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Effect of an Alcohol-Based Caries Detector on the Surface Tension of Sodium Hypochlorite Preparations

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The purpose of this study was to evaluate the effect of an alcohol-based caries detector (Kurakay) on the surface tension of a conventional sodium hypochlorite (NaOCl) preparation, and a product containing a surface-active agent (Chlor-XTRA). The surface tensions of the following solutions were tested: NaOCl, a mixture of NaOCl and Kurakay 9:1 w/w, Chlor-XTRA, a mixture of Chlor-XTRA and Kurakay 9:1 w/w. Ten measurements per test solution were made at 20 °C, using an optical method called the "Pendant drop method", with a commercially available apparatus. The addition of Kurakay reduced the surface tension for NaOCl ($p<0.05$) whilst no significant difference was detected for Chlor-XTRA ($p>0.05$). Statistically significant differences between the NaOCl and Chlor-XTRA groups were found ($p<0.05$). The addition of an alcohol-based caries detector resulted in a reduction of the original surface tension values for NaOCl only. Taking into account the fact that mixtures of NaOCl and Kurakay have been used to assess the penetration of root canal irrigants *in vitro,* the related changes in surface tension are a possible source of bias.

Key Words: alcohol, caries detector, root canal irrigation, sodium hypochlorite, surface tension.

Introduction

Because of the inability to analyse commonly used irrigant penetration and distribution in the root canal system, researchers have recently relied on the radiographic tracing of radiopaque solutions (1-10), or in the observation of cleared teeth (1-3), using sodium hypochlorite (NaOCl) solutions made directly visible by the addition of dyes.

These experimental mixtures have been assumed *a priori* to behave like commonly used root canal irrigants. However, some of their physical properties, for example their surface tension, might have an influence on their penetration in experimental conditions. Surface tension is defined as the force per unit length exerted by one surface, and depends on the forces that attract molecules at the surface towards the bulk of a liquid (11). The cohesive forces between liquid molecules are responsible for the surface tension of the liquid. Considering a liquid drop, surface tension tends to minimize the surface area by making the drop spherical, while gravity deforms the drop by elongating a pendant drop or flattening a sessile drop (12). These effects are mathematically reflected in the Laplace equation of capillarity (13). Many conditions can affect the surface tension of liquids, such as temperature, surfactants, and the impurities of the liquid (11). Measuring surface tension thus becomes a crucial step in the development and quality control of formulations.

As the surface tension of a solution has a direct impact on its ability to spread in contact with a surface (14), the mixtures used to study dynamics of root canal irrigation should ideally present with values similar to those of commonly used root canal irrigants, to allow experimental results to be extrapolated to clinical practice. Sodium hypochlorite (NaOCl) mixtures with Kurakay Caries Detector (Kurakay) (Kurakay America Inc., New York, NY, USA), have been used in previous investigations (1-2). Accoding to the manufacturer, the Kurakay Caries Detector contains a mixture of dyes and propane-1,2-diol, with the latter component being an alcohol, and known to be incompatible with oxidizing agents. Chlorine-containing solutions such as NaOCl are oxidizing agents (15), and the addition of a different alcohol, ethanol, as a surface tension depressant increases the penetration of NaOCl containing mixtures *in* vitro (16). Therefore, a better understanding of the behaviour of NaOCl and Kurakay mixtures is necessary.

The aim of this study was to assess the effect of adding Kurakay on the surface tension of a conventional NaOCl preparation, and a product containing a surface-active agent.

Material and Methods

The surface tension of the mixtures was tested with an optical method, the so called "Pendant drop method", using the Phoenix 300 system (Goniometer and software by SEO-Surface Electro Optics, Suwon City, Gyunggido, South Korea), according to the manufacturer's instructions. In brief, the test liquid is pushed automatically (computer-controlled) out of a syringe needle until it almost detaches from the tip. Following this, the drop shapes are captured by an incorporated digital charged-coupled device camera. The surface tension of the liquid is automatically estimated by the apparatus. The equations describing the drop profile are derived from the Young-Laplace equation. Using the selected plane method the surface tension is rapidly obtained. This method calculates the surface tension by measuring the equatorial diameter, d_e, and the diameter d_s of a pendant drop in a plane located at a distance d_e from the tip of the droplet.

Surface tension (ST) can be mathematically calculated by the following equation:

$$ST=(\Delta\rho \cdot g \cdot d_e^2)/H$$

Where $\Delta\rho$ is the density difference of fluids, g is the gravitational acceleration, and H is the correction factor.

All measurements were carried out at 20 °C, in order to replicate the conditions of previous assays, as this value is often described as equivalent to "room temperature" (17). Distilled water was used for calibration prior to the assays. The test solutions were: 6% NaOCl (Vista Dental Products, Racine, WI, USA), a mixture of 6% NaOCl and Kurakay 9:1 w/w, Chlor-XTRA (Vista Dental Products), a mixture of Chlor-XTRA and Kurakay 9:1 w/w. According to the manufacturer Chlor-XTRA has a 3-6% active chlorine concentration, and contains Triton-X, a non-ionic surfactant, of an undisclosed concentration.

Ten measurements per test solution were made. The mean and standard deviation were calculated for each group of 10 samples. Comparisons between the two groups were performed using a non-parametric test, the Mann-Whitney U test. The level of significance was set at 0.05.

Results

The means and standard deviations of the surface tension of the groups are presented in Table 1. The Mann-Whitney U test showed statistically significant differences among the tested groups ($p<0.05$), apart from between the Chlor-XTRA groups. The addition of Kurakay reduced the surface tension of 6% NaOCl ($p=0.004$) whilst no significant difference was detected for Chlor-XTRA. Chlor-XTRA presented significantly lower surface tension values than NaOCl ($p=0.001$). Statistically significant differences were also found when comparing Chlor-XTRA+Kurakay and NaOCl+Kurakay ($p<0.001$).

An incidental finding of the investigation was colour loss for the mixtures occurring within minutes for NaOCl, and several hours for Chlor-XTRA

Table 1. Surface tension values (mN/m ± SD) of the solutions tested.

Group (N=10)	Mean (mN/m) ± SD
6% NaOCl	56.1 ± 1.8[a]
NaOCl (90%) +Kurakay (10%) w/w	36.7 ± 3.5[b]
Chlor-XTRA	16.9 ± 2.0[c]
Chlor-XTRA (90%)+Kurakay (10%) w/w	18.2 ± 1.6[d]

Groups identified by different superscript letters indicate statistically significant difference (Mann-Whitney U test). When comparing (a) with (b) the p value was 0.004; when comparing (c) with (a) the p value was 0.001; when comparing (d) with (b) the p value was <0.001. SD: standard deviation

Discussion

The addition of Kurakay to NaOCl led to a statistically significant reduction in surface tension, as expected. The increase in value for the Chlor-XTRA following the addition of Kurakay, while not statistically significant, may be explained because of the interactions between the different components within the mixtures, particularly the surface-active agent and the propane-1,2-diol. Regarding the discoloration and degradation observed in the preparations, we consider that this is probably due to the oxidation of the complex aromatic structure of the dye (acid red). This is significant from an experimental design standpoint, as it would make the mixtures less likely to be detected with the passing of time, thereby making it harder to observe their penetration, and introducing a possible source of bias. Therefore pilot studies looking into the stability of dyes mixed with the specific chlorine-containing preparations should be carried out prior to the performance of full-scale research. It is also necessary to consider the possible differences in the chemical characteristics of different batches of commercially available products.

Several methods have been developed to measure surface tension (du Nuoy ring, Wilhelmy plate, capillary rise, shape analysis of pendant drop, maximum bubble pressure, drop weight, amongst other) (18). The pendant drop technique measures surface tension with an optical tensiometer, based on the liquid's drop shape, which depends on the balance between interfacial and gravitational forces (12). It is commonly used to study physical properties in basic sciences and has been previously used in endodontic research (19).

The role of surface tension and other physical properties in root canal irrigant penetration and distribution need further understanding. Although several benefits have been suggested, the reduction in surface tension has been shown to improve penetration in the main canal only, by using experimental models that do not necessarily correspond to the naturally wet tooth, such as glass tubes and extracted teeth kept in unspecified storage conditions (16,20,21). Though it has been traditionally suggested that surface tension influences the re-wetting of dry surfaces only (17), a recent investigation on non-dehydrated dentine has shown that the addition of a surfactant to NaOCl reduces its contact angle and surface tension (19). Therefore, surface tension might still be relevant in assays where teeth have been cleared, as they are normally imbibed in substances like methyl salicylate, and *in vivo*, as endodontically treated teeth present with an unbound water content of around 12% in weight (22). The surface tension of radiopaque solutions used to study root canal irrigation *in vitro* should be assessed with special care, as these are often used in teeth that might have lost their intrinsic moisture content during storage and preparation procedures. A similar situation will occur if either plastic or glassware is used. Other factors that influence the surface tension of liquids are their temperature and how smooth and clean the surface is (11). Therefore, experimental models should ideally aim to mimic the irregularities of the root canal surface and the normal body temperature. Clinicians and researchers should be aware that mixing materials, such as root canal medicaments or irrigants, can have chemical consequences that may lead to antagonistic interaction with subsequent negative effects in their performance (23-25).

In summary, the addition of an alcohol-based caries detector leads to a reduction in surface tension values for NaOCl alone, and there are no statistically significant differences for Chlor-XTRA, a NaOCl containing a surface-active agent.

Resumo

O objetivo deste estudo foi avaliar o efeito de um detector de cárie com álcool (Kurakay) sobre a tensão superficial de um preparado convencional de hipoclorito de sódio (NaOCl) e um produto contendo um agente surfactante (Chlor-XTRA). Foram testadas as tensões superficiais das seguintes soluções: NaOCl, uma mistura de NaOCl e Kurakay na proporção de 9:1 em peso, Chlor-XTRA e um mistura de Chlor-XTRA e Kurakay na proporção de 9:1 em peso. Dez medidas foram feitas com cada solução, a 20 °C, utilizando um método óptico chamado "Método da gota pendente" (*Pendant drop method*) usando aparelhos disponíveis. Adição do Kurakay reduziu a tensão superficial do NaOCl (p<0,05), mas não houve diferença significante para Chlor-XTRA (p>0,05). Foram encontradas diferenças estatisticamente significantes entre os grupos NaOCl e Chlor-XTRA (p<0,05). Adição de um detector de cárie com álcool resultou na diminuição do valor original da tensão superficial apenas para NaOCl. Considerando que as misturas de NaOCl e Kurakay tem sido usadas para estudar a penetração *in vitro* dos irrigantes radiculares, as diferenças acima são uma possível fonte de desvio nos resultados.

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