Statistical analysis

Because the microleakage scores were obtained from teeth that did not fit the normal distribution, descriptive statistics of the microleakage scores are shown with the smallest, largest, and median values [interquartile range (IQR)]. Kruskal–Wallis nonparametric analysis of variance (ANOVA) was used to compare the effect of the irrigation solutions into the gingival and occlusal surfaces. When differences were found using the Kruskal–Wallis nonparametric ANOVA, a Bonferroni-corrected Mann–Whitney test was used to make *post-hoc* bilateral comparisons to determine the differences between the groups. The Mann–Whitney test was used to evaluate the differences between microleakage scores on the occlusal and gingival surfaces. Microsoft Excel 2003 and SPSS for Windows Ver. 15 software programs were used to conduct the statistical analysis and calculations. A level of $P \leq 0.05$ was adopted as an indicator of statistically significant differences.

RESULTS

Gingival surface results

When the microleakage scores observed on the gingival surface in five different groups were examined statistically, the median microleakage score differed from the others in at least one group ($\chi^2 = 13.292$; $P = 0.010$). Bonferroni correction *post-hoc* pairwise comparison was used to determine differences between groups. We observed statistically significant differences between NaOCl and the control ($Z = 2.866$; $P = 0.004$), and EDTA ($Z = 3.082$; $P = 0.002$) and CHX ($Z = 2.797$; $P = 0.005$) groups, but there were no significant differences between the other groups. These results show that NaOCl irrigation solution causes more microleakage than all of the other irrigation solutions [Figure 2].

When the microleakage scores of the groups that used SA were examined, we found that the median microleakage score of at least one group was different from that of the others ($\chi^2 = 20.759$, $P < 0.001$). Bonferroni correction *post-hoc* pairwise comparison was used to determine differences between groups.

Statistically significant differences were observed between the control and EDTA + SA ($Z = 3.161$; $P = 0.003$), and the NaOCl + SA and EDTA + SA ($Z = 3.683$; $P = 0.001$) groups. Microleakage scores were similar between the other groups. The median gingival microleakage score of the EDTA + SA group was significantly lower than that of the NaOCl + SA group [Figure 3].

Occlusal surface results

When the microleakage scores observed on the occlusal surface in five different groups were examined statistically, the median microleakage scores of the groups were similar ($\chi^2 = 8.847$; $P = 0.065$) [Figure 4].

When the microleakage scores of the groups that used SA were examined, we found that the median microleakage scores differed between the groups ($\chi^2 = 28.596$; $P < 0.001$). Bonferroni correction *post-hoc* pairwise comparisons were used with the aim of determining the differences between the groups.

Statistically significant differences were found between the control and EDTA + SA ($Z = 4{,}668$; $P < 0.001$), control and sterile saline + SA ($Z = 3.636$; $P = 0.001$), and control and CHX + SA ($Z = 3.884$; $P < 0.001$) groups, and there were no significant differences between the other groups [Figure 5]. The differences between the NaOCl and NaOCl + SA groups, and the NaOCl + SA and sterile saline + SA groups were not statistically significant because of the Bonferroni correction.

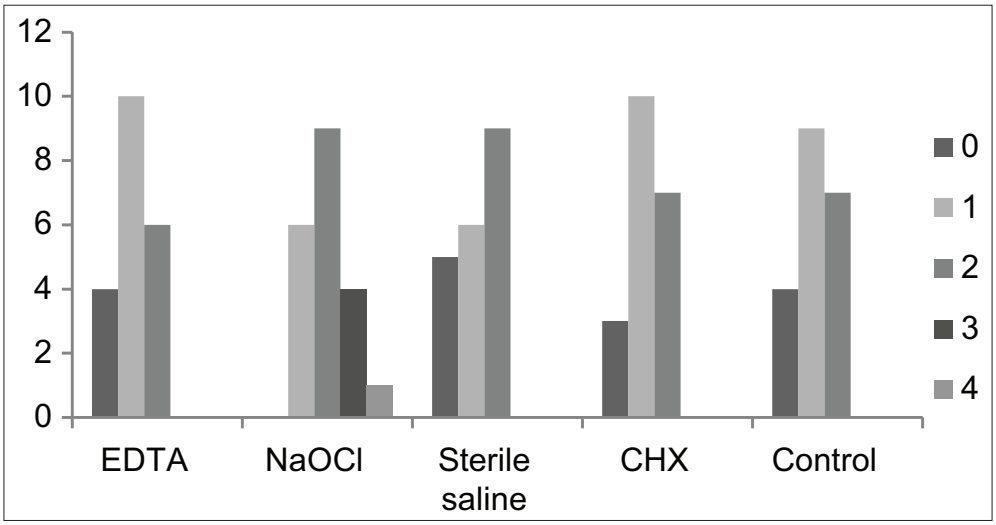

Figure 2: Microleakage scores on the gingival surfaces in the groups in which SA was not applied

Comparisons of gingival and occlusal surfaces

When the median microleakage scores observed on the gingival and occlusal surfaces were examined in the control group, the score on the gingival surface was 2 (IQR = 1), while that on the occlusal surface was 0 (IQR = 1). The median microleakage scores were the same in the control,

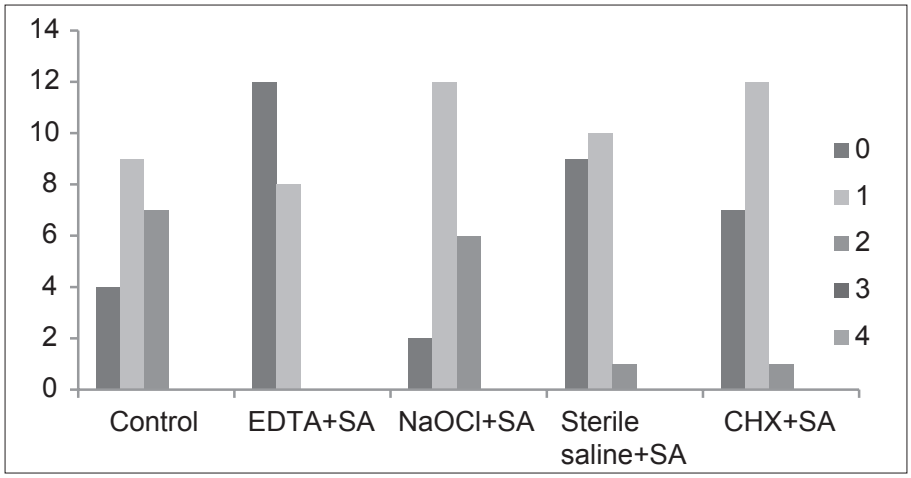

Figure 3: Microleakage scores on the gingival surfaces in the groups in which SA was applied

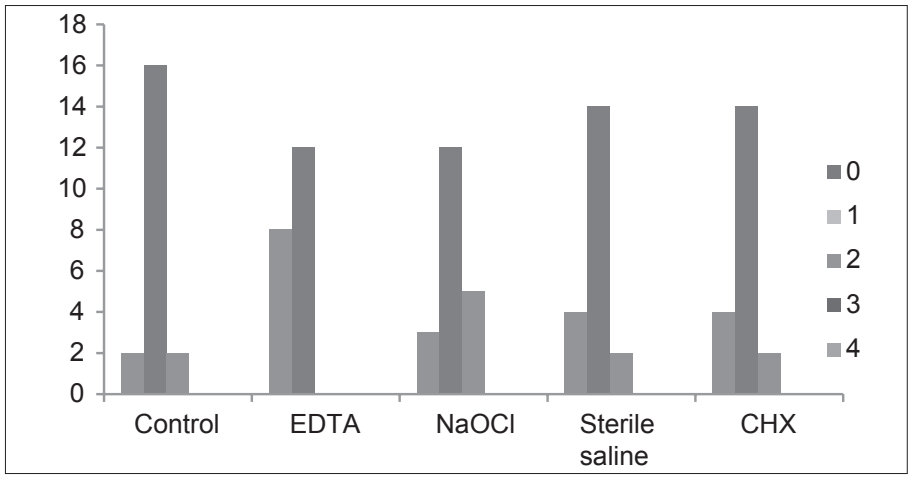

Figure 4: Microleakage scores on the occlusal surfaces in the groups in which SA was not applied

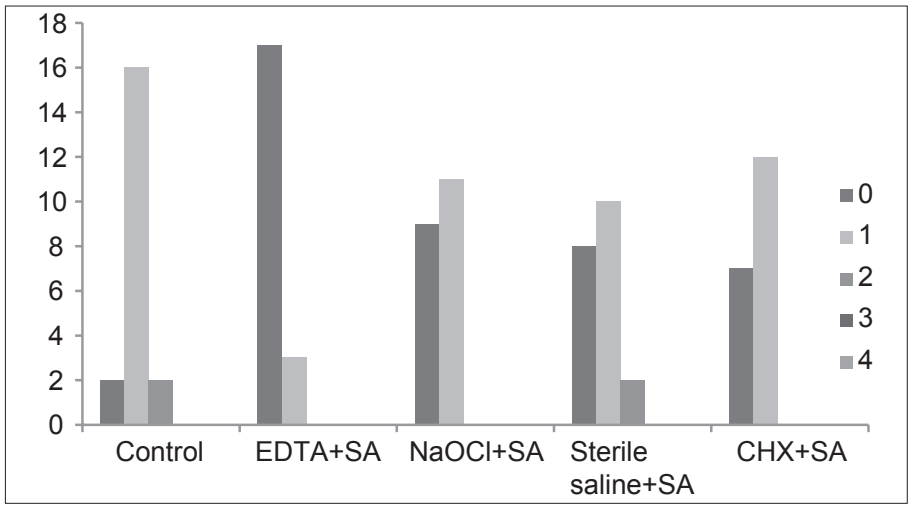

Figure 5: Microleakage scores on the occlusal surfaces number in the groups in which SA was applied

sterile saline, and CHX groups in both the gingival and occlusal surfaces. Additionally, in the EDTA group, the median microleakage score on the gingival surface was statistically higher than the median microleakage score on the occlusal surface ($Z = 3.162$; $P = 0.002$). Similarly, in the NaOCl group, the median microleakage score on the gingival surface was statistically higher than the median score of microleakage on the occlusal surface ($Z = 3.626$; $P < 0.001$). In the CHX + SA group, the median microleakage score on the gingival surface was 1 (IQR = 1) while that on the occlusal surface was 0 (IQR = 1). The median microleakage scores of the gingival and occlusal surfaces were observed to be statistically the same in the control, CHX + SA, and sterile saline + SA groups. In the EDTA + SA ($Z = 2.236$; $P = 0.025$) and the NaOCl + SA groups, the median microleakage score on the gingival surface was statistically higher than that on the occlusal surface ($Z = 3.606$; $P < 0.001$).

DISCUSSION

NaOCl remains the most widely recommended irrigating solution for endodontic therapy because of its capacity to dissolve necrotic tissue remnants.[14-16] It is a strong biological oxidant and deproteinization agent that undergoes destruction as sodium chloride and oxygen. Oxygen has been shown to reduce bond strength. It also negatively affects polymerization.[17,18] Reactive residual free radicals and adhesive vinyl free radicals formed during the implementation of light are available on the dentin surfaces irrigated with NaOCl. Limited or late polymerization may occur as a result.[16]

A few studies have examined the effect of irrigants on endodontic dentin permeability and adhesion.[19] The vast majority of these studies have reported that NaOCl reduces bonding to dentin.[16]

Moosavi *et al*.[9] reported that irrigation with NaOCl during root canal therapy has a negative effect on the microleakage of resin composite restorations. Extended restoration time did not compensate for the negative effect of NaOCl. Shinohara *et al*.[10] evaluated the effect of three different adhesive systems on the microleakage of class V restorations after the use of NaOCl. As a result, even when adhesive systems were used, use of NaOCl still increased the microleakage.

In our study, when the microleakage scores between groups were examined on gingival surfaces, statistically significant differences were seen between the NaOCl and control groups and the other groups. When the occlusal surface microleakage scores between the groups were examined statistically, no significant differences between the NaOCl group and other groups were detected. When the results were evaluated on the gingival surface, the teeth on which the NaOCl irrigation solution was applied had greater microleakage levels than all of the other groups.

The use of EDTA helps smear layer removal by forming calcium complexes with calcium formations in the root canal dentin or smear layer.[1] Various concentrations and combinations of EDTA are used in root canal treatment.[4] The effectiveness of these solutions depends on the root canal length; material penetration depth; dentin hardness; and material application time, concentration, and pH. Despite the fact that EDTA is usually used at concentrations of 10-17%, the most preferred concentration is 17%.[20,21]

Jahromi *et al*.[22] investigated the effect of three irrigation solutions [doxycycline, citric acid, and Tween 80 (MTAD); citric acid; and EDTA/NaOCl] on the coronal microleakage of root canals. They stated that use of MTAD, citric acid, and EDTA/NaOCl all resulted in less microleakage compared with normal saline, which was likely to be due to various factors, including their ability to remove the smear layer. In our study, when the gingival and occlusal surface microleakage scores were compared, no significant difference was seen between the EDTA and control groups.

CHX is an antibacterial solution that has been commonly used in both medicine and dentistry since the 1970s.[1] It affects the metabolic activity of bacteria, is bacteriostatic at low concentrations, and functions as a bactericidal that can irreversibly collapse the cellular content at high concentrations.[23] CHX is especially effective against microorganisms such as *Streptococcus mutans* and is available on the market as solution, toothpaste, mouthwash, gel, and irrigation solution.[20,21]

Nassar *et al*.[24] assessed the adhesion of Epiphany self-etch root canal sealer to dentin treated with different irrigation regimens. They reported that CHX had neither a negative nor a positive influence on bond strength.

Sung *et al*.[19] evaluated the microleakage of class V composite restorations after irrigation of an acid conditioner with various solutions. As a result, they reported that CHX has no effect on the microleakage. Similar to this result, while gingival and occlusal surface microleakage scores between the groups were examined statistically, there was no significant difference between the CHX and control groups in our study.

SA, a sodium salt of ascorbic acid that fixes oxygen, is used to prevent oxidation. Celik *et al*.[1] suggested that if bond strength decreases on NaOCl-treated dentin due

to the oxidative effect of NaOCl, the reaction can be reversed using a biocompatible antioxidant such as SA. Ascorbic acid and sodium salts of SA are well-known antioxidants that are capable of reducing the diversity of oxidative components, especially free radicals. In addition, the use of SA has been reported to reduce the microleakage caused by H_2O_2 and NaOCl irrigation solutions.[12]

The real reason for the increased adhesion is the chemical reaction between SA and the surface. In a study, the effect of 10% SA on NaOCl-treated dentin using different self-etching and etch-and-rinse adhesives was studied. In this study, SA was applied for 10 min to eliminate the harmful effects of NaOCl to dentin surface, and increased adhesion grades and statistically significant results were obtained. As a result, the researchers stated that sodium ascorbate application after NaOCl treatment improved the bond strength values.[1]

Kimyai *et al*.[25] compared the effects of the hydrogel and solution forms of SA on the microleakage of composite restorations after a nonvital bleaching procedure using 10% carbamide peroxide. They reported that use of 10% carbamide peroxide significantly increased the microleakage of composite restorations when bonding was performed immediately after nonvital bleaching. The compromised sealing ability of composite restorations is reversed by use of either form (hydrogel and solution) of SA as an antioxidant.

Vongphan *et al*.[12] aimed to determine the microtensile bond strengths of total etching adhesive systems to pulpal chamber wall dentin after treatment with various irrigants. They reported that the use of NaOCl significantly reduced the bond strengths of the total etching adhesives and the application of SA to sodium hypochlorite-treated dentin significantly improved the bond strength.

Celik *et al*.[1] evaluated the effects of SA on the bond strengths of different adhesive systems on NaOCl-treated dentin. For this purpose, they mounted the teeth in a self-curing resin and irrigated the dentin surfaces with NaOCl for 10 min. Half of the specimens were treated with SA for 10 min. They reported that SA application after NaOCl treatment improved the bond strength values.

In our study, we determined that the amount of microleakage on the gingival and occlusal surfaces in groups treated with SA was lower compared with the groups in which SA was not applied, and the use of SA showed the best results on the gingival and occlusal surfaces after EDTA application.

The median microleakage scores were the same in the control, sterile saline, CHX, CHX + SA, and sterile saline + SA groups for the gingival and occlusal surfaces. Additionally, in the EDTA, NaOCl, EDTA + SA, and NaOCl + SA groups, the median microleakage score on the gingival surface was statistically higher than the median microleakage score on the occlusal surface.

CONCLUSION

In our study, the NaOCl irrigation solution caused greater microleakage than any other irrigation solution on both gingival and occlusal surfaces. When the groups with SA were compared with those without SA, significantly less microleakage was observed on both gingival and occlusal surfaces in the groups with SA.

In conclusion, SA application reduces the microleakage on gingival and occlusal surfaces. In addition, SA application is most effective after the use of EDTA irrigation solution on both gingival and occlusal surfaces.

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