The formaldehyde inspiration by the child patient, dentist, and dental assistant during formocresol pulpotomy

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Abstract Although using Buckley's Solution of formocresol (FC) in pulpotomy procedures is becoming less common in pediatric dentistry. This study measured concentrations of formaldehyde (FA) evaporated during fixing and investigated safe procedures for FC pulpotomy. Methods: Ten measurements were taken for each of the conditions described below. Locations measured for each condition were 1) at a position equivalent to the patient, 2) at a position equivalent to the dentist, and 3) at a position equivalent to the assistant dentist. Condition 1 used no peripheral equipment. Condition 2 used an intraoral air evacuator, Condition 3 used extraoral air evacuators, Condition 4 used both extraoral and intraoral air evacuators. At the patient's FA levels were 0.414 ppm during Condition 1, 0.158 ppm during Condition 2, 0.252 ppm during Condition 3, and 0.091 ppm during Condition 4. FA levels at the dentist were 0.115 ppm during Condition 1, 0.042 ppm during Condition 2, 0.081 ppm during Condition 3, and 0.028 ppm during Condition 4. FA levels at the dental assistant were 0.067 ppm during Condition 1, 0.038 during Condition 2, 0.059 ppm during Condition 3, and 0.025 ppm during Condition 4. Exposure concentrations of FA during FC pulpotomy might have using of an extraoral, intraoral air evacuator during FC pulpotomy reduces formaldehyde exposure to patient, dentist, and dental assistant.

Key words

Formaldehyde,
Formocresol,
Pulpotomy,
Sick house syndrome

Introduction

Pulpotomy is performed in pediatric dental practice when caries progress to reversible pulpitis^{1,2)}. Reports show that dental pulp healing differs according to the agent applied to the pulp tissue during pulpotomy^{3,4)}. Buckley's Solution of formocresol (FC) devitalizes the root pulp according to application time and concentration of formaldehyde. Maintaining healing radicular pulp tissue is an important outcome of an FC pulpotomy. Higher clinical rates of success are generally reported for pulpotomies conducted with

FC, compared to calcium hydroxide⁴⁻⁸⁾.

Formaldehyde (HCHO), an ingredient of FC, is colorless with a molecular weight of 30.03 Da, forms a combustible vapor with a strong odor, and becomes readily soluble in water, ethanol, and ether. Formaldehyde is widely used as an ingredient in a number of resins, as an embalming agent, and as a disinfectant. Formaldehyde and formulations that contain formaldehyde (up to 1%) are designated as deleterious substances⁹⁾. Formaldehyde is a gas at room temperature, but the gas readily converts to a variety of derivatives. One important derivative is the cycle compound trioxane, the "trimer" of formaldehyde with formula is (CH₂O)₃. When dissolved in water, formaldehyde converts to H₂C(OH)₂, a

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Fig. 1 Schematic of experiment

An experimental model assuming the pulpotomy of the lower left second primary molar with a pre-procedure placement of a rubber dam. Intraoral air evacuator was provided 5 cm. Extraoral air evacuator was provided 15 cm.

diol (i.e. a compound with two hydroxy groups). Aqueous solutions of formaldehyde are referred to as formalin¹⁰. Formaldehyde is severely irritative and sensitizing to the skin mucosa, and causes protein fixing¹⁰. The median lethal oral dose of formaldehyde (LD₅₀) in animals is 280 to 800 mg/kg. Animal exposure to high concentrations of formaldehyde or oral administration of large quantities results in hemorrhage, edema and degeneration in the trachea and lungs, hyperemia, edema and necrosis in the lungs and kidneys, and cerebral edema and necrosis of the gangliocytes¹¹. Even exposure to low concentrations of formaldehyde can cause a severe irritation of the eyes and trachea, sneezing, coughing, and salivation. Levels of 5 ppm can cause a mild irritation of the nose and throat and lacrimation in people who are unaccustomed to the chemical, while even people adjusted to the effects can stand no more than eight hours of continuous exposure at this level. Exposure to formaldehyde is not known to be a definite cause of chronic illness, although reports have found chronic obstructive ventilatory impairment in workers exposed to formaldehyde, and also sensitization of the skin and respiratory tract¹². Contact dermatitis is a common occurrence during the manufacture of formaldehyde. A study in rats has shown a long term, repeated exposure to 6 to 15 ppm formaldehyde causes squamous cell cancer, although these results have yet to be corroborated by epidemiological analysis of carcinogenicity in humans. Occupational Safety and Health Administration (OSHA) reported that the finding

of nasal cancer in two strains of rats in three independent studies on formaldehyde alone to be extremely strong and reproducible evidence that formaldehyde is an animal carcinogen. Evidence of a dose-response relationship, finding cancers of identical cell-type and location in two species and evidence that formaldehyde is genotoxic strengthens the scientific relationship of formaldehyde exposure causing cancer¹³. Formaldehyde is classified as "Group 1: Carcinogenic to humans," according to the International Agency for Research on Cancer (IARC)^{14,15}. The American Conference of Governmental Hygienists (ACGIH) recommends a ceiling limit of worker exposure to formaldehyde of 0.3 ppm¹⁶, and the Japan Society for Occupational Health has set an acceptable concentration of 0.5 ppm for workplace¹⁷.

This study measured the airborne concentration of formaldehyde during FC pulpotomy, for a one-time exposure and obtained findings that described methods for minimizing formaldehyde exposure, and for confirming the safety of the procedure.

Materials and Methods

An experimental model assuming the pulpotomy of the lower left second primary molar with a pre-procedure placement of a rubber dam was undertaken in a mannequin used for pediatric dentistry training and a dental cast according to clinical operative procedures (Fig. 1). Each single procedure used 0.05 ml of the tissue fixing fluid included in Palpack

Fig. 2 Patient's nasal aperture formaldehyde levels

At the patient's nasal aperture formaldehyde levels were 0.414 ± 0.085 ppm during no peripheral equipment, 0.158 ± 0.053 ppm during intraoral air evacuator, 0.252 ± 0.038 ppm during extraoral air evacuator, and 0.091 ± 0.012 ppm during both extraoral and intraoral air evacuators. A significant difference was found between the conditions.

V® (Neo Dental Chemical Products). Palpack V® as Buckley's solution (each 100 ml contains: 35 ml cresol, 19 ml formalin). On application of the swab soaked with the fixing fluid, a gas detector tube (Kitakawa Formaldehyde Detector Tube 713, Komyo Rikagaku Kogyo K.K.) and air sampler (S-21, Komyo Rikagaku Kogyo K.K.) were used to measure evaporated formaldehyde, with an air inflow of 350 ml/minute for ten minutes. This measurement repeated for 10 times. Before starting measurements, an air conditioning system was used to control the room at a temperature of 25°C (Ve-up II, Daikin Kogyo) and humidity of 35% (KC-W45, Sharp).

Measured locations

Five measurements were taken for each of the conditions described below. Locations measured for each condition were 1) at a position equivalent to the nasal aperture of the patient mannequin (10 cm), 2) at a position equivalent to the nasal aperture of the dentist (35 cm), and 3) at a position equivalent to the nasal aperture of the assistant dentist (40 cm). Each location was measured clinical position by ruler. Condition 1 used no peripheral equipment. Condition 2 used an intraoral air evacuator (6.2 m/s/cm^2) during measurements, Condition 3 used extraoral air evacuators (extraoral aspiration device for dentist and assistant dentist) (3.8 m/s/cm^2) during measurements, Condition 4 used both extraoral and intraoral air evacuators, and Background levels of formaldehyde were measured for complain the room before each

measurement. A Kruskal-Wallis test was used to for comparing the exposure FA levels of each location for each condition.

Results

Background levels were measured for Conditions 1 to 4 before experiment for all condition background levels of FA were not detected. No significant difference was found between background readings at the four conditions. Figure 2 shows measurements obtained at a position equivalent to the nasal aperture of the patient. At the patient's nasal aperture formaldehyde levels were 0.414 ± 0.085 ppm during Condition 1, 0.158 ± 0.053 ppm during Condition 2, 0.252 ± 0.038 ppm during Condition 3, and 0.091 ± 0.012 ppm during Condition 4. Figure 3 shows measurements obtained at a position equivalent to the nasal aperture of the dentist. Formaldehyde levels at the nasal aperture of the dentist were 0.115 ± 0.018 ppm during Condition 1, 0.042 ± 0.025 ppm during Condition 2, 0.081 ± 0.038 ppm during Condition 3, and 0.028 ± 0.012 ppm during Condition 4. A significant difference was found between the conditions. Figure 4 shows measurements obtained at a position equivalent to the nasal aperture of the dental assistant. Formaldehyde levels at the nasal aperture of the dental assistant were 0.067 ± 0.015 ppm during Condition 1, 0.038 ± 0.012 ppm during Condition 2, 0.059 ± 0.012 ppm during Condition 3, and 0.025 ± 0.019 ppm during Condition 4. Significant

Fig. 3 Dentist nasal aperture formaldehyde levels

At the nasal aperture of the dentist formaldehyde levels were 0.115 ± 0.018 ppm during no peripheral equipment, 0.042 ± 0.025 ppm during intoral air evacuator, 0.081 ± 0.038 ppm during extoral air evacuator, and 0.028 ± 0.012 ppm during both extraoral and intraoral air evacuators. A significant difference was found between the conditions.

Fig. 4 Dental assistant nasal aperture formaldehyde levels

At the nasal aperture of the dental assistant formaldehyde levels were 0.067 ± 0.015 ppm during no peripheral equipment, 0.038 ± 0.012 ppm during intoral air evacuator, 0.059 ± 0.012 ppm during extoral air evacuator, and 0.025 ± 0.019 ppm during extraoral and intraoral air evacuators. A significant differences were found between the conditions.

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Discussion

Pulpotomy is a popular procedure that is performed on a daily basis for cases of primary molar caries. In clinical practice, both pulp capping and vital pulpotomy are widely performed on primary teeth affected by caries that cause dental pulp exposure and localized pulpitis^{1,2}.

Buckley's Solution of formocresol (FC) devital-

izes the root pulp according to application time and concentration of formaldehyde. Maintaining healing radicular pulp tissue is an important outcome of an FC pulpotomy. Higher clinical rates of success are generally reported for pulpotomies conducted with FC, compared to calcium hydroxide⁴⁻⁸.

Allowing the exposed dental pulp to create the hard dentin tissue needed to cover itself is the ideal outcome of treatment. Pulp capping, which is a method of placing a preparation consisting mainly of calcium hydroxide in contact with the

pulp tissue to stimulate hard dentin tissue formation, and pulpotomy, are both common methods used in current clinical practice³⁾. A high pH of calcium hydroxide forms a necrotic layer of pulp tissue, promoting the ability of the pulp tissue to form hard tissue in the layer immediately below⁴⁾. Long periods of highly alkali conditions inside the dentin can cause persistent problems and necrosis of the pulp tissue surface, and prevent the acquisition of protective activity. This leads to inflammation even with a minor bacterial invasion, and in a significant number of patients, the lack of anti-inflammatory action leads to pulpectomy. In recent years, there has been research into highly biocompatible pulp capping materials and methods that are minimally irritating to pulp tissue, such as mineral trioxide aggregate^{18,19)}, ceramics³⁾, calcium carbonate²⁰⁾, lasers²¹⁾. FC pulpotomies in primary teeth are reported to achieve high rates of clinical success¹⁾.

This study measured concentrations of formaldehyde in the air during FC pulpotomy, and gained insights into methods for minimizing formaldehyde exposure and confirming the safety of the procedure. The acute toxicity of formaldehyde raises concerns over its effect on the human body, particularly its irritant effect on the mucous membranes, and more recently, suspicion over its role in causing sick house syndrome when used in building materials²²⁾. Use of formaldehyde-containing compounds is common in endodontic treatment of adults, and there are reports of allergy to preparations that contain FC^{23,24)}. Occupational exposure to formaldehyde causes irritation of the upper respiratory tract and asthmatic responses have been noted. A report²⁵⁾ also states the asthma-like symptoms caused by formaldehyde are not dependent on immunological mechanisms of activity.

According to Kramps²⁶⁾, formaldehyde-specific IgE could not be detected in 85 out of 86 people with opportunities for exposure to formaldehyde, with no IgE-mediated allergy symptoms reported. According to Salkie²⁷⁾, testing of 63 medical pathologists identified for high occupational exposure to formaldehyde by questionnaire (23 were also allergic to formaldehyde) detected no IgE antibodies for formaldehyde in any person. The likelihood that formaldehyde induces an allergic response mediated by formaldehyde-specific IgE is believed to be extremely low²⁸⁾. Formaldehyde appears to be capable of binding to DNA, a well known mechanism by which chemicals cause cancer. Formaldehyde appears

to be both an initiator and a late stage cancer causing chemical²⁹⁾.

Transdermal exposure to formaldehyde occurs with the patch test with a 1% to 2% aqueous solution of formaldehyde, while patients who exhibit hypersensitivity dermatitis have been reported as having reactions to a 0.003% aqueous solution of formaldehyde²⁶⁾. Patch test results have suggested the involvement of cellular immunity in formaldehyde exposure. The International Agency for Research on Cancer (IARC) has classified formaldehyde as Group 1 for carcinogenicity, IARC reported that formaldehyde is reasonably anticipated to be a human carcinogen based on limited evidence of carcinogenicity in human and sufficient evidence of carcinogenicity in experimental animals³⁰⁾. Cohort studies of emblers and other professional that use formaldehyde showed some excess risk of the nasal and brain cancer¹⁴⁾. The American Conference of Governmental Hygienists (ACGIH) recommends a ceiling limit for worker exposure of 0.3 ppm¹⁶⁾, and The Japan Society for Occupational Health sets an acceptable concentration of 0.5 ppm for the workplace³¹⁾. Compared to the WHO guideline value of 0.08 ppm for indoor air formaldehyde concentration in general indoor environments³²⁾, it has been suggested that, during FC pulpotomy, children are potentially exposed to these levels for a period of just five minutes. Results of the experiments undertaken by this study show that when local ventilation was not performed, formaldehyde values for the child patient as well as the dentist and assistant dentist became close to concentrations that cause discomfort (0.04 to 0.24 ppm), according to the measurement of International Program of Chemical Safety (IPCS)³³⁾. This study suggests that exposure to the concentrations of formaldehyde present during FC pulpotomy will cause feelings of discomfort but no subjective symptoms in the child, and carry a potential risk of formaldehyde exposure for the dentist and assistant dentist, depending on air direction, temperature and humidity in the examination room. The rubber dam is obligatory during the pulpotomy procedure in pediatric dentistry. Pulpotomy without a rubber dam increases the possibility of contamination of pulp and damage to the surrounding tissue from formaldehyde and irrigation solution. Rats administered formaldehyde in drinking water had increased incidences of forestomach papillomas in one study and leukemia and gastrointestinal tract tumors in another¹⁵⁾.

Results also show that use of local ventilation (unit-attached intraoral air evacuation 6.2 m/s/cm²) and extraoral aspiration equipment for the dentist and assistant dentist (3.8 m/s/cm²) during fixing with FC allow existing dental equipment to be used effectively in reducing airborne concentrations of formaldehyde. Increasing formaldehyde concentrations with increasing temperature also point to the importance of active ventilation, temperature and humidity control in the examination room during FC pulpotomies.

Conclusions

Based on this study's results, the following conclusions can be made:

1. Using of an extraoral or intraoral air evacuator during fixing of FC pulpotomy reduces formaldehyde exposure to patient, dentist, and dental assistant.
2. FC pulpotomy introduced concerns regarding exposure of the child's nasal mucosa to formaldehyde. Increasing formaldehyde concentrations with increasing temperature also point to the importance of active ventilation, temperature and humidity control in the examination room during FC pulpotomies.

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