
	12	31	-	-	29	-	2	31	-	-	31	-	-
Color match	3	31	-	-	30	1	-	31	-	-	30	1	-
	6	31	-	-	29	2	-	31	-	-	28	3	-
	12	31	-	-	29	2	-	30	-	1	27	4	-
Seconder caries	3	31	-	-	31	-	-	31	-	-	31	-	-
	6	31	-	-	31	-	-	31	-	-	31	-	-
	12	31	-	-	31	-	-	31	-	-	31	-	-
Post-operative densitivity	3	24	7	-	24	7	-	26	5	-	25	6	-
	6	28	3	-	27	4	-	28	3	-	28	3	-
	12	29	2	-	28	3	-	30	-	1	30	1	-
Anatomic form	3	31	-	-	31	-	-	31	-	-	31	-	-
	6	31	-	-	30	-	1	31	-	-	31	-	-
	12	31	-	-	29	-	2	31	-	-	31	-	-

The marginal adaptation criterion is used to evaluate the adaptation of the restoration with the tooth in the marginal regions. Conventional method, Papacarie Duo and laser groups were 100% successful in terms of marginal adaptation for 12 months, and all restorations were scored with alpha. In the Carisolv group, it was scored with Charlie because of the deterioration in its marginal adaptation in 1 restoration in 6th month and in 2 restorations in 12th month. In terms of marginal adaptation, no statistically significant difference was found between the data of the 3rd, 6th, and 12th months, depending on the time in each material, and depending on the time between the groups (Table 6 and 7).

In terms of color matching criteria, the conventional group achieved 100% success in 12 months. In the Papacarie Duo group, there is a restoration given 1 Charlie score in the 12th month. It is noteworthy that the Bravo group's laser score increased from 1 in 3 months to 3 in 6 months and 4 in 12 months. In terms of color matching, no statistically significant difference was found between the 3rd month, 6th month and 12th month data depending on the time in each material. According to the data of the 3rd and 6th months, there was no statistically significant difference between the groups in terms of color matching. According to 12-month data, there was a significant difference between only conventional and laser groups in the evaluation between groups in terms of color matching ($p = 0.040$) (Table 6 and 7).

In none of the restorations, secondary caries was observed during the 12-month control period and all restorations were scored with an alpha score. According to the data at all control times, there was no statistically significant inter-group and in-group difference in terms of secondary caries (Table 6 and 7).

In terms of postoperative sensitivity criterion, the number of bravo scores, which was higher in all groups at 3 months, decreased at 6 and 12 months. (Table 4) In the evaluation of each group based on time periods, a significant change was observed only in the conventional method in terms of post-operative sensitivity in the period between the 3rd month and the 6th month. In the period between 6th and 12th

Table 6. Time-dependent evaluations of caries removal methods in terms of Modified USPHS criteria.

Comparison by time		3-6 months	6-12 months	3-12 months
Marginal discoloration	Conventional	0.317	1.000	0.317
	Carisolv	0.083	0.317	0.046*
	Papacarie Duo	0.317	1.000	0.317
	Laser	0.157	0.157	0.046*
Marginal adaptation	Conventional	1.000	1.000	1.000
	Carisolv	0.137	0.317	0.157
	Papacarie Duo	1.000	1.000	1.000
	Laser	1.000	1.000	1.000
Color match	Conventional	1.000	1.000	1.000
	Carisolv	0.317	0.317	0.317
	Papacarie Duo	1.000	0.317	0.317
	Laser	0.157	0.317	0.317
Post-operative sensitivity	Conventional	0.046*	0.317	0.025*
	Carisolv	0.083	0.317	0.046*
	Papacarie Duo	0.157	0.083	0.025*
	Laser	0.180	0.157	0.025*
Anatomic form	Conventional	1.000	1.000	1.000
	Carisolv	0.137	0.317	0.157
	Papacarie Duo	1.000	1.000	1.000
	Laser	1.000	1.000	1.000

months, a significant difference was found in post-operative sensitivity in all groups (Table 6). In terms of postoperative sensitivity, no statistically significant difference was found in all control times (Table 7).

Conventional method, Papacarie Duo and laser groups were 100% successful in terms of anatomic form for 12 months, and all restorations were scored with alpha. In the Carisolv group, it was scored with Charlie because of the deterioration in its anatomic form in 1 restoration in 6th month and in 2 restorations in 12th month. These 2 restorations are those that are given the Charlie score in terms of marginal adaptation criteria. According to the data at all control times, there was no statistically significant inter-group and in-group difference in terms of anatomic form (Table 6 and 7).

DISCUSSION

One of the main reasons for trying to develop alternative caries removal methods is that the patients cannot tolerate the pain caused by pressure and

Table 7. Inter-group evaluation of caries removal methods in terms of modified USPHS criteria depending on time

Compare by Groups		3 months	6 months	12 months
Marginal discoloration	Conventional-Carisolv	0.283	0.228	0.228
	Conventional-Papacarie Duo	0.644	0.721	0.721
	Conventional-Laser	0.099	0.141	0.048*
	Carisolv-Papacarie Duo	0.133	0.122	0.122
	Carisolv-Laser	0.547	0.785	0.425
	Papacarie Duo- Laser	0.040*	0.071	0.021*
Marginal adaptation	Conventional-Carisolv	1.000	0.154	0.317
	Conventional-Papacarie Duo	1.000	1.000	1.000
	Conventional-Laser	1.000	1.000	1.000
	Carisolv-Papacarie Duo	1.000	0.154	0.317
	Carisolv-Laser	1.000	0.154	0.317
	Papacarie Duo- Laser	1.000	1.000	1.000
Color match	Conventional-Carisolv	0.317	0.154	0.154
	Conventional-Papacarie Duo	1.000	1.000	0.317
	Conventional-Laser	0.317	0.078	0.040*
	Carisolv-Papacarie Duo	0.317	0.154	0.583
	Carisolv-Laser	1.000	0.644	0.394
	Papacarie Duo- Laser	0.317	0.078	0.184
Post-operative sensitivity	Conventional-Carisolv	1.000	0.691	0.644
	Conventional-Papacarie Duo	0.524	1.000	0.154
	Conventional-Laser	0.757	1.000	0.557
	Carisolv-Papacarie Duo	0.524	0.691	0.078
	Carisolv-Laser	0.757	0.691	0.305
	Papacarie Duo- Laser	0.742	1.000	0.317
Anatomic form	Conventional-Carisolv	1.000	0.154	0.317
	Conventional-Papacarie Duo	1.000	1.000	1.000
	Conventional-Laser	1.000	1.000	1.000
	Carisolv-Papacarie Duo	1.000	0.154	0.317
	Carisolv-Laser	1.000	0.154	0.317
	Papacarie Duo- Laser	1.000	1.000	1.000

vibration during the caries removal process with conventional method and need for anesthesia.[14] Many studies have been conducted to measure the degree of pain caused by alternative caries removal methods during the procedure. While removing caries with the conventional method, scraping of the affected dentine or intact dentine can cause pain.[15] Since chemomechanical methods only remove infected dentine, it has been shown in many studies that they produce less pain compared to the conventional method. FACES evaluation has been demonstrated in many studies where chemomechanical methods only cause less pain compared to the conventional method since they remove infected dentin.[16] Carisolv is also reported to reduce somatosensory sensations at the tooth and cause a localized reversible analgesia of the tooth.[17] Korkut et al. applied the Wong-Baker FACE Pain Assessment questionnaire to 120 patients in their clinical study to evaluate and compare pain perception during the caries removal process with Er:YAG laser and conventional rotary instruments. They reported that the use of Er:YAG laser caused less pain during caries removal than conventional rotary instruments.[18] In this study, similar to the studies in the literature, alternative methods were found to cause less pain than the conventional method. The least painful group is Er,Cr:YSGG laser. Laser produces transient anesthetic effect on the tooth by blocking nerve conduction at Na/K pump and ablating dentinal tubules.[19] It is also reported to cause of disruption of nerve terminals in the dentin tubules, combined with a degeneration of nerve terminals between the odontoblasts and the disruption of the myelin sheath in the pulp core.[20] The null hypothesis that all the caries removal methods evaluated were not different when compared to patient comfort.

Carisolv causes the breakdown of the damaged collagen in the carious tissue. In addition, chloramines destroy collagen, whose structure has deteriorated due to caries. While protected collagen is resistant to structural deterioration, the damaged collagen network by carious within the porous mineral structure is easily destroyed and removed. In this way, only infected dentin is removed.[21]

The protective effect of alpha-1-antitrypsin on healthy collagen tissue by inhibiting the proteolytic effect of papain and pepsin is demonstrated. Also, the loss of alpha-1-antitrypsin in impaired collagen tissue is responsible for the proteolytic effect of papain is proved. In addition, similar to the impaired collagen tissue, papain could destroy the infected tissues by losing the alpha-1-antitrypsin molecule. For this reason, many researchers think that the papain will not harm healthy dentin but will only affect carious dentin due to the inhibition effect of the alpha-1-antitrypsin molecule.[22]

Arora et al. observed minimal smear layer formation and open dentinal tubules as a result of caries removal with Papacarie.[23] It has been stated that there is no smear layer on the dentin surface excavated with Carisolv and the dentinal tubules are not covered by the smear layer, so it has an improved wetting potential.[24,25] In the SEM observation of the cavities prepared with laser, a scaly appearance or an irregular surface was observed due to micro irregularities after laser irradiation, the smear layer was not observed and the dentine tubules were exposed.[7] It is known that there is no smear layer in the cavities prepared with alternative methods used in our study based on the literature information.[7,17,23,25] Since there is no need for pickling to remove the smear layer, the use of self-etch adhesive systems was preferred. In many studies, it has been proved that after the removal of caries with all the alternative methods used in this study, acceptable bonding strength is formed when self-etch adhesive system is used in dentin.[8,26] In addition, the self-etch adhesive system was preferred due to the difficulties in clinical applications encountered in Etch & rinse adhesive systems, the time required for application and postoperative sensitivity. The bonding mechanisms of self-etch adhesive systems to enamel and dentin have been extensively investigated and it has been stated that there is a two-step bonding mechanism, "micro-mechanical locking and chemical bonding", in terms of the durability of the restoration.[11] Functional acidic monomers in its structure chemically interact with hydroxypatite and consist of specific carboxyl and phosphate groups. It has been reported that 10-MDP, one of the functional acidic monomers in its structure, is responsible for etching and chemical bonding, long carbonyl chains provide hydrophobic properties and give hydrolytic stability to this acidic monomer. 10-MDP forms a strong ionic bond with the calcium ion originating from enamel or dentin hydroxyapatite and forms Ca-monomer salts.[27]

The modified USPHS evaluation system is a common method for evaluating clinical follow-up studies.[28] This scoring technique is easy to apply and clinically acceptable or unacceptable restorations can be scored with this system.[29]

Marginal discoloring is a parameter that can vary depending on time. As the follow-up periods increase, the increase in discoloration is a normal course.[10] Within the scope of this study, it was observed that the success rate in terms of marginal discoloration decreased in the restorations performed in all groups. However, only the increase in Carisolv and laser groups was found significant. In the intergroup evaluations depending on time, there was a difference between Papacarie Duo and laser groups at 3 and 12 months. It is known that a scaly, irregular and rough appearance of dentin occurs after laser irradiation and the smear layer is not formed. Laser irradiation can reduce

resin infiltration to the prepared surface as a result of collagen fibril fusion and denaturation and may cause low adhesion to dentine by closing interfibriller spaces.[10] In this study, due to the low adhesion between the cavity surfaces we prepared with Er, Cr: YSGG laser and the self-etch bonding system we used, more microleakage may have occurred in the laser group compared to other groups. This microleakage may be the reason for the significantly higher marginal discoloration in the laser group than in the other groups.

In terms of marginal adaptation, conventional, laser and Papacarie Duo showed 100% success for 12 months. Only in Carisolv, in the 6th month in 1 restoration, in the 12th in 2 restorations, a small part rupture occurred in the tooth junction area and the Charlie score was obtained. In this study, a self-etch adhesive system was used, which mainly connected with the smear layer. Although in-vitro studies demonstrated that Carisolv causes a smear layer on the cavity surface, we could not prove the presence of a smear layer in our study.[30,31] For this reason, there is a possibility that an ideal integrity cannot be found in the dental tissue and restorative material interface. On the other hand, this effect may be related to the fact that we do not use a selective-etch method with the self-etch adhesive system. This may be the reason why the Charlie score occurred in two cases.

In terms of color matching, in the intra-group and inter-group time-dependent evaluations, only 12th month found a significant difference between the conventional group and the laser group. While evaluating color matching clinically, the marginal discoloration in the restorations reflected on the composite mass may have misled the observers. Since the marginal discoloration in the laser group is significantly different compared to the conventional method, this may also have affected the color matching scores. In addition, the color matching of composites can change according to the patient's nutrition and hygiene habits. In this study, although the same type of composite was used in 124 teeth in 31 patients, the difference in color matching in 12th month may have resulted from the different nutrition and hygiene habits of the patients.

Secondary caries formation is directly related to the microleakage of the restoration and the patient's oral care. It has also been reported that restorative materials facilitate plaque build-up and bacterial retention, which also increases secondary caries.[32] There are many clinical studies in the literature that follow the restorations in terms of secondary caries.[33] It can be said that this study is similar to the studies in the literature. When the restorations in this study were evaluated in terms of secondary caries criteria, 100% success was achieved in all groups as a result of 1-year controls.

When the restorations in this study were evaluated between groups in terms of post-operative sensitivity, no statistically significant difference was found between the 3rd, 6th and 12th months. In the evaluation of each group in terms of time periods, a significant decrease was observed only in the conventional method in terms of post-operative sensitivity in the period between 3 months and 6 months. A heal in post-operative sensitivity was observed between 6 months and 12 months in all groups. As the response of dentine to caries removal, we think that post-operative sensitivity has developed in the near-term clinical follow-up due to narrowing of dentin tubules and motility of dentin fluid during the stage of repair dentin. Over time, repair dentine forms and post-operative sensitivity decreases as the dentinal tubules that are exposed while removing caries are closed. Although post-operative sensitivity is a clinical problem associated with composite restorations, the use of self-etch adhesives - as observed in this study - has been reported to reduce post-operative sensitivity.[34]

There was no statistically significant difference between the groups and within the groups in terms of anatomical form criteria depending on the time. In the Carisolv group, 1 restoration in the 6th month and 2 restorations in the 12th month scored Charlie score, and at the end of the year, the success rate was 93.5%. These two restorations are those that are given the Charlie score in terms of marginal adaptation. The failure of the two restorations in the Carisolv group may have been due to the poor connection of the self-etch adhesive with the smear-free dentin surface prepared with Carisolv.[25]

As a result of evaluations made with Modified USPHS criteria; the null hypothesis was accepted that the restorations performed with caries removal methods were not different in terms of clinical success.

CONCLUSION

Alternative methods caused less pain than the conventional method, the need for anesthesia was less, the patient was found more acceptable in terms of comfort. All methods tested by considering their advantages and disadvantages can be effectively used for caries removal. It was concluded that the alternative caries removal methods are not different in terms of the success of the restorations. This study, which has short-term clinical follow-up, needs to be supported by studies with long-term clinical follow-up.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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