0099-2399/95/2105-0253$03.00/0
JOURNAL OF ENDODONTICS

Printed in U.S.A.
VOL. 21, NO. 5, MAY 1995

SCIENTIFIC ARTICLES

Stability of Various Sodium Hypochlorite Solutions

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Although the manufacturers use at least a 2-yr expiration date for sealed undiluted NaOCl solutions, chemical stability of NaOCl may be adversely affected by many factors. The purpose of this study was to investigate the effects of storage temperature, concentration, and time on the stability on three different brands of commercial household bleaching agents as a source of NaOCl, and to compare the stability of these brands. All solutions showed degradation versus time; however, this degradation occurred very slowly except for the group of solutions containing 5% available chlorine stored at 24°C. Solutions containing 0.5% available chlorine stored at 4°C and 24°C and 5% solutions stored at 4°C showed satisfactory stability at 200 days. No significant difference was found among three brands in respect to their chemical stability.

The disinfecting and deodorizing properties of chlorine were first recognized at the beginning of the nineteenth century (1). Hypochlorites are the most useful of the chlorine disinfectants (2). Sodium hypochlorite (NaOCl) was first recommended as an antiseptic solution by Henry Dakin for irrigating soldier's wounds during World War I (3). In 1920, Crane (4) described the use of Dakin's solution, 0.5% NaOCl, in endodontic therapy. NaOCl solution is still the most favored endodontic irrigant in modern endodontic practice because of its antibacterial, lubricative, and tissue-dissolving properties (5). Although NaOCl has many advantages, the lack of chemical stability is an important disadvantage of this solution (1, 2, 6–8). In many countries, the NaOCl solutions used in dentistry are supplied from household bleaching agents (9). The most popular one among these solutions is Clorox, which was first introduced as a root canal irrigation solution by Lewis in 1954 (10). The manufacturers use at least a 2-yr expiration date for sealed undiluted NaOCl solutions (11). However, there is some concern regarding the chemical stability of the solution after bottles have been opened, because it is known that stability of NaOCl solutions may be affected by temperature, concentration, pH, light, the presence of catalysts and organic material, and the presence of atmospheric carbon dioxide (1, 2, 6, 11–13).

The purpose of this study was to investigate the effects of storage temperature, concentration, and time on the chemical stability of three different brands of commercial household bleaching agents as a source of NaOCl, and to compare the stability of these brands.

MATERIALS AND METHODS

Three brands of household bleaching agents (Hypo, Koruma, Adana; Clorox, Clorox Co., Oakland, CA; Domex, Lever, Istanbul) were used in this study. All brands of agents supplied by the manufacturer had the same production date. Solutions were obtained ~2 wk after their production and immediately subjected to the test procedures. To evaluate the effect of different concentrations and storage temperature on the stability of solutions, 12 groups were prepared as shown in Table 1.

Household bleaching agents were used as supplied by the manufacturer and readily checked for available chlorine in the solutions. 0.5% solutions were prepared by dilution (1:10) with sterile distilled water.

The solutions were protected from the light in tightly covered amber glass bottles. Each bottle was totally full at the beginning of the study period and was opened only during sampling.

To determine the stability of solutions, an assay that measures the percentage of available chlorine, an iodometric titration, as described by the TS 3664 (14) was used. Two measurements for each solution were taken at days 0 to 15 then 22, 29, 36, 43, 60, 95, 131, 177, and finally at 200 days. Mean values of two measurements were calculated. A total of 25 values were obtained for each brand.

The pH of solutions was measured using a digital pH meter at days 0, 60, and 200.

Data were statistically analyzed by paired t test and analysis of variance.

RESULTS

At the end of the study period, 200-day percentages of available chlorine loss are shown in Table 2.

All groups showed a negative correlation between the available chlorine titer and time.

Paired t test indicated that 5% solutions stored at 24°C showed a higher decomposition rate than ones stored at 4°C in all brands ($p < 0.05$). However, the decomposition rate of 0.5% solutions of

TABLE 1. Distribution of groups

Group No.	Brand of Agent	% Available Cl	Storage Temperature
1	Hypo	0.5 ± 0.02	24°C
2	Hypo	0.5 ± 0.002	24°C
3	Hypo	5 ± 0.02	4°C
4	Hypo	0.5 ± 0.002	4°C
5	Clorox	5 ± 0.02	24°C
6	Clorox	0.5 ± 0.002	24°C
7	Clorox	5 ± 0.02	4°C
8	Clorox	0.5 ± 0.002	4°C
9	Domex	5 ± 0.02	24°C
10	Domex	0.5 ± 0.002	24°C
11	Domex	5 ± 0.02	4°C
12	Domex	0.5 ± 0.002	4°C

all brands did not show statistically significant differences at storage temperatures of 4°C and 24°C ($p > 0.05$).

Analysis of variance showed that the differences of decomposition rate observed in 5% and 0.5% solutions stored at 4°C and 24°C did not create statistically significant differences among the three brands ($p > 0.05$).

Loss of available chlorine versus time was not significant except for 5% solutions stored at 24°C. Degradation curves of these solutions are shown in Fig. 1.

A gradual decline in the pH of all solutions was noted over time, proportional with loss of available chlorine. pH data are shown in Table 3.

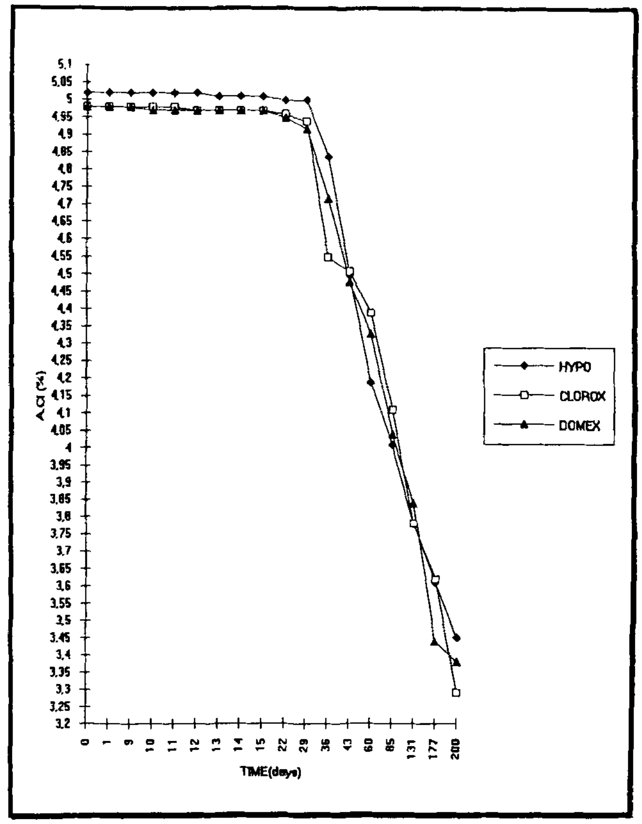

FIG 1. Degradation curves of 5% solutions stored at 24°C.

DISCUSSION

It is suggested that the NaOCl solutions are inherently unstable and when used for disinfecting, they should be prepared fresh daily (15). However, other studies have indicated that, under varying conditions of storage and use, chlorine solutions are stable over long period (2, 8, 15). All three brands of solutions tested in this study showed satisfactory stability at 200 days when stored at suitable conditions.

According to results of this study, storage temperature is an important factor in the stability of NaOCl solutions. As seen in Fig. 1, there is no difference in decomposition rates of both concentrations at the storage temperature of 4°C. But for solutions stored at 24°C, the solutions containing 0.5% available chlorine kept their stability, the others showed 31 to 34% available chlorine loss at the end of a 200-day period. Hoffman et al. (2) had also shown that storage at 4°C kept the solutions stable for at least 2 yr. However, at 24°C, the concentrations of available chlorine had fallen to <50% of the original.

As can be seen from Fig. 1, the concentration of the NaOCl is another important factor in the deterioration of the solutions. The solutions containing 5% available chlorine have shown rapid decomposition at 24°C at the end of the test period. However, similar findings were not observed in 0.5% solutions. This finding is in agreement with previously published reports (2, 7) Hoffman et al. (2) showed that a more rapid deterioration occurred in the undiluted solution (~10% available chlorine) than in diluted ones (1:2 or 1:10). Pappalardo et al. (7) demonstrated that Dakin's solution (0.5% available chlorine) had a higher decomposition rate than diluted forms. However, their finding of 70% loss of available chlorine contrasts with the maximal 4.20% loss found in this study. An interpretation cannot be made, because those authors did not explain the storage conditions and temperature of solutions used in their study.

It is a well-known fact that the decomposition rate increases when the pH of solution decreases. Therefore, it is suggested that the pH of solution should be >9 (1). Manufacturers generally keep the solutions at or above pH 11 (8). In this study, pH values of solutions were between 10.98 and 12.11. No significant difference was observed among them (Table 3). A gradual decrease of pH over time in this study is consistent with Johnson and Remeikis's (6) findings.

The following conclusions can be drawn from the results of this study: (a) all brands of solutions tested in this study can be used as an endodontic irrigating solution in respect of their chemical stability when stored at suitable conditions; (b) storage temperature and concentration of solution are important factors that may effect

TABLE 2. Percentage of available chlorine loss at the end of 200 days

	Group No.											
	1	2	3	4	5	6	7	8	9	10	11	12
Cl loss (%)	31.07	2.40	0.99	0.60	33.93	4.20	0.80	0.80	32.12	2.61	0.80	0.60

TABLE 3. pH decrease of solutions versus time

	Group No.											
	1	2	3	4	5	6	7	8	9	10	11	12
pH day 0	12.11	12.03	12.21	12.03	11.16	10.98	11.16	10.98	12.00	11.96	12.10	11.96
pH day 60	11.91	11.79	12.09	11.90	10.98	9.96	11.10	9.99	11.87	11.62	12.00	11.78
pH day 200	11.66	11.32	11.86	11.76	9.64	9.31	11.01	9.83	11.75	11.39	11.88	11.70

the decomposition rate; and (c) the pH of the solutions used in this study did not affect stability.

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Still very basic research as yet and the long torturous path of human clinical trials lie ahead—but promising indeed.

William McMaster