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ORIGINAL RESEARCH

Clinical Evaluation of Caries Removal in Primary Teeth using Conventional, Chemomechanical and Laser Technique: An *in vivo* Study

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ABSTRACT

Aim: To evaluate four different techniques of caries excavation in primary teeth in terms of efficacy, efficiency and pain experienced during the procedure.

Materials and methods: Sample of 120 teeth from children aged 5 to 9 years were equally divided into 4 groups – Air rotor (group A), Carisolv (group B), Papacarie (group C) and Er:YAG laser (group D). Visual and tactile criteria along with DIAGNOdent pen value was used to evaluate efficacy. Time was recorded to determine efficiency and FLACC scale was used to assess the pain experienced.

Results: Air rotor and laser were more effective and efficient method whereas laser and CMCR methods were more comfortable methods.

Conclusion: Laser irradiation and CMCR methods are comparable to conventional methods in terms of effectiveness and are less painful methods.

Clinical significance: Newer techniques of CMCR and laser irradiation of dentinal caries are minimally invasive methods and are less painful and thus should be more frequently employed in pediatric dentistry.

Keywords: Carisolv™, Papacarie®, Er:YAG laser, Chemomechanical caries removal, DIAGNOdent pen, Dentinal caries, Primary molars.

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INTRODUCTION

Dental caries is the most prevalent chronic disease in the global population.[1,2] Treatment of dental caries is thought to be frightening and thus commonly avoided. Earlier principles of cavity preparation were constrained by the knowledge of the disease process and the restorative materials available at that time.[3] With the advent of adhesive materials and greater understanding of the disease process we are moving into the era of 'minimal intervention dentistry. The revolution of minimal intervention dentistry gave us some gentle techniques to treat caries which consisted of chemomechanical and laser ablation method for excavation of dental caries.

In l998, Mediteam in Sweden introduced Carisolv™ which removes caries selectively by reacting with denatured collagen thereby making carious dentin soft. The gel does not affect healthy dentin.[4] Papacarie®, another chemo-mechanical caries removal (CMCR) reagent (Formula e Aeao, Sao Paulo, Brazil) was introduced in Brazil in 2003. It has bactericidal, bacteriostatic arid anti-inflammatory characteristics and like Carisolv removes carious dentin selectively and painlessly.[5]

Principle of laser is also investigated for various applications in dentistry. Stern and Sognates[6] and Goldman et al[7] were first to investigate its impact on hard tissues. Paghdiwala tested for the first time the ability of the Erbium: Yttrium-Aluminum-Garnet (Er:YAG) laser to ablate dental hard tissues.

With the intention of tracing the more suitable method for caries excavation in pediatric population this present study was conducted to compare the efficacy, efficiency and patient comfort level with traditional, chemomechanical and laser techniques in removal of caries in deciduous teeth.

MATERIALS AND METHODS

The study sample consisted of 120 teeth from pediatric patients. These children were selected applying following criteria:

Selection Criteria

1. Age group: 5 to 9 years.
2. Occurrence of at least one open carious lesion into dentin on occlusal surface.

Exclusion Criteria

1. Primary molars with clinical and/or radiographical signs and symptoms of pulpal and periapical lesions.
2. Primary molars with radicular resorption involving more than half root length.
3. Primary molars with presence of developmental defects.
4. Children with presence of any major and minor systemic illness.

The study sample was divided into four groups, having 30 teeth in each group. Following methods of caries excavation were used:

Group A: Conventional air rotor method
Group B: Chemomechanical method-Carisolv™
Group C: Chemomechanical method-Papacarie®
Group D: Photoablation using Er:YAG laser method.

PROCEDURE

This study commenced after the due permission and clearance obtained from the Ethical Committee and Institutional Review Board. Informed consent was obtained from the parent or the guardian. Subject tooth was isolated with an aid of rubber-dam and prophylactically cleaned and rinsed thoroughly in order to reduce the bacterial count.

DIAGNOdent Pen Value

DIAGNOdent (KaVo, Biberach, Germany) is a laser-based instrument developed for detection and quantification of dental caries. In this study DIAGNOdent pen was used. The instrument was calibrated using ceramic mounting, provided by manufacturer (standard calibration). Baseline reading for each tooth was set zero by placing the probe on sound tooth surface (individual calibration) and peak value was obtained and recorded. To maintain adequate standardization, teeth with preoperative value ranging from 30 to 99 were included into the study. Postoperative cut-off for sound tissue was set at 15.[8]

Group A (Air Rotor)

Caries were excavated by means of no. 245 round bur in high speed air-turbine hand piece (Unique KaVo Dental Excellence). Intermittent cutting along with water coolant was done until all the caries were excavated.

Group B (Carisolv™)

Dental caries were covered with the Carisolv™ gel for 30 seconds. A special set of hand instruments designed by the manufacturer for the Carisolv™ gel was used for caries excavation. It was initiated using Carisolv® hand instrument 2 (multistar, star 3) because multistar tip promotes penetration of the gel and scrapes in all directions thus aiding in bulk excavation. Remaining four instruments were used as required. When the gel became heavily contaminated with debris, it was replaced by fresh gel. This procedure was repeated until the gel no longer became turbid and all surfaces of the cavity were hard on probing, indicating that no soft carious dentin was left.

Group C (Papacarie®)

The carious cavity was first filled with Papacarie® gel which was allowed to act for 40 to 60 seconds. Carisolv™ hand instruments were used to excavate caries in order to maintain standardization. The gel was reapplied as many times as necessary, until it remained unchanged in color indicating that no soft carious dentin was left.

Group D (Laser)

Er:YAG laser (Fotona Fidelis III, Italy) with an emission wavelength of 2.94 μm, pulse energy of 200 mJ and frequency 20 Hz was set to obtain the power of 4W. Caries excavation was carried out under contact mode using sapphire laser tip held in hand piece number R14, under continuous water spray. Once in dentin the contact cutting tip was repositioned in a noncontact relationship to the surface of the tooth to decrease the energy density. This facilitated to continue the excavation of caries without the change of operating parameters, once set.

Evaluation of Caries Excavation

The complete excavation of the caries was confirmed by tactile and visual method of caries detection. The caries removal was considered to be complete when the explorer did not stick in the dentin, and there was no 'tug-back' sensation. In addition postoperative DIAGNOdent pen value (Table 1) was obtained which served as an adjunct method.[9]

Evaluation of Time

The time taken for all the procedures was measured in seconds from start of caries removal till the cavity was confirmed to be free of caries.

Table 1: DIAGNOdent pen value interpretation, Lussi et al[9]

Value	*Diagnosis*
0-13	No caries(no active care advised)
14-20	Enamel caries(preventive care advised)
20-30	Dentinal caries(preventive/operative care advised depending on patients risk)
>30	Dentinal caries(operative care advised)

Evaluation of Pain and Patient Comfort

This was assessed using FLACC (face, leg, activity, cry, consolability scale) (Table 2A). This tool includes five categories of pain behaviors, including facial expression, leg movement, activity, cry and consolability. These behaviors are to be reliably associated with pain in young children. Examiner was provided with guide to use this scale (Table 2B). Scoring of the patient's behavior was done during the procedure.

Statistical Analysis

The entire data was statistically analyzed in SPSS. The statistical significance of difference of obtained DIAGNOdent values, time required in seconds and FLACC score for intergroup comparison has been tested using one-way analysis of variance (ANOVA) and Turkey's test. Intragroup comparison of difference of DIAGNOdent pen values between preoperative and postoperative have been tested using paired t-test.

RESULTS

Efficacy

1. Pre- and postoperative comparison of DIAGNOdent pen values: Each group showed a significant drop in DIAGNOdent pen value after the procedure as depicted in Fig.1. In groups A and D, DIAGNOdent pen value showed significantly more drop compared to method groups B and C (Table 3).
2. Intragroup comparison of change in DIAGNOdent pen values: Change in DIAGNOdent pen value within each was calculated in percentage using formula:

$$\frac{(\text{Preoperative value} - \text{Postoperative value})}{\text{Preoperative value}} \times 100$$

Percentage change in DIAGNOdent pen values for groups A and D was more than groups B and C as depicted in Fig. 2. Percent change in DIAGNOdent pen value was not significantly different between method groups A and D and between group B and C respectively (Table 4A).

3. Intergroup comparison of change in DIAGNOdent pen value after the procedure: Methods A and D were significantly more efficacious than methods B and C. There was no significant statistical difference in terms of efficacy between methods A and D and also between methods B and C respectively (Table 4B).

Efficiency (Fig. 3)

1. Intragroup comparison of time required for procedure: Average time required is significantly higher in groups B, C and D compared to group A (Table 5A).
2. Intergroup comparison of time required for procedure: Based on average time required method A was significantly faster than groups B,C and D. Method D was faster than groups B and C. Average time required was not significantly different between method groups B and C (Table 5B).

Pain and Discomfort (Fig. 4)

1. Intragroup comparison of FLACC score obtained during procedure: Air–rotor method scored highest scores and

Table 2B: Interpretation of FLACC scale[27]

Score	*Interpretation*
0	Relaxed and comfortable
1-3	Mild discomfort
4-6	Moderate pain
7-10	Severe pain or discomfort or both

Table 2A: FLACC scale[27]

Face	0 No particular expression or smile	1 Occasional grimace or frown, withdrawn, disinterested	2 Frequent to constant Frown, clenched jaw, quivering chin
Legs	0 Normal position or relaxed	1 Uneasy restless tense	2 Kicking or legs drawn up
Activity	0 Lying quietly normal position moves easily	1 Squirming, shifting back/forth tense	2 Arched rigid or jerking
Cry	0 No cry awake or asleep	1 Moans or whimpers occasional complaint	2 Crying steadily screams or sobs frequent complaints
Consolability	0 Content, relaxed	1 Reassured by occasional touching, hugging or talking to distractible	2 Difficult to console or comfort

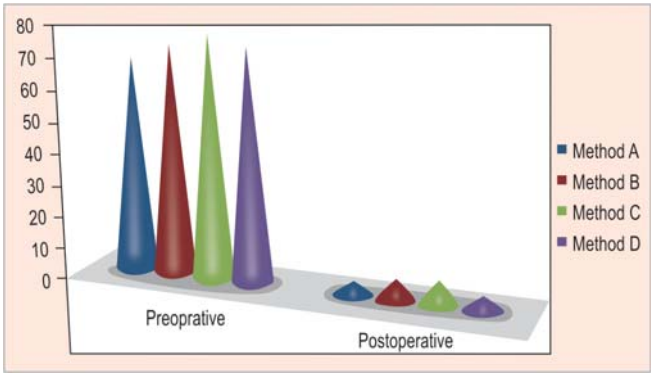

Fig. 1: Pre- and postoperative comparison of DIAGNOdent value

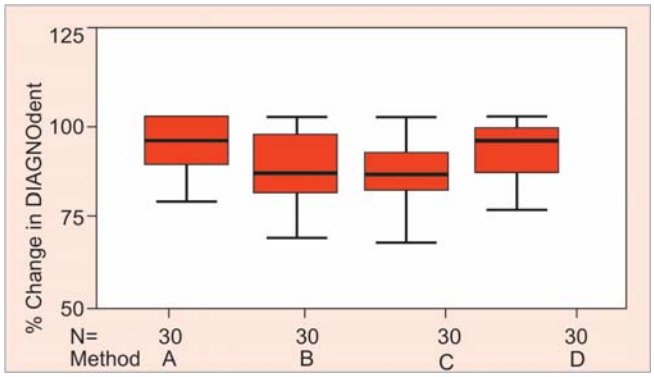

Fig. 2: Percent change in DIAGNOdent values

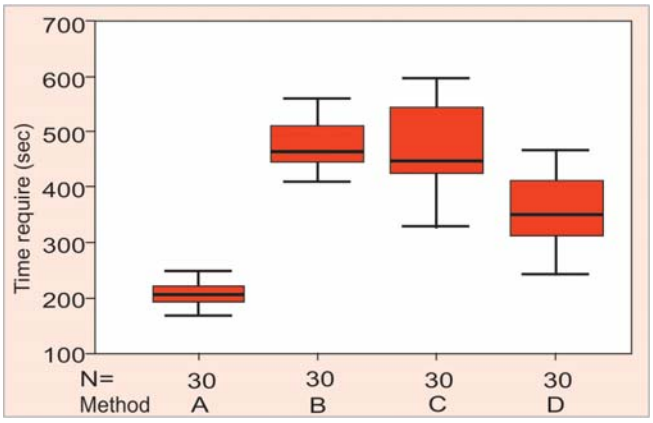

Fig. 3: Group comparison of time required

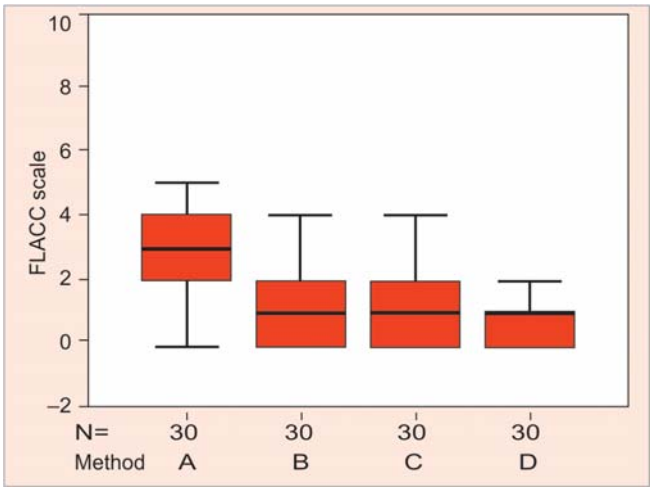

Fig. 4: Group comparison of FLACC score

Table 3: Comparison of preoperative and postoperative DIAGNOdent pen value

Method groups	*DIAGNOdent (Preoperative)*	*DIAGNOdent (Postoperative)*	*p-value*
A (n = 30)	67.8 (24.1)	4.4 (4.3)	0.001
B (n = 30)	73.2 (22.8)	7.0 (4.5)	0.001
C (n = 30)	77.7 (17.3)	8.5 (4.2)	0.001
D (n = 30)	73.9 (16.2)	4.8 (3.9)	0.001

Values are mean (SD). p-values by paired t-test. p-value <0.05 is considered to be statistically significant

Table 4A: Percent change in DIAGNOdent pen values

Method groups	*% change in DIAGNOdent*
A (n = 30)	92.9 ± 9.2
B (n = 30)	87.7 ± 6.4
C (n = 30)	88.9 ± 6.0
D (n = 30)	93.9 ± 4.9

Values are mean (SD) percent change in DIAGNOdent. Percentage change is calculated using formula: (Preoperative value–Postoperative value) × 100/Preoperative value. Positive values indicate drop in DIAGNOdent value after the surgery.

Table 4B: Intergroup comparison of change in DIAGNOdent pen values

Comparison of methods	*p-value*	*Comparison of methods*	*p-value*
A *vs* B	0.027	B *vs* C	0.576
A *vs* C	0.002	B *vs* D	0.039
A *vs* D	0.598	C *vs* D	0.002

p-values by one-way analysis of variance (ANOVA) with Tukey's correction for multiple group comparisons

Table 5A: Comparison of time required

Method groups	*Time required (sec)*
A (n = 30)	206.7 ± 22.1
B (n = 30)	474.7 ± 43.0
C (n = 30)	471.3 ± 68.2
D (n = 30)	359.9 ± 59.9

Values are mean (SD). p-values by independent sample t-test. p-value <0.05 is considered to be statistically significant

Table 5B: Intergroup comparison of time required

Comparison of methods	*p-value*	*Comparison of methods*	*p-value*
A *vs* B	0.001	B *vs* C	0.994
A *vs* C	0.001	B *vs* D	0.001
A *vs* D	0.001	C *vs* D	0.001

p-values by one-way analysis of variance (ANOVA) with Tukey's correction for multiple group comparisons.

proved to be more painful and uncomfortable compared to other methods (Table 6A).

2. Intergroup comparison of FLACC score obtained during procedure: Average FLACC score is significantly higher in group A compared to groups B, C and D. Average FLACC score is not significantly different between method groups B, C and D (Table 6B).

Table 6A: Comparison of FLACC score

Method groups	*FLACC score*
A (n = 30)	2.93 ± 1.74
B (n = 30)	1.13 ± 1.25
C (n = 30)	1.37 ± 1.79
D (n = 30)	1.10 ± 1.56

Values are Mean (SD). p-values by independent sample t-test. p-value <0.05 is considered to be statistically significant

Table 6B: Intergroup comparison of FLACC score

Comparison of methods	*p-value*	*Comparison of methods*	*p-value*
A *vs* B	0.001	Method B *vs* C	0.942
A *vs* C	0.001	Method B *vs* D	0.998
A *vs* D	0.001	Method C *vs* D	0.917

p-values by one-way analysis of variance (ANOVA) with Tukey's correction for multiple group comparisons

DISCUSSION

New methods of caries removal have always been a major objective for dental researchers seeking possible alternative to existing conventional methods in the field of pediatric dentistry. In this study we made clinical comparison between conventional air rotor, Carisolv™, Papacarie® and Er:YAG laser irradiation. Caries were evaluated based on visual and tactile sensation criteria. These criteria were shown to be adequate to ensure removal of most of the infected dentin by Kidd et al.[3] In this study DIAGNOdent pen (KaVo, Biberach, Germany) served as an adjunct to visual and tactile criteria to evaluate caries. Attrill and Ashley and Lussi and Francescut obtained good intraexaminer reproducibility under daily practice conditions using DIAGNOdent on occlusal surfaces in primary teeth, compared to visual inspection, histology, radiography, and quantitative light-induced fluorescence. Lussi and Hellwig in an *in vitro* study comparing the old DIAGNOdent classic device and the new DIAGNOdent pen, by histological examination of teeth showed no statistically significant difference between the two systems.[9] Reich et al and Lussi et al concluded that another promising application of the DIAGNOdent is the detection of residual caries during excavation.[9] Hence, DIAGNOdent pen values were obtained preoperatively as well as postoperatively to serve as clinical parameter for intergroup comparison of efficacy of each technique. The laser fluorescence score depends on the amount of metabolic byproducts of caries causing bacteria and fluorescent protoporphyrine and the color of carious dentin.[10] Thus, the presence of discolored affected dentin could be a reason for yielding higher postoperative DIAGNOdent pen values for chemomechanical techniques which selectively removed only soft infected dentin.

Air rotor method of caries excavation proved to be most efficacious method. Carbide or diamond bur when used at high speed tends to over prepare the cavities and remove reversibly affected dentin leaving minimally discolored, hard, glossy dentinal surface.[11-13] This resulted in extremely low DIAGNOdent values to be obtained postoperatively.

Carisolv™ selectively removes infected carious dentin. When the gel containing 0.1 M mixtures of three amino acids, lysine, leucine, glutamic acid, and the fluid containing 0.5% sodium hypochlorite are mixed, amino acids bind chlorine and form chloramines at a pH of 11. This chlorination affects the secondary and/or quaternary structure of the collagen, by disrupting hydrogen bonding and thus brings about proteolytic reaction. It does not affect healthy dentin because amino acids act as homing devices for active chlorine. The chlorine atom of hypochlorite is transferred to the amino group of each amino acid and in this way it is made less reactive and less aggressive to healthy tissue.[14]

Even Papacarie® claims to selectively remove caries although mechanism of action is different. It consists of papain, chloramines, toluidine blue dye, water, salts and thickeners. It has bactericidal, bacteriostatic and anti-inflammatory characteristics. Papain acts as a debridant anti-inflammatory agent and targets only in infected tissues because of absence of plasmatic anti-protease called alpha-1 anti-trypsin in infected tissues which is present only in sound tissues and it inhibits protein digestion. Toluidine blue is antimicrobial agent and water acts as a vehicle.

Despite the advantages of chemomechanical methods, it is important to point out the need for a minute assessment of the cases based on indications and inclusion criteria for its application. It is of importance to have good access to the dentine caries and check all surfaces for complete caries removal, especially the dentino-enamel junction, before restoring the cavity.[3,15,16] Chaussain-Miller et al in their investigation concluded that chemomechanical technique is of slightly less interest for small and moderate cavities.[17] Moreover, in the present study some teeth were encountered where accessible lesions coexisted with isolated pit and fissures which were carious where chemomechanical treatment is ineffective. In such situations use of air rotor was required.

In contrast to chemomechanical methods, efficacy of Er:YAG laser was comparable to air rotor method. The explosive interaction between the water molecules and the Er:YAG laser pulse on the tooth tissue surfaces disrupts enamel, dentin and decay. The rapid subsurface expansion of the interstitially trapped water within the mineral substrate causes a massive volume expansion, and this expansion causes the surrounding material to be exploded away.

Insignificant statistical differences in the effectiveness of caries removal by an Er:YAG laser compared to air rotor method have been reported by Hibst and Keller;[18] Keller and Hibst[19] and Shigetami et al.[20] Results of the present study are also in accordance to these conclusions. Eberhard et al observed that there was less difference between preoperative and postoperative cavity dimensions prepared by laser method than that prepared by conventional bur, indicating less loss of dentin in laser method compared to bur method.[21]

In terms of efficiency several studies have shown that Carisolv™ system was slower compared to conventional method.[3,22-33] Even Papacarie® was reported to be a slower method for caries removal compared to air rotor by many studies. According to Kakaboura et al, the reason for increased time taken might be because of the multiple applications of the gel for complete caries removal.[31] In the present study multiple applications at times were required in maxillary teeth because confinement of gel within the cavity was difficult which may be attributed due to gravity effect. While Lozano-Chourio MA et al stated that the variation in the time may have been related to the differences in type and size of the cavities, type of teeth and age of the patient.[24] In this study also, the above reasons could attribute to the longer caries excavation time by chemomechanical methods compared to mechanical (air rotor) method. Because natural lesions were used, it was not possible to standardize all variables of the sample, e.g. shape and activity status of the lesions. Time consumed for caries removal by chemomechanical and laser methods was found to be cavity size dependent whereas with air rotor method it was independent of the size of the cavity. This was in accordance with the observation made by Celiberti et al in their study.[16] Although in the same study laser was proved to be significantly slower compared to conventional bur excavation. This difference could be attributed to variation in parameters used for Er:YAG laser. Yamanda et al in their study comparing air rotor, Carisolv™ and Er:YAG laser reported that Carisolv™ was slowest, following laser and air rotor was fastest.[34] Our results are in confirmation with that study. According to Takamori et al laser irradiation could be hasten by two possible approaches: The first would be increased irradiation energy; but this would cause thermal damage to enamel and dentin, a discomforting vibration and simultaneous pain.[35] The second would be to increase the rate of pulse repetition. In the present study 'VSP' (very short pulse) waveform was selected in order to maintain an adequate ablation with sufficient speed.

The behavior of the child during the caries excavation procedures was recorded with FLACC scale. Because of its elaborate nature, this scale was selected to be used in this study. In each case the scoring was carried out by a single appointed independent examiner to rule out the bias, which otherwise would have been possible if scoring was done by operator, parent or child himself.

Air rotor tends to evokes pain due to pressure and vibration produced. In our own study, it was observed that excavation of caries with air rotor is most commonly associated with frightened cry followed by pain cry.[36] Accordingly even in the present study, air rotor yielded higher FLACC score compared to all other methods (Table 3A). Anusavice and Kindhloe demonstrated that cutting sound dentine often results in some level of pain.[37] Thus, lower FLACC scores were obtained with respect to CMCR methods owing to selective removal of only infected dentin. Also in case of CMCR methods the gel itself may have a thermal insulating function because it covers the cavity during the procedure. Carisolv™ is also reported to reduce somatosensory sensations at the tooth and cause a localized reversible analgesia of the tooth.[38] Less pain encountered may also be due to the fact that Carisolv® instruments are specially designed for a safe scraping action, have 90º edge and not a sharp cutting profile. That allows working in two or more directions and reduces breaking off healthy dentine and opening more dentin tubules.[28,39] Additional benefit observed for chemomechanical methods was lowering of child's anxiety when they were informed that drill may not be used.

Low pain and higher comfort level experienced by patients undergoing laser irradiation caries excavation could be attributed to various reasons. Mean vibration speed during laser cavity preparation reaches 166 ± 28 μm/second, at a characteristic frequency of 230 Hz, whereas the air rotor induces an almost 400 times greater vibration speed than the Er:YAG laser irradiation, which causes pain and displeasure in the patient.[35] Takamori et al suggested that high-speed drilling may cause greater bone conduction than the Er:YAG laser irradiation which could possibly lead to mild headaches or discomfort. Laser produces transient anesthetic effect on the tooth by blocking nerve conduction at Na/K pump and ablating dentinal tubules.[40] 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.[41] Thus, it could be assumed that if use of laser could avoid anesthetic injection then complications related to administration of anesthesia, such as allergy, toxicity, drug interactions and tongue and/or lip biting could also be avoided.

Noise during procedure is another factor associated commonly to both conventional drilling and laser irradiation. Yip and Samaranayake in their study observed that patient

acceptance of the popping sound of lasers was much better than the infamous sound of the air rotor, dreaded by most patients.[42] Even in this study too it was observed that children remained quite comfortable in the presence of popping sound produced during laser irradiation indicating that noise along with vibration and pressure is more crucial factor than noise alone in producing discomfort.

Every method employed in the study had its own merits and demerits in terms of three objectives studied (Table 4A). In a clinical scenario any method employed should be weighed against the treatment objective to be achieved. In shallow lesions air rotor method would be preferred because associated pain is generally absent. In moderate cavities laser irradiation could be efficiently employed whereas in deep cavities chemomechanical methods would be beneficial as anesthesia could be avoided and thus compensating for time required for anesthesia as well as behavior management if air rotor was used. A CMCR method decreases the risk of pulp exposure and hence proves to be viable alternative method in stepwise excavation technique.

In uncooperative patients chemomechanical is advantageous but many times especially in very young children the best behavior management technique would be to shorten the treatment time and thus air rotor could be used. Also in agreement to Carrillo et al chemomechanical methods, being virtually painless can be used successfully in SHCN (special health care needs) children, since any stimulus, be it auditory, sensorial, or emotional, can lead to negative responses.[6]

Isolation is another factor to be considered. Although all the procedures in the present study were done under rubber dam, it is assumed that in absence of adequate isolation, air rotor method would require frequent rinsing and more frequent change of cotton rolls, efficacy of chemomechanical method may reduce due to contamination or due to washing away of gel by saliva and laser irradiation would be harmful. Thus, ideal rubber dam isolation would be recommended.

Cost of the treatment can also affect the clinical utility of the method. Although CMCR and laser methods are successful in achieving patient cooperation and producing patient comfort, its cost limits their routine use in clinical practice. Major drawback of laser would be the high cost of the device and other equipments. Chemomechanical methods can also prove to be slightly less economical because of cost, limited shelf-life. However, the CMCR methods would prove to be comparatively less expensive than laser irradiation method. Although the conventional air rotor is very cost-effective method but patient preference and acceptance of CMCR and laser methods cannot be ignored.

From the account of these methods, it is clear that chemomechanical caries excavation and laser irradiation follow the principles of minimally intervention dentistry by being virtually painless and minimally invasive. Although these methods can minimize the use of air rotor but cannot completely eliminate it. Finally, from the experience of use of all the four methods, it would be right to quote Banerjee, Watson and Kidd statement.

CONCLUSION

Air rotor and laser irradiation were more efficient and less time-consuming methods of caries excavation in primary teeth, whereas chemomechanical and laser irradiation were less painful techniques, as experienced by young children.

CLINICAL SIGNIFICANCE

Chemomechanical caries excavation and laser irradiation follow the principles of minimally intervention dentistry by being virtually painless and minimally invasive. Although these methods can minimize the use of air rotor but can not completely eliminate it.

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