Original Article

The assessment of chlorine concentrations in sodium hypochlorite solutions used by dental practitioners in Morocco: A survey

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Abstract

Introduction: The purpose of this survey was to assess the concentration of chlorine in sodium hypochlorite solutions (NaOCl) used as root canal irrigation solutions by the dentists in Marrakech, Morocco.

Materials and Methods: A survey was carried out among 74 practitioners registered with the Moroccan Order of Dentists, of whom 36 (48.6%) were men and 38 (51.4%) were women. A self-administered questionnaire was used. Among the questions, participants were asked about the number of treatments performed per week, the type of irrigation solution used, and the storage of the irrigation solution. After this interview, a 30 mL sample of that solution was sent to a laboratory to determine the amount of chlorine by iodometric titration. Jamovi version 1.8.1/ANOVA and the *t*-test were used to perform the statistical analysis ($P < 0.05$).

Results: All the practitioners except two used the NaOCl as an irrigant. Besides, 84.7% prepared their solutions. The solutions were stored 63.8% of the time in opaque containers. The mean percent of chlorine concentration was 0.95% ± 0.68%. The concentration was also higher in the ready-to-use solutions (1.39%) than those prepared in the office (0.87%). Moreover, this difference was statistically significant ($P = 0.01$).

Conclusion: The results confirmed that the NaOCl is the solution that practitioners use mostly. The conditions of dilution and storage are inappropriate, and the concentration is very low at 0.95%.

Keywords: Concentration, endodontics, irrigation, sodium hypochlorite, storage

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INTRODUCTION

Despite modern root canal preparation techniques using the Nickel-Titanium Endodontic Instruments, more than 35% of root canal surfaces may be uninstructed after the shaping phase.[1,2] To clean all the walls of the canals, it is important to use an abundant amount of a root canal irrigation solution.[3] The ideal solution has been described by Zehnder.[4] It must be nontoxic for the tissues, it should have a low allergic potential, an antiseptic action with a broad spectrum, a solvent capacity on living and/or necrotic tissues, and finally, it must be capable of dissolving the organic component of the smear layer.[4] Several solutions have been studied to analyze their different

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properties, but the ideal solution meeting all the above criteria has not been reported yet.[5-7] Sodium hypochlorite is the irrigation solution that has most of these properties. It has a broad spectrum and can dissolve the organic components of the tissues, which are located in the canal but also those that make up the smear layer. However, it remains toxic at certain concentrations.

Several authors, therefore, recommend its dilution to limit cytotoxic actions. At a certain dilution, the solutions become less toxic but they also lose their solvent capacities and their antiseptic actions.[8,9] Usually, the hypochlorite is used at concentrations varying from 0.5% to 5.25%.[10-12] However, the consensus seems to be around 2.5% for a solution, which is sufficient for the desired dissolving and antiseptic actions and less toxic than the 5.25% or higher concentrations.[9-11]

However, sodium hypochlorite solutions (NaOCl) is not very stable and can undergo degradation with time, with temperature, and with exposure to light. Its stability depends on several factors related to storage and conservation precautions.[12-14] However, despite all the recommendations on the use of NaOCl, there is still a large number of practitioners who continue to prepare their solutions themselves and store them under inappropriate conditions.[9-11]

Exposure to light, air, and contact with metal or organic contaminants can rapidly alter chlorine, which leads to a decrease in its antiseptic and solvent properties. According to some authors, the chlorine content decreases as soon as the bottle is opened.[14,15] Other parameters such as storage, time, and temperature can also degrade the amount of active chlorine.[14] The study conducted by Pişkin and Türkün showed that all the solutions recorded a decrease in active chlorine over time. This decrease was more rapid with solutions stored at temperatures of 24°C compared to those stored at 4°C.[12]

Since root canal irrigation greatly influences the success of endodontic treatments, it is important to analyze the quality of the irrigation solution. The aim of this study was to assess the concentration of chlorine in NaOCl used as root canal irrigation solutions by the dentists in the city of Marrakech, Morocco.

MATERIALS AND METHODS

The study design

The study design was approved by the Medical and Ethics Committee of the Faculty of Dental Medicine at the International University of Rabat-Morocco. The ethical approval number (IRB) was CUMD/FIMD 001/21. Besides, the participation in this study was voluntary.

A threepart questionnaire was distributed and collected. The first part aimed to collect general information (demographic) such as (age, gender, seniority, types of continuous education in endodontics). The second part inquired about the number of endodontic treatments performed per week, the type of irrigation solution used, the method of preparation, and the storage of the irrigation solution. Moreover, the second part of the survey consisted also of questions regarding the sodium hypochlorite's use as an irrigation solution. In addition, the survey also included questions about the chlorometric degree and the percent concentration of chlorine in the NaOCl solution.

After collecting the survey answers from the participants, a volume sample of 30 mL of the irrigation solution was collected and saved in an opaque bottle. This sample was sent directly to the RADEEMA Chemistry Laboratory located in Marrakech, 4000 Sidi Moussa-Morocco, to determine the amount chlorine in the sodium hypochlorite's solution.

The iodometric titration method was used to evaluate the concentration of chlorine, as it was described by Fabian and Walker.[16] Thus, 10 mL of the solution taken from the practitioner were diluted in a flask with 50 mL of ultra-pure water. Then, 5 mL of 6 mol/L glacial acetic acid and 1 g of potassium iodide (KI) were added to this solution. After the oxidation reaction of the hypochlorite's ions in an acidic medium, iodine is released (I_2) and the solution turned brown. With a sodium thiosulfate solution of 0.1 mol/L concentration, a titration of the released iodine was carried out. At the end of the titration approaches, which took around 3 min, the color of the solution changed from orange, brown to light yellow. At this point of the reaction, 1 mL of starch solution was added to the sample, which gave the solution a blue color. The titration with the thiosulfate continued until the complete dissipation of the blue color indicating the end of the reaction. Each milliliter of the 0.1 mol/L sodium thiosulfate solution used was equivalent to 3.722 mg of sodium hypochlorite. The colorimetric degree of the solution was determined from the volume of thiosulfate used. This figure has been converted into a percentage of active chlorine by the Gay-Lussac multidirectional colorimetric degree converter to facilitate comparisons. The average concentration was calculated, and the comparisons were statistically carried out with the Jamovi version 1.8.1 using the ANOVA and the *t*-tests. The level of significance was set at $P < 0.05$.

RESULTS

Demographic information

The survey was carried out among practitioners (n = 110) regularly registered with the Order of Dentists of Morocco. Among the 86 who were randomly selected, only 74 agreed to participate in this study; 36 (48.6%) were men and 38 (51.4%) were women. The selection was performed by putting the names of 110 dentists in a ballot box and by picking randomly 86 names.

The most representative age group was 30–39 years old (55.5%) followed by 40–49 years old (32.4%) then 23–29 years old, and the last age range was 50–59 years old. 73% of the practitioners work in an individual practice, the remaining 27% or 20 practitioners work in a group practice. Furthermore, there is no difference in the type of practice regardless of the practitioner's gender (P = 0.145). In addition, 50% of the practitioners had more than 10 years of experience. For the rest of the sample, 25.7% had <5 years of experience and 24.3% had between 6 and 10 years of clinical practice. According to seniority, the distribution was almost similar in the different age groups.

All practitioners state that they follow continuing education sessions in endodontics, 25.7% have a university degree in endodontics, documents of proof, or certificates in endodontics; 64.9% have benefited from practical training workshops; and the remainder 9.5% regularly participated in Endodontics' Congress. In this present study, most practitioners knew the ideal concentration of sodium hypochlorite.[13] Fifty-four practitioners (76.1%) estimated this concentration to be between 2.5% and 5%.

The number of endodontic treatments and the use of the rubber dam

The number of treatments performed per week varied. Twenty-six (35.6%) were performed between 6 and 10 per week and 29 (39.7%) between 10 and 20 endodontic treatments per week. Finally, 12 practitioners performed more than 20 root canal treatments per week. Of the 74 surveyed, only 8 (11%) practitioners used the rubber dam during endodontic treatments; and the rest 66 (89%) performed their endodontic treatments without a rubber dam.

Types of sodium hypochlorite solutions and methods of preparation

All the practitioners except two used the sodium hypochlorite's solution as an irrigation solution when they performed endodontic treatment; 15.3% used the NaOCl solution out-of-the-bottle and 84.7% prepared their solutions in their practice. Most of the time, it was the assistant who prepared the solution. The dilution was made using more than 84% of running tap water. The most used solutions were the ACE® brand (68.3%) followed by the Javel brand at 14%, and the rest was made up of other brands such as Maxis®, Clarel®, Syrias® (the companies of these brands are in Casablanca, Morocco). The concentration of these brands was 3.8%.

Storage modes and duration of the solution

The solutions prepared were stored in 63.8% of the cases in opaque containers and 36.2% of the time in transparent vials. Plastic containers (66.7%) were the most used containers, unlike the ones made of glass (33.3%). These solutions were left 95.6% of the time at room temperature, and only 4.4% of the solutions were stored under 4°C. Very few solutions (5.9%) were prepared just before the treatment. Moreover, the rest of the solution was prepared and stored, respectively, for 24 h (27.9%), for 1 week (48.5%), for 15 days (16.2%), and for 1 month (1.5%).

Chlorine concentration in irrigation solutions

The mean percent of chlorine concentration was 0.95% ±0.68% with a maximum of 2.94% and a minimum of 0.046%. Twenty-five practitioners (33.78%) used a solution with a concentration <0.5%, 35 (47.29%) between 0.5 and 1.5%, and 12 practitioners (16.21%) utilized a solution with a concentration varying between 1.6% and 2.5%. Finally, the last two practitioners (2.70%) used a solution with a concentration >2.6%.

Male dentists used a higher concentration of chlorine 1.07% ± 0.71% compared to female 0.83% ± 0.6% but the difference was not statistically significant (P = 0,14). The concentration was also higher (1.39%) in the ready-to-use solutions compared to those prepared in the office (0.87%), and this difference was statistically significant (P = 0.01). Furthermore, dentists who tended to use this type of solution utilized more the rubber dam during the root canal treatment, but the difference was not significant (P = 0.08). On the other hand, a significant difference was noted between the solutions prepared by the practitioners 1.16% ± 0.74% and those prepared by the assistants 0.77% ± 0.58% (P = 0.021). Regarding the seniority of the practitioners, there was no significant difference in the chlorine concentration used (P = 0.34). Furthermore, depending on the type of activity the practitioners conducted, there was no statistically significant difference in the chlorine concentration of the hypochlorite solutions (P = 0.39). Furthermore, the concentration was higher in solutions stored in an opaque container (0.8%)

than in transparent containers (0.5%), but again this difference was not statistically significant ($P = 0.37$).

DISCUSSION

The type and quality of root canal irrigation solutions have been the subject of several studies. Some have focused on the properties of solutions and others on the methods of use and possible associations.[6,9,10,17] In this present study, only 74 practitioners responded to the survey, for a response rate of 86.04%. This response rate is within the average of the rates found in the literature for similar studies.[14,15] Moreover, all the practitioners state that they have benefited from continuous training in endodontics, and they know the ideal consensus concentrations of the NaOCl irrigating solution, which is between 2.5% and 5.25%. In addition, these percent concentrations are within the range used by various scientific societies (0.5%–6%).[18]

In the present study, NaOCl was used as an irrigation solution during root canal treatments by 97.29% of practitioners. This result showed that practitioners trust this solution and are in compliance with the latest scientific recommendations. This proportion of practitioners who used NaOCl as an irrigation solution was higher than the percentage found in some countries. In a research investigation conducted by Al-Omari in 2004, he found that in Jordan, only 32.9% of practitioners use NaOCl as an irrigation solution and 33.6% of practitioners use hydrogen peroxide.[19] In addition, Clarkson's study in Australia showed that 94% of endodontic specialists used NaOCl compared to <75% of general practitioners.[15]

With the number of treatments carried out per week in Marrakech, more than 70% of these solutions are used within a week, and very few are kept beyond 15 days. The findings of this study concluded that NaOCl solutions with low chlorine concentrations were degraded faster than the solutions with higher concentrations. This was confirmed by the research work done by Johnson and Remeikis, who had reported that the effective shelf life of NaOCl ranged from 1 day to 10 weeks in concentration of 5.25%, 2.62%, and 1.0%. The tissue-dissolving ability of the 2.62% and 1% concentrations remained relatively stable for 1 week after dilution then rapidly deteriorated, while the 5.25% solution remained stable for at least 10 weeks.[20]

Only 11% of the participants used the dental rubber dam during endodontic treatment while others experienced difficulty to use it. This low percentage might be due to several reasons, such as the educational training of the practitioner, the time it takes to apply the rubber dam, and sometimes the refusal of the patient. Similarly, this low number in the rubber dam use was registered in other parts of the world. It was recorded that only 18% of the practitioners in Southern Nigeria used the rubber dam.[21] Furthermore, in another study, it was confirmed that the rubber dam was used more by the endodontists than by the generalists.[12] If the rubber dam is not used in these types of treatments, there is a risk of accident with the NaOCl in the event of extrusion beyond the apex. Moreover, it can also cause tissue injury such as pharyngitis, burns, and even violent reactions in some patients, and it could also affect the taste.

In a study of 643 practitioners from the United Kingdom, NaOCl was used by 71% of them. Moreover, they also used the dental rubber dam during the endodontic treatment.[22] In Senegal, a study carried out among practitioners in Dakar reported that 98.5% of practitioners used NaOCl, but the majority of endodontic treatments were carried out without the dental rubber dam.[11] Similarly, in the USA, 91% of practitioners declared that NaOCl was their first irrigation solution. The dental rubber dam was routinely used by all endodontic specialists.[17]

In conclusion, these various findings showed that the use of NaOCl at ideal concentrations largely depended on the use of the dental rubber dam, which constitutes a barrier against inhalation and ingestion of the root canal irrigant.[17,22]

In this report, despite the high rate of practitioners using NaOCl, ready-to-use solutions stored in appropriate containers represented only 15.3% of users. The rest (84.7%) were prepared it by dilution in the cabinets by the practitioners themselves or their assistants. The main reason behind that was the cost of the products. In addition, running tap water which probably contains inorganic salts and metal ions was used to dilute the concentration of the NaOCl solution. This can act on chlorine and cause its rapid degradation and consequently reduce its effectiveness.[11] Furthermore, there is no practitioner, who uses deionized or distilled water to dilute the solution. In addition, the storage conditions of diluted solutions were unsuitable because more than 1/3 were saved in transparent containers and 95.6% were left at room temperature; and some practitioners also kept the solutions in plastic syringes. Most syringes had metal needles that corrode when they were in contact with NaOCl.[11] Furthermore, more than 2/3 (66.2%) of the solutions were stored for more than a week, and only ready-to-use solutions were kept in their original bottles.

According to Basudan, 70% of the dentists in Riyadh city had dental assistants prepare and dilute the NaOCl solution for them. Onequarter of these dentists (25.4%) had the solution prepared just before treatment, 9.6% had it prepared once a week, and half of the dentists (50%) did not know when it was prepared.[23] NaOCl was stored at room temperature by 75.5% of the dentists, and 8% stored it in the refrigerator. Regarding the storage containers, 41.4% reported the use of opaque containers, 39.5% stored the solution in clear containers, and 17.2% did not know how it was stored.[23] The present study had many similarities with Basudan's research group, in terms of storing the solution in clear containers, leaving the solution at room temperature, and the fact that the assistant prepared most of the time the solution. On the other hand, the differences were more dentists in Riyadh prepared the solution just before treatment, and in Marrakech, more dentists stored the solution in opaque containers. Another study conducted by Dash *et al*. in 2017 explored the quantity of chlorine, the pH of a diluted NaOCl solution, the effect of temperature, and time on NaOCl storage. They concluded that when performing a dilution, it is better to use the NaOCl solution, which was stored at room temperature, within 3 h. In addition, the team confirmed that storing this solution at 4°C would increase its shelf life and that heating the solution to around 65°C before irrigation would make it more effective.[24]

Moreover, the chlorine concentrations found in this present study varied between 0.046% and 2.94%. The mean was 0.95% ±0.68%. A study carried out in Australia in 2003 showed that 90% of the practitioners used a hypochlorite solution with a 1% concentration.[15] In the USA, 79.85% of practitioners used a hypochlorite solution with a concentration varying between 2.5% and 5.25%. Of these, 57% used a hypochlorite solution dosed at more than 5%. These high concentrations of NaOCl are explained by the fact that very few diluted solutions are used and that all the participants are specialists who are members of the American Association of Endodontists and that they systematically placed the dental rubber dam during the root canal treatment.[17]

The low observed concentrations of the NaOCl solutions in some studies may hinder the quality of root canal cleaning because during the root canal preparation, more than 35% of surfaces are not touched. They should be cleaned of debris by irrigation solutions. The persistence of debris can serve as a substrate for intracanal bacteria. The use of low concentrations could be explained in this study on the one hand by the conditions of dilution and by the storage of the prepared solutions and on the other hand by the nonsystematization of the dental rubber dam. Moreover, to perform an efficient root canal cleaning, the practitioner needs to use both a good instrumentation and an ideal NaOCl concentration, which has an antibacterial effect and a tissue dissolving property.

The current study had also several limitations such as: it was conducted only in Marrakech, and from the selected 110 dentists, only 74 answered the survey. Besides, this was a preliminary study and we are aiming to use other parameters in the future. In addition, sodium hypochlorite 2.5% (8° colorimetric degree) is the consensus solution recommended by scientific societies; it is sufficiently dosed for its antiseptic and solvent actions and is less toxic compared to concentrations of 5.25%. However, its use without a dental rubber dam is very unpleasant for the patient, toxic for the oral mucous membranes and can cause violent reactions for some patients. The results of the present study would be helpful to practitioners to improve the quality of sodium hypochlorite used during the root canal instrumentation procedures. This preliminary study must be supplemented by further studies to analyze all the factors that may influence the success rate of endodontic treatment. In addition, a planning to conduct a national survey about the use of dental rubber dams by dentists in Morocco will be done.

CONCLUSION

Sodium hypochlorite is the most widely used solution among Moroccan dentists. The prepared solution in the office is more prevalent than the ones that are already made but the conditions of dilution and storage by some practitioners are inappropriate. The concentration of chlorine is very low (0.95%).

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Conflicts of interest

There are no conflicts of interest.

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