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Original Research Article

In Vitro Assessment of pH and Surface Contact Angle of Triton as a Novel All-In-One Disinfectant

Bilge Özcan[1], **Lena Bal**[2], **İsen Güleç Koçyiğit**[3], **Aybüke Karaca Sakallı**[3*], **Görkem Liman**[4]

[1]*Specialist Dentist, DentTarz Academy Dental Clinic, Altay, Ankara/ Türkiye.*
[2]*Assistant Professor, Department of Restorative Dentistry, Faculty of Dentistry, Ankara Medipol University, Ankara, Türkiye.*
[3]*Assistant Professor, Department of Endodontics, Faculty of Dentistry, Ankara Medipol University, Ankara, Türkiye.*
[3*]*Assistant Professor, Department of Endodontics, Faculty of Dentistry, Ankara Medipol University, Ankara, Türkiye.*
[4]*Research Assistant, Department of Physical Chemistry, Gazi University, Ankara, Türkiye.*

ABSTRACT

Introduction: This study compared the pH levels and surface wettability of conventional endodontic irrigants with Triton, a novel all-in-one solution. Sodium hypochlorite (NaOCl), ethylenediaminetetraacetic acid (EDTA), chlorhexidine (CHX), and Triton were tested.

Materials and Methods: Each irrigant (10 mL) was stored in glass tubes (n=10). pH was measured with an electronic pH meter on days 1, 2, 5, 7, and 14, with three repeated measurements at each time point. For contact angle analysis, 26 extracted anterior teeth were sectioned, standardized, and exposed to the irrigants. Angles were measured using a goniometer device (SEO Phonix Contact Angle, Republic of Korea). Data were analyzed using repeated-measures ANOVA followed by Bonferroni-adjusted pairwise comparisons ($p<0.05$).

Results: Significant differences were found among irrigants for both pH and contact angle ($p<0.05$). All solutions showed lower pH values at day 14 compared to day 1 ($p<0.05$). In the Triton group, values at days 1, 2, and 5 were not significantly different, whereas decreases were observed at days 7 and 14 ($p<0.05$). CHX (14.73°) and NaOCl (15.82°) demonstrated the lowest contact angles, Triton an intermediate value (19.35°), and EDTA the highest (21.46°).

Conclusion: Triton maintained stable pH values during the first week and provided satisfactory dentin wettability, superior to EDTA but lower than CHX and NaOCl. These properties support its potential as a next-generation irrigant that combines multiple functions in a single solution.

Keywords: Conservative treatment; Dentin; Endodontics; Hydrogen-ion concentration; Surface properties; Wettability

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INTRODUCTION

The aim of endodontic treatment is the comprehensive removal of both vital and necrotic tissues, as well as microorganisms, from the root canal system.[1] The smear layer is composed of debris and bacterial residues generated during the shaping of root canals and cavity preparation, consisting of both organic and inorganic components.[2] Studies have demonstrated that the removal of the smear layer allows for enhanced penetration and improved sealing, as the sealants are able to establish a mechanical connection within the dentinal tubules.[3,4] Complete removal of the smear layer is essential for the success of root canal treatment.[5] Achieving this initial objective requires the combined use of mechanical instrumentation and irrigation, along with ensuring proper coronal restoration to prevent bacterial leakage.[6,7]

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Corresponding author: Assistant Professor Aybüke Karaca Sakallı Department of Endodontics, Faculty of Dentistry, Ankara Medipol University, Eti, Celal Bayar Blvd, no: 88/1, 06570 Çankaya, Ankara, Türkiye.
E-mail: aybuke.karaca@ankaramedipol.edu.tr

Ideally, the physical properties and chemical composition of dentin should remain unaffected following the use of irrigating solutions in the root canal and dentinal tubules. However, studies have demonstrated that irrigating solutions, despite their beneficial effects, cause alterations in both the organic and inorganic components of dentin.[8-10] These structural changes may result in reduced bond strength, alterations in micro and nano-hardness, and increased surface roughness.[11] The acidic or alkaline pH of root canal irrigants, along with their direct contact with periapical and coronal tissues, can significantly impact both the treatment prognosis and the dentin surface within the cavity.[12] Sodium hypochlorite (NaOCl) is regarded as the gold standard irrigant in endodontic treatment.[13,14] Although the average pH of sodium hypochlorite is approximately 8.5, high concentrations of hypochlorous acid promote protein degradation and enhance reactivity with amines. To maintain the stability of sodium hypochlorite, the pH should not drop below 9.[15] Furthermore, it is recommended that the pH range be maintained between 11 and 12, as the toxicity of hypochlorous acid increases with its concentration, and it becomes cytotoxic within this pH range.[16]

Chlorhexidine (CHX) is commonly used as an irrigation solution at a 2% concentration, and its effect persists for a duration ranging from 72 hours to 12 weeks. The antibacterial efficacy of CHX is optimal within a pH range of 5.5 to 7. At lower concentrations, CHX exhibits a bacteriostatic effect, while at higher concentrations, it exerts bactericidal properties. However, its efficacy is significantly diminished in the presence of organic tissue due to its pH dependency. Despite its bactericidal action, CHX lacks the ability to eliminate biofilms and other organic debris effectively. A key factor contributing to the widespread use of CHX is its ability to adhere to hard tissues, thereby maintaining its antibacterial activity. However, the primary limitation of CHX is its insolubility in tissue. Additionally, CHX functions as a matrix metalloproteinase (MMP) inhibitor, exhibiting broad-spectrum anti-collagenolytic activity.[17]

Ethylenediaminetetraacetic acid (EDTA) is the most commonly used for removing the inorganic component of the smear layer, functioning as an effective chelating agent. An initial application of a 15% EDTA solution with a pH of 7.3 is recommended. The interaction of dentin calcium ions with the solution leads to the formation of calcium chelates. Although EDTA effectively removes the smear layer formed during root canal preparation, several studies have reported its potential adverse effects on the radicular dentin beneath the smear layer. Specifically, the application of 17% EDTA in root canals for durations exceeding one minute may cause dentin erosion in the root canal and coronal cavity.[18,19]

The wettability of a liquid on a solid surface is determined by the relative surface free energy of the solid, which can be evaluated through the contact angle formed by the liquid. A lower contact angle indicates higher surface free energy. In endodontics, the contact angle between an irrigant and the dentin surface plays a critical role.[20]

The contact angle of irrigating solutions indicates their ability to establish contact with and spread across dentin surfaces. A lower contact angle reflects improved wettability, allowing the solution to spread more effectively over the dentin substrate. This enhanced spreading capacity facilitates deeper penetration into dentinal tubules and irregularities, thereby improving the overall cleaning and disinfection potential of the irrigant within the root canal system.[21]

Triton (Brasseler, Savannah, USA) is a mixture composed of two solutions, recently developed for use as a cavity and canal irrigant. A limited number of studies have assessed the efficacy of Triton on dentin tissue.[22-25] This study aims to compare the pH values and contact angle of Triton, an all-in-one formulation, with those of commonly used root canal irrigants in endodontics.

The null hypotheses were defined as follows: (1) Triton would not exhibit stable pH values over the specified time period and (2) there would be no significant differences in contact angle values between Triton and the other irrigants.

MATERIALS AND METHODS

This study was approved by the Ethics Committee of Ankara Medipol University on 29 August 2025, in accordance with the Declaration of Helsinki (Reference number: E-85859696-604.01.01-7331).

The research was conducted in full compliance with the ethical principles set out in the Declaration of Helsinki, and informed consent was obtained from all participants.

Irrigant solutions and pH measurements

Four irrigants were tested in this study: NaOCl, EDTA, CHX and Triton (a novel all-in-one solution). Information regarding the composition of these solutions is presented in Table 1. For pH measurements, each solution was distributed into 10 glass tubes (10 mL each), with a total of 40 tubes prepared (n = 10 per group). Outside of measurement periods, the tubes were stored in an incubator set at 25 °C.

pH measurements were performed on days 1, 2, 5, 7, and 14 using an electronic pH meter (OHAUS, Aquasearcher, USA) in accordance with the manufacturer’s instructions. At each time point, three repeated measurements were obtained per tube, and the mean values along with standard deviations were recorded. During measurement, the indicator probe was immersed in the solution, and the sample was gently agitated for 30 seconds without the electrode tip contacting the glass surface. The pH value was documented once it was stable. To ensure accuracy, the probe tip was rinsed between each measurement. During storage, all samples were kept in tightly sealed, capped glass tubes to prevent evaporation. The solution volumes were visually inspected before and after storage, and no measurable volumetric loss was observed.

Contact angle measurements

For contact angle analysis, 26 extracted human anterior teeth with intact roots and free of caries, cracks, or previous endodontic treatment were selected. The teeth were stored in 0.1% thymol solution until use, then rinsed thoroughly with distilled water. A standardized notch was prepared at the cemento-enamel junction, and each tooth was sectioned buccolingually using a diamond disc under water cooling, yielding two halves per tooth. This procedure provided a total of 52 dentin surfaces for analysis.

The dentin surfaces were flattened and standardized using 600-grit silicon carbide abrasive paper under water irrigation to produce a uniform smear layer. After preparation, surfaces were rinsed with distilled water and gently air-dried. For each specimen, a droplet of irrigant solution (NaOCl, EDTA, CHX, or Triton) was applied to the dentin surface using a micro-syringe. Contact angles were immediately measured using a goniometer device (SEO Phonix Contact Angle Analyzer, Suwon, Republic of Korea) equipped with high-resolution imaging and analysis software. All measurements were conducted under controlled laboratory conditions (room temperature and humidity) to minimize variability.

The contact-angle measurements were based on the single processed output values generated by the device software for each droplet. Because the software provided only a single processed value per droplet and raw replicate outputs were not retained, standard deviations could not be calculated; therefore, only mean contact-angle values are reported.

Statistical analysis

Sample size calculation was performed using GPower 3.1 software (Heinrich Heine University, Düsseldorf, Germany). Because no study

Table 1. Irrigation solutions, product name, and contents

Irrigation Soluiton	Product Name	Content
NaOCl	Wizard (Istanbul,Turkey)	%5.25 NaOCl
EDTA	Microvem (Sakarya,Turkey)	%5 EDTA
CHX	Microvem (Sakarya,Turkey)	%2 CHX
ALL-IN-ONE	Triton (Brasseler, USA)	Part-A: 1,2,4-Butanetricarboxylic acid, 2-phosphono- Citric acid, Sodium dodecylbenzenesulfonate, Alcohols, C9-11, ethoxylated, liquids, Polyethylene glycol 4-(tert-octylphenyl) ether, liquid, Sodium lauryl sulfate, 2-Ethylhexyl sodium sulfate, Sodium cumenesulphonate, Sodium hydroxide Part-B: Sodium hypochlorite, Sodium hydroxide

with analytical parameters directly comparable to those of the present research was identified in the literature, the effect size could not be derived from a fully matched model. Therefore, we referred to the closest available study evaluating similar contact angle related surface characteristics to guide the estimation.[21] Based on the variability reported in that study, an effect size within the moderate to large range (approximately f = 0.40) was considered a reasonable approximation for planning the analysis. Using α = 0.05 and a power of 0.80, the sample-size calculation indicated that at least 13 surfaces per group were required; therefore, 26 teeth were included to obtain 52 dentin surfaces.

The pH data were analyzed using IBM SPSS Statistics software (version 20.0, Chicago, IL, USA). Normality was assessed with the Shapiro–Wilk test. Levene's test was used to assess the homogeneity of variances, and the results confirmed that this assumption was satisfied, supporting the use of ANOVA for both outcomes. As the outcome variable, pH values over time were analyzed with repeated-measures ANOVA and Bonferroni correction, while post hoc Tukey multiple comparison tests were applied when appropriate. Contact angle values among the four irrigants were compared using one-way ANOVA with Bonferroni-adjusted post hoc tests. Statistical significance was set at $p<0.05$.

RESULTS

The changes in pH values are presented in Table 2. All four irrigants showed a statistically significant decrease in pH between day 1 and day 14 ($p< 0.05$). The smallest absolute changes over this period were observed in CHX and EDTA, while NaOCl and Triton exhibited slightly larger reductions. In the Triton group, no significant differences were observed between days 1, 2, and 5; however, significant decreases occurred on days 7 and 14 ($p<0.05$). Additionally, no significant differences were found between the measurements on days 2, 5, and 7 ($p>0.05$).

The mean contact angles obtained from 26 extracted anterior teeth, based on the processed output values of the measurement software, are presented in Table 3. Statistical analysis revealed a significant difference among the groups ($p<0.05$). Pairwise comparisons revealed that CHX and NaOCl had significantly lower contact angles than both Triton and EDTA ($p<0.05$). In addition, Triton exhibited a significantly lower contact angle compared with EDTA ($p<0.05$). These findings indicate superior wettability for CHX and NaOCl, intermediate wettability for Triton, and the lowest wettability for EDTA. Contact angles of irrigation solutions are illustrated in Figure 1.

Table 2. pH changes of solutions

Irrigation Solution	Day 1	Day 2	Day 5	Day 7	Day 14
EDTA^{A}	10.71(±0.16)^{Aa}	10.47(±0.09)^{Ab}	10.41(±0.06)^{Ab}	10.32(±0.06)^{Ac}	10.34(±0.07)^{Ac}
NaOCl^{B}	12.21(±0.16)^{Ba}	12.06(±0.03)^{Bab}	11.97(±0.13)^{Bb}	11.80(±0.28)^{Bb}	11.62(±0.58)^{Bb}
TRITON^{C}	9.90 (±0.79)^{Ca}	9.55(±0.47)^{Cab}	9.32(±0.30)^{Cac}	9.22(±0.17)^{Cbc}	9.14(±0.04)^{Cc}
CHX^{D}	7.61 (±0.30)^{Da}	7.39(±0.03)^{Dab}	7.29(±0.11)^{Db}	7.27(±0.15)^{Db}	7.25(±0.15)^{Db}

The p-value was calculated using the one-way ANOVA test
** Indicates significance at $p<0.05$.
a,b,c Superscript differences in the same row indicate significant ($p<0.05$) differences between groups. Capital letters demonstrate irrigant pH values. The post hoc test was conducted using Tukey's HSD test.

Table 3. Mean contact angle values of the tested irrigation solution

Irrigation Solution	Mean Contact Angle (°)
CHX	14.73^{a}
NaOCl	15.82^{b}
TRITON	19.35^{c}
EDTA	21.46^{d}

Values represent the mean contact angle (°) measured on dentin surfaces. Lower values indicate greater wettability.
Different superscript lowercase letters indicate statistically significant differences between groups ($p<0.05$).

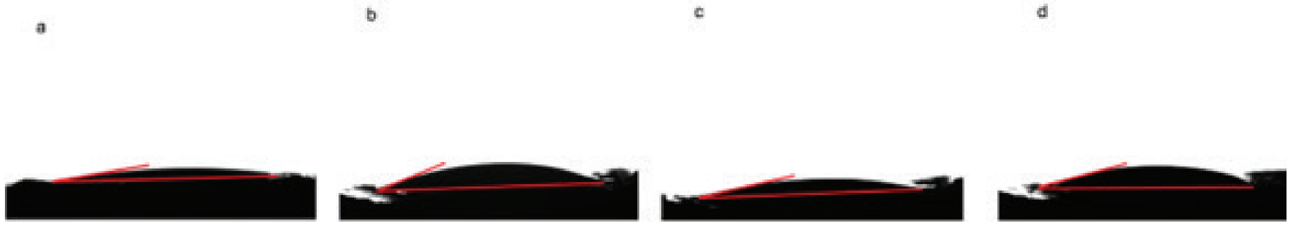

Figure 1. The contact angle of irrigation solutions reflects the wettability of the surface. A lower contact angle indicates higher surface wettability, whereas an increased contact angle corresponds to reduced wettability and higher surface energy. a) demonstrates a contact angle of CHX of 14.73°. b) demonstrates a contact angle of EDTA of 21.46°. c) demonstrates a contact angle of NaOCl of 15.82°. d) demonstrates a contact angle of Triton of 19.35°.

DISCUSSION

In this study, the pH values and surface contact angles of commonly used irrigation solutions and the all-in-one solution Triton were compared and analyzed. The efficacy of irrigants is influenced by factors such as root canal length, penetration depth of the substance, duration of application, dentin hardness, as well as the concentration and pH value of the solutions.[26-28] Based on the findings of this study, the first null hypothesis—stating that Triton would not exhibit a stable pH the specified time period—was confirmed. However, the second null hypothesis—predicting no significant differences in contact angle values among the irrigants—was rejected.

The most widely used method for measuring pH values is pH measuring electrodes. These electrodes consist of an electrochemical sensor comprising a measuring electrode and a reference electrode. Compared to alternative methods, pH electrodes provide the highest sensitivity and the broadest measurement range for pH determination. Consequently, in this study, pH measurements were conducted using a pH electrode. To ensure standardization in this study, Eppendorf tubes were used, as different pH values can be measured in various regions of the root of extracted teeth.[29] In addition to pH evaluation, contact angle analysis was employed to assess the wettability of irrigants on dentin surfaces, since this parameter reflects the ability of a solution to spread and penetrate into dentinal tubules. The combination of pH stability and favorable contact angle is therefore critical for predicting the overall disinfection potential and clinical effectiveness of new all-in-one irrigants such as Triton.

In this study, a newly developed irrigation solution was used in addition to the conventional irrigants. According to the manufacturer, unlike traditional irrigants or other advanced 2:1 formulations, Triton functions in a completely different mechanism. The NaOCl-free components in Triton enable a lower concentration of NaOCl to effectively dissolve residual organic debris with minimal buffering. The synergistic and simultaneous dissolution of organic and inorganic debris enables clinicians to use smaller volumes of irrigation solution while achieving optimal clinical efficiency.

Containing a lower concentration of NaOCl, a surfactant, and a combination of chelating agents, Triton is the first irrigation solution to offer the combined benefits of NaOCl, EDTA, and CHX in a single-step application.[22] Our comprehensive literature review revealed no studies evaluating the pH value of the Triton solution, suggesting that the results of this study may address this gap in the literature.

Previous studies have reported that the pH of 5.25% NaOCl ranges between 10.8 and 13.2. In the present study, the pH value was measured at 12.21 on day 1 and 11.80 on day 5. The average pH range of the EDTA solution has been documented as being between 7 and 9.[30]

As there are no existing studies or information regarding the pH range and changes in the Triton solution in the literature or on the manufacturer's website, a direct comparison could not be made.[22] The pH value, resulting from the mixture of various chemicals in Triton's part A and part B solutions using an injector, indicates that this solution may become one of the commonly used options in routine practice. Furthermore, the combination of an organic tissue-dissolving agent like NaOCl with an inorganic tissue-dissolving irrigation solution, such as citric acid, within the root canal offers not only ease of use and cost-effectiveness but also the potential to reduce environmental waste due to the decreased use of syringes. However, further clinical studies are necessary to evaluate the antibacterial efficacy and determine whether this new all-in-one solution can effectively replace the irrigation solutions currently used in routine practice.

If the contact angle is less than 90°, the liquid (sealer) is considered to wet the substrate, whereas a value greater than 90° indicates non-wettability. A contact angle of 0° represents complete wetting. Therefore, the contact angle provides an inverse measure of wettability, meaning that the lower the contact angle, the greater the wettability. Contact angle measurement is a useful indicator of the wetting behavior of any tested liquid. This angle is formed by a liquid at the three-phase boundary where the liquid, gas, and solid intersect.

The clinical effectiveness of an irrigating solution is not determined by a single property but rather by the interplay of its physicochemical characteristics. For instance, a solution with a high pH may exert strong antimicrobial activity; however, if its surface wettability is poor, its ability to adequately spread over the canal walls and penetrate into dentinal tubules is compromised, thereby limiting its disinfection potential. Conversely, a solution with excellent wettability but low pH and limited dentin-dissolving capacity may also demonstrate restricted effectiveness. Thus, both pH and wettability can be regarded as fundamental determinants of the clinical performance of irrigants. These parameters are particularly critical when evaluating newly developed all-in-one solutions such as Triton, BioPure MTAD, or QMix, as they provide essential benchmarks for assessing their potential efficacy prior to clinical application.

Within the limitations of this study, experimental conditions do not fully simulate the clinical environment, which could influence the behavior of irrigants *in vivo*. Only two parameters (pH stability and contact angle of irrigation solution) were assessed in this study; other crucial factors, such as antibacterial activity and dentin–sealer interactions, were not evaluated. These could be considered for future research. The observation period was limited to 14 days, and measurements were taken from standardized tooth sections, which might not represent clinical variations. Additionally, long-term and clinical studies are necessary to validate these findings.

CONCLUSION

Considering the limitations of this *in vitro* study, it can be concluded that Triton exhibited relative pH stability during the initial 7 days and demonstrated intermediate contact angle values that indicate satisfactory wettability on dentin surfaces. These combined properties suggest that Triton possesses favorable physicochemical characteristics for clinical application as an irrigant. Although its wettability was not superior to CHX and NaOCl, Triton performed better than EDTA, highlighting its potential as a balanced all-in-one solution. Future studies are required to further investigate the long-term effects of Triton, particularly in relation to dentinal tubule penetration, smear layer removal, and its influence on the adhesion of root canal sealers.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

Yeni Nesil Bir Dezenfektan Olan Triton’un Yüzey Temas Açısı ve pH Değerinin *İn Vitro* Olarak Değerlendirilmesi

ÖZET

Giriş: Bu çalışmada, geleneksel endodontik irrigasyon solüsyonlarının pH seviyeleri ve yüzey ıslanabilirliği, yeni bir hepsi bir arada solüsyon olan Triton ile karşılaştırılmıştır. Sodyum hipoklorit (NaOCl), etilendiamintetraasetik asit (EDTA), klorheksidin (CHX) ve Triton test edilmiştir.

Gereç ve Yöntemler: Her irrigasyon solüsyonu (10 mL) cam tüplerde saklanmıştır (n=10). pH, 1., 2., 5., 7. ve 14. günlerde elektronik bir pH metre ile ölçülmüştür ve her zaman noktasında üç tekrarlı ölçüm yapılmıştır. Temas açısı analizi için 26 adet çekilmiş ön diş kesitlere ayrılmış, standardize edilmiş ve irrigasyon solüsyonlarına maruz bırakılmıştır. Açılar bir gonyometre cihazı (SEO Phonix Contact Angle, Kore Cumhuriyeti) kullanılarak ölçülmüştür. Veriler, tekrarlı ölçümler ANOVA ve Tukey post-hoc testleri ile analiz edilmiştir ($p<0.05$).

Bulgular: Hem pH hem de temas açısı açısından irrigasyon solüsyonları arasında anlamlı farklılıklar bulundu ($p<0.05$). Tüm solüsyonlar, 14. günde 1. güne kıyasla daha düşük pH değerleri gösterdi ($p<0.05$). Triton grubunda, 1., 2. ve 5. günlerdeki değerler anlamlı bir farklılık göstermezken, 7. ve 14. günlerde düşüşler gözlendi ($p<0.05$). CHX (14.73°) ve NaOCl (15.82°) en düşük temas açılarını gösterirken, Triton orta düzeyde bir değer (19.35°) ve EDTA en yüksek değeri (21.46°) gösterdi.

Sonuç: Triton ilk hafta boyunca stabil pH değerlerini korumuş ve dentin yüzeyinde tatmin edici ıslanabilirlik sağlamıştır. Bu özellikleri ile EDTA'dan üstün, ancak CHX ve NaOCl'den daha düşük performans göstermiştir. Bulgular, Triton'un birden fazla işlevi tek bir solüsyonda birleştiren yeni nesil bir irrigasyon ajanı olma potansiyelini desteklemektedir.

Anahtar Kelimeler: Dentin; Endodonti; Hidrojen iyonu konsantrasyonu; Islanabilirlik; Konservatif tedavi; Yüzey özellikleri

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