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Original Research Article

Effect of Different Irrigation Needle Tips on Apically Extruded Irrigant of Over-instrumented Root Canals

Taşkın Prepare Edilmiş Kök Kanallarında Farklı İrigasyon Uçlarının Apikalden Taşan Solüsyon Miktarına Etkisi

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ABSTRACT

Aim: This study evaluated the effect of various irrigation needle types on the amount of apically extruded irrigant in teeth with both intact and disrupted apical constrictions.

Material and Method: A total of 40 mandibular teeth were examined under a dental operating microscope to determine the apical foramen, and the specimens were divided into two groups (n = 20). In one group (intact apical foramen group), the teeth were instrumented 0.5 mm short of the apical foramen, while in the other, the instrumentations were done 0.5 mm beyond the apical foramen (over-instrumented group). An open-tip needle and three different types of side-vented closed-tip needles were used for final irrigations. All specimens were irrigated with each needle type using a randomized crossover design. The extruded irrigants were collected in plastic containers with floral foam inserts, which were weighed before and after irrigation to determine the amount of extrusion by subtracting initial weights from final weights. Statistical analysis was conducted using repeated measures of two-way ANOVA and Tukey's post hoc tests.

Results: In the over-instrumented group, all needle types resulted in significantly higher extrusion compared to the intact apical foramen group (p=0.001). Among the needles, the double-side-vented needle produced the least extrusion in the intact group, while the open-tip needle produced the most. In the over-instrumented group, the one-side-vented needle resulted in the least extrusion, with the open-tip needle again causing the most (p=0.001).

Conclusion: Within the limitations of this study, the one-side-vented needle is recommended for irrigation procedures in over-instrumented teeth. Since NaOCl can cause severe toxic effects when in contact with tissue, even in minimal amounts, the statistical differences found in this study may also be of clinical importance.

Keywords: Apical foramen; Irrigation; Root canal preparation; Safety; Tooth apex

ÖZET

Amaç: Bu çalışmada, apikal daralımı bozulmuş ve bozulmamış dişlerde kullanılan farklı tipte irigasyon iğnelerinin apikalden taşan solüsyon miktarına etkisi değerlendirilmiştir.

Gereç ve Yöntem: 40 mandibular dişin apikal foramenleri dental operasyon mikroskobu altında belirlendi ve örnekler iki gruba ayrıldı (n=20). Gruplardan biri (sağlam apikal foramen grubu) apikal foramene 0.5 mm mesafede, diğeri ise (taşkın preparasyon grubu) apikal foramenin 0.5 mm ilerisinden taşkın olarak enstrümante edildi. Her bir preparasyon grubunun final irrigasyonunda biri açık uçlu ve üçü kapalı uçlu (yandan delikli) olmak üzere dört farklı iğne kullanıldı. Tüm örnekler, randomize çapraz tasarım kullanılarak tüm iğne tipleri ile ayrı ayrı irrige edildi. İşlemler esnasında apikal bölgeye taşan solüsyonlar, plastik kaplara yerleştirilmiş çiçek süngerleri içerisinde toplandı. Taşan solüsyon miktarları, kapların başlangıç ağırlıklarının son ağırlıklarından çıkarılmasıyla hesaplandı ve kaydedildi. İstatistiksel değerlendirmeler için Tekrarlanan İki-Yönlü ANOVA ve Tukey post-hoc testleri kullanıldı.

Bulgular: Taşkın enstrümantasyon yapılan gruplarda, kullanılan iğnelerden bağımsız olarak, sağlam apikal foramene sahip dişlere göre önemli ölçüde daha fazla irrigan ekstrüzyonu gerçekleşti. Sağlam apikal daralıma sahip irigasyon gruplarında ekstrüzyon miktarı çift delikli kapalı uçlu iğnede en az, açık uçlu iğne grubunda en fazlaydı. Taşkın enstrümantasyon yapılmış gruplarda, en az ekstrüzyon tek delikli iğne grubunda, en fazla ise açık uçlu iğne grubunda gözlendi.

Sonuç: Bu çalışmanın sınırlamaları altında, taşkın enstrümantasyon yapılmış dişlerdeki irigasyon işlemleri için tek delikli kapalı uçlu iğnenin kullanımı önerilebilir. NaOCl'nin minimal miktarları bile doku ile temas ettiğinde ciddi toksik etkiler oluşturabildiğinden, bu çalışmada elde edilen istatistiksel farkların, klinik olarak da önem taşıyabileceği söylenebilir.

Anahtar Kelimeler: Apikal foramen; Diş apeksi; Güvenlik; Kök kanal preparasyonu; Yıkama

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INTRODUCTION

Ensuring a balance between cleaning efficacy and patient safety is crucial during root canal irrigation. Although irrigation is essential for disinfecting the root canal system, it carries risks of tissue damage, chemical irritation, nerve injury, and potentially severe complications such as allergic reactions.[1,2]

The apical constriction, the narrowest portion of the root canal near the apex, is traditionally regarded as the endpoint for root canal treatment procedures. However, certain conditions, including root resorption, developmental anomalies, or iatrogenic errors, can disrupt or eliminate the apical constriction.[3,4] In these situations, the clinician faces challenges in controlling the flow of irrigants and preventing their extrusion beyond the apex.

The design of irrigation needles, including factors such as taper, diameter, and tip type, influences the flow dynamics and may contribute to irrigant extrusion.[5,6] A clear understanding of the relationship between needle design and apical extrusion allows for the optimization of irrigation protocols to enhance treatment outcomes and ensure patient safety. By selecting the appropriate needle based on clinical factors such as root canal anatomy, the degree of apical disruption, and the type of irrigant used, the risk of extrusion and its associated adverse effects can be minimized.

This study evaluates the effect of four different irrigation needles on the amount of apically extruded irrigant in teeth with intact or disrupted apical constrictions. The null hypothesis is that final irrigation with different types of needles does not affect the amount of solution extruded from the apex in teeth with or without an intact apical constriction.

MATERIAL AND METHOD

Ethical Approval

This study's protocol was approved by the Non-Invasive Clinical Research Presidency of Van Yuzuncu Yıl University (date: 21/01/2022, approval number: 2022/01-11).

Teeth Selection and Chemomechanical Preparations

A total of 40 recently extracted single-rooted human mandibular incisor teeth with single canals and mature roots were collected from the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Van Yuzuncu Yıl University. Teeth exhibiting caries, previous restorations, prior root canal treatments, crown or root fractures, root curvature, or cracks were excluded. Radiographic imaging was used to ensure the absence of internal or external resorption or calcification on the buccal and proximal surfaces. The teeth were cleaned and scaled using ultrasonic scalers to remove calculus and soft tissue debris. Following cleaning, each tooth was inspected under an operating microscope to confirm the presence of a single apical foramen. The specimens were then stored in physiological saline until further use in the experiment.

A diamond fissure bur (Bosphorus, Türkiye) with a high-speed handpiece. Working lengths were determined by inserting a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) into the canal until the file was visible at the apical foramen under ×16 magnification using a dental operating microscope. The apical foramen's distance to the reference point was recorded for each tooth.

In Group 1, the root canals of 20 teeth were prepared 0.5 mm short of the apical foramen. The preparation was performed using TruNatomy (Dentsply Sirona, Maillefer, Ballaigues, Switzerland) endodontic files, following the manufacturer's recommendations. Continuous rotation at 500 RPM with a torque setting of 1.5 N/cm was used with the sequence of instruments: an orifice modifier (20/.08), a glider (17/.02), and a prime file (26/.04). The files were cleaned after three in-and-out motions, and apical patency was maintained using a #10 K-file throughout the procedure. If a file failed to reach the working length, it was removed from the canal and cleaned, the canal was re-irrigated, and the file was then reinserted for another pass until the working length was reached.

During the instrumentation, each canal was irrigated with 5 mL of 5% NaOCl (sodium hypochlorite, Microvem, Turkey). Canal preparation was considered complete when the file easily reached the required length. Afterward, the smear layer was removed by irrigating with 3 mL of 5% NaOCl, 3 mL of 5% ethylenediaminetetraacetic acid

(EDTA, Microvem, Turkey), and 3 mL of distilled water. The canals were dried using absorbent paper points (Pearl Dent Co., Ltd., Vietnam).

In Group 2, the remaining 20 teeth were instrumented 0.5 mm beyond the apical foramen using the aforementioned procedures.

Experimental Set-Up

The set-up for collecting the extruded irrigant was based on the model of Myers and Montgomery[7] and Altundaşar *et al*.[8] adapted by Genc Sen and Kaya.[9] Floral foam was fitted into a 25-mL cylindrical polystyrene container (Figure 1).

The foam and container (without the lid) were weighed three times using an analytical balance (Sartorius Basic, Sartorius AG., Gottingen, Germany) with an accuracy of 10^{-4} g. The average weight was recorded as the initial weight (W0).

A hole was prepared in the center of the container's lid, and the root was inserted into the hole with its apical part embedded in the foam (Figure 2a, c). The space between the root and the hole was sealed using a light-curing glass ionomer cement (Ionoseal, VOCO GmbH, Cuxhaven, Germany) to prevent leakage (Figure 2b, c). A 27 G dental needle was inserted and fixed into the lid to equalize the internal and external pressures. Finally, the root was isolated using a rubber dam (Figure 2d).

Final Irrigation Procedures

All samples were assigned to irrigation groups using a randomized crossover design. Each sample in Group 1 (the intact apical foramen group; n = 20) was irrigated separately with four different needle types as outlined below:

Group 1A: A 30 G closed-tip, one-side-vented needle (Kerr-Hawe irrigation probe, KerrHawe SA, Biggio, Switzerland) was used.
Group 1B: A 30 G closed-tip, double-side-vented needle (C-K Blunt, CK Dental, Gyeonggi-Do, Korea) was used.
Group 1C: A 30 G flat, open-tip needle (Ultradent Navitip, Ultradent Products Inc., South Jordan, UT, USA) was used.
Group 1D: A two-side-vented, conical plastic needle (TruNatomy, Dentsply Sirona, Maillefer, Ballaigues, Switzerland) was used.

Similarly, each sample in the subgroups of Group 2 (over-instrumented foramen group; 2A, 2B, 2C, and 2D; n=20) was sequentially irrigated using the same needles as Group 1.

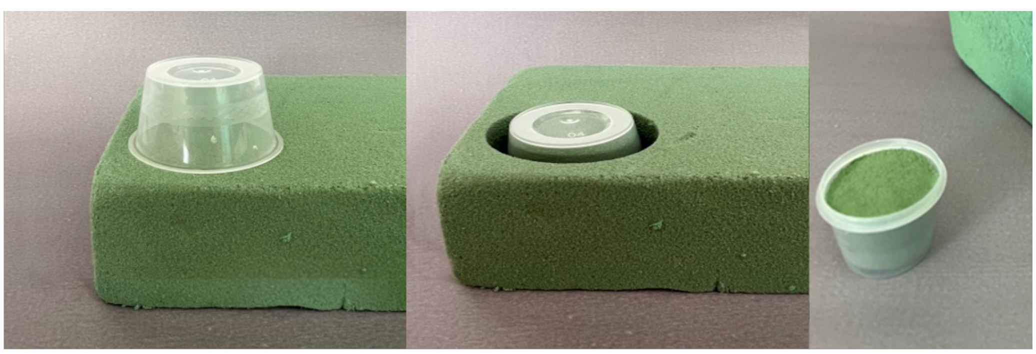

Figure 1. Fitting procedure of the floral foam into the cylindrical container.

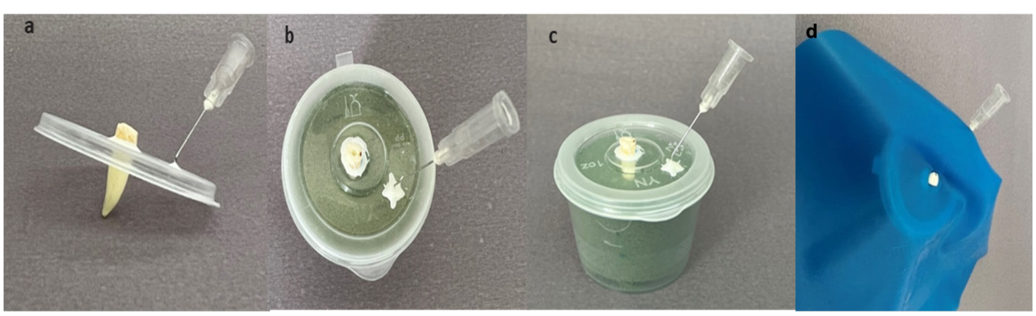

Figure 2. a) Lid with the root and needle b) side view of the experimental setup c) Top view of the experimental setup. d) Rubberdam-isolated setup

For each irrigation group, 5 mL of distilled water was injected into the root canal using a Luer-lock syringe connected to the selected needle. Irrigation was performed 2 mm from the apical foramen at a 5 mL/min flow rate. During irrigation, the needle was continuously moved with a vertical amplitude of 1–2 mm to ensure effective delivery of the irrigant.

After completing the final irrigation procedure, the lid (with the attached root and pressure equalization needle) was separated from the container. Each container, including the floral foam and the extruded irrigant, was weighed three times using the analytical balance. The average of these measurements was recorded as the final weight (W1). The exact amount of extruded irrigant was calculated by subtracting the initial weight from the final weight (W1-W0).

Statistical Analysis

The normality assumption of the variables was tested with the Kolmogov-Simirnov test. After the normality test, the Scheirer–Ray–Hare test was used to compare two-factor levels. Descriptive statistics were presented as mean, standard deviation, median, IQR, minimum, and maximum values for the non-normal distributed variable. The Dunn multiple comparison test was used to determine different subgroups. Statistical significance level was considered as 5% and SPSS (ver: 21) and R statistical program was used for all statistical computations.

RESULTS

The graphical representation of the amount of extruded irrigants is given in Figure 3. Mean values, standard deviations (SD), minimum-maximum (min-max) ranges, medians, and inter-quarter ranges (IQR) for the apically extruded irrigants were shown in Table 1.

In teeth with intact apical constrictions, no significant differences in apically extruded irrigant were observed between the one-side-vented, double-side-vented, and TruNatomy needle groups ($p > 0.05$). However, significant differences were found between the double-side-vented and TruNatomy needles ($p < 0.05$), and the open-tip needle group extruded significantly more irrigant than all other groups ($p = 0.001$). The order of extrusion was: Double-side-vented < One-side-vented < TruNatomy < Open-tip.

In over-instrumented teeth, all needle types resulted in significantly greater irrigant extrusion compared to intact apical constrictions. The one-side-vented needle group extruded significantly less irrigant than all other groups ($p = 0.001$). No significant differences were observed between the double-side-vented and TruNatomy groups ($p > 0.05$). The open-tip needle extruded the greatest amount of irrigant, significantly more than all other groups ($p = 0.001$). The order of extrusion was: One-side-vented < Double-side-vented = TruNatomy < Open-tip.

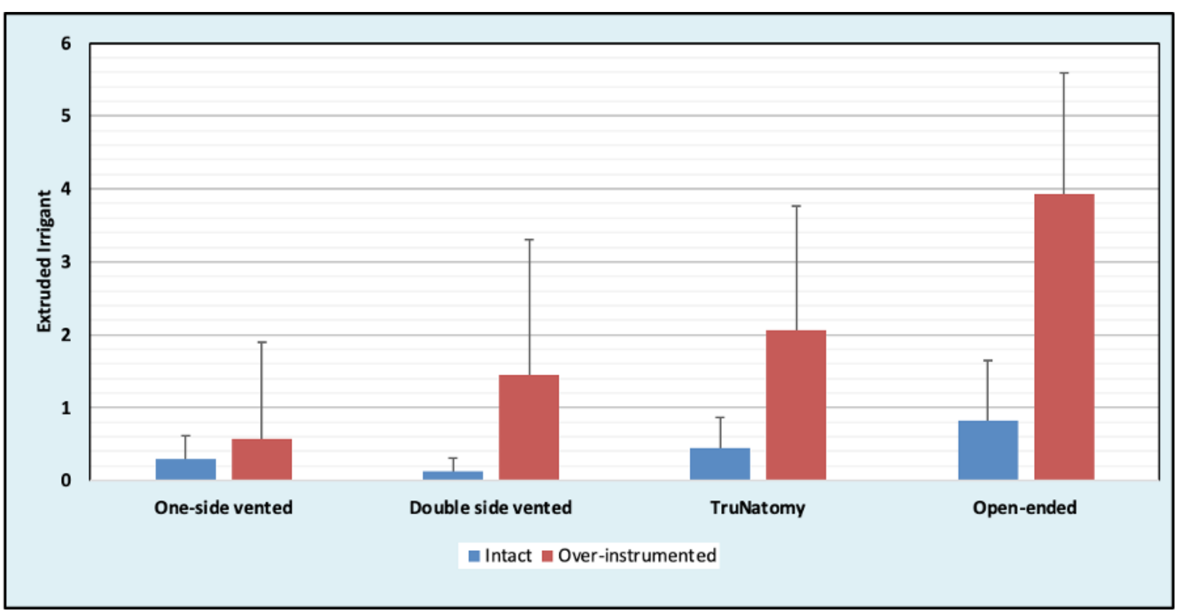

Figure 3. Graphical representation of the amount of extruded irrigants' median and standard deviation values according to the experimental groups.

Table 1. Mean values, standard deviations (SD), minimum-maximum (min-max) ranges, medians, and inter-quarter ranges (IQR) for the apically extruded irrigant (in grams) with different types of needles.

	Intact				Over-instrumented				
	Mean±SD	**Min Max**	**Median**	**IQR**	**Mean±SD**	**Min Max**	**Median**	**IQR**	**p**
One-side-vented	0.328±0.246 **bc**	0.048 0.986	0.295	0.316	0,814± 0.639 **c**	0.155 1.937	0.571	1.322	**0.001**
Double-side-vented	0.198±0.151 **c**	0.031 0.642	0.132	0.172	1,607± 0.9 **b**	0.433 3.785	1.450	1.085	**0.001**
TruNatomy	0.471±0.315 **b**	0.060 1.111	0.454	0.411	1,951± 0.87 **b**	0.609 3.140	2.062	1.699	**0.001**
Open-ended	0.899±0.643 **a**	0.096 2.904	0.829	0.822	3,550± 1.179 **a**	1.064 4.850	3.928	1.665	**0.001**
p			**0.001**			**0.001**			

a, b, c: ↓ different lowercases in the same column indicate significant differences among needle types ($p<0.05$).

DISCUSSION

This study investigated the amounts of apically extruded irrigants during final irrigation using different needle types in root canals with preserved apical constrictions and those with disrupted apical constrictions due to over-instrumentation. The null hypothesis was rejected as the over-instrumented groups were associated with significantly greater irrigant extrusion, and significant differences were observed between needle types.

In this study, the groups and methodology were designed using a crossover design, which mitigates issues arising from anatomical variations and facilitates more standardized measurements through repeated assessments on the same samples. Irrigation was performed with all needle types in 20 teeth prepared with intact apical constrictions and in an additional 20 teeth that were over-instrumented, allowing for a more reliable measurement of the extrusion caused by different needles on the same samples.

Previous studies on irrigant extrusion have embedded extracted human teeth in various materials, such as water, gel, putty silicone, and floral foam, to simulate periapical tissues.[10] In this study, floral foam was selected, consistent with its use in earlier research,[8,11] with slight modifications made by placing the foam in a plastic container. This adjustment was implemented to address the foam's delicate structure, which is prone to crumbling and wear. This approach effectively prevented any potential weight loss in the foam during the experimental procedures.[9]

The apical foramen is reportedly located 2–3 mm from the anatomical apex, but its precise location cannot always be accurately determined by radiographs. Consequently, disruption of the apical constriction during root canal preparation or instrumentation is common. Conditions such as an open apex or disrupted apical constriction caused by internal or external resorption, immature roots, and proximity to the maxillary sinus (covered by a thin membrane) complicate the identification of this critical anatomical landmark. These factors can increase the likelihood of irrigant extrusion through the disrupted or open apical constriction.[12] In this study, to reliably assess the effects of apical disruption, one group of samples had standardized apical disruptions, while the other group's apices remained intact.

Several factors influence the amount of irrigant extrusion during positive-pressure irrigation, including the flow rate of the irrigant solution, the needle's size and insertion depth, and the type of needle used.[6] Boutsioukis *et al.*[13] reported a direct relationship between flow rate and irrigant extrusion, indicating that greater extrusion occurs as flow rate increases. Various flow rates for irrigation are recommended in the literature. To achieve adequate irrigant exchange within the canal, it is suggested that a flow rate of 0.01–0.26 mL/s be used at a distance of 1 mm from the working length.[14] This rate should be adjusted depending on the diameter of the needle. Chang *et al*.[15] recommended a flow rate of 0.06 mL/s for passive irrigation with a 30 G needle, while Gopikrishna *et al*.[16] suggested 0.09 mL/s. In the present study, a 0.08 mL/s flow rate was used to balance effective irrigant exchange with minimizing extrusion, considering clinical safety and practicality.

The most common needle sizes used in conventional needle irrigation range between 27 and 30 G.[17] In our research, a 30 G needle was selected because it is considered a standard irrigation needle that can reach the apical part of the canal and enhance cleaning and debridement while simultaneously providing space for irrigation replacement even in minimally prepared root canals.

Boutsioukis compared various 30 G needle designs and found that an open-tip needle tip could fully replace the irrigant in a canal when placed 2 mm from the working length whereas a side-vented closed-tip needle tip required to be inserted 1 mm from the working length to achieve the same purpose.[18] In this study, the insertion depth of the needles was standardized at 2 mm from the apical foramen. This approach helped control for the effect of insertion depth, which significantly influences the amount of irrigant solution extruded, and allowed a clear assessment of the specific impact of needle types on the apically extruded irrigant.

This study observed no significant difference in the amount of extruded irrigant between single-vented and double-vented side needles in teeth with intact apical constrictions. However, the double-side-vented needle exhibited the lowest extrusion among all needle types, likely due to reduced solution pressure from its dual exit points. Similarly, Silva *et al*.[19] reported lower extrusion levels with the double-side-vented needle, aligning with our findings.

The TruNatomy needle is a 30 G plastic, side-vented needle with a 4% taper, designed to provide effective cleaning of complex canals while minimizing the risk of extrusion due to its closed end. To the best of our knowledge, there is no study in the literature comparing TruNatomy with other types of needles in terms of irrigant extrusion. In this study, no significant difference was observed between the one-side-vented needle and TruNatomy in terms of the amount of irrigant extruded from teeth with intact apical constrictions. In over-instrumented teeth, the extruded irrigant amounts were similar in double-side-vented needles and TruNatomy. Moreover, TruNatomy was associated with less extrusion compared to open-tip needles regardless of the instrumentation level of the teeth. Therefore, it can be a safer alternative against open-tip needles.

In this study, the highest irrigant amount was extruded when an open-tip needle was used in teeth with intact apical constriction and over-instrumentation. This result can be attributed to the fact that open-ended needles create higher apical pressure due to direct periapical access, increasing the risk of irrigant and debris extrusion. Similar to our results, Boutsioukis *et al*.[20] reported that the irrigant tends to eject more strongly from the open-tip needle and causes greater extrusion than the closed-tip one. The same results were supported by Kalhoro *et al*.[21], who reported that the incidence of extrusion by open-tip needles (62%) was higher than by closed-tip side-vented needles (24%). In addition, Altundasar *et al*.[8], Psimma *et al*.[22], Fikirli *et al*.[23], and Chang *et al*.[24] also found similar results despite differences in the gauge of needles or apical preparation size.

In this study, the amount of irrigant extruded from over-instrumented teeth was higher in all needle groups compared to teeth with preserved apical constrictions. This outcome aligns with reports suggesting a direct relationship between over-instrumentation—resulting in apical constriction deterioration—and increased irrigant extrusion.[9,25] Tinaz *et al*.[25] also examined the effect of different instrumentation techniques on the extrusion of materials from teeth with disrupted apical constrictions, though without simulating periapical tissues. Their findings similarly indicated greater extruded amounts in these teeth, consistent with the results of this study.

CONCLUSION

Within the limitations of this study, the following conclusions were drawn:

Irrigation of teeth instrumented to 0.5 mm short of the working length, as well as those over-instrumented by 0.5 mm, resulted in measurable quantities of apical irrigant extrusion across different needle types. The amount of irrigant extruded from teeth with apical disruption was consistently higher than that from teeth with intact apical constrictions, regardless of the needle type used. Therefore, it is evident that the integrity of the apical constriction plays a more critical role in apical irrigant extrusion than the specific irrigation needle employed.

In teeth with intact apical constrictions, the double-side-vented closed-tip needle resulted in the least amount of extruded irrigant. In contrast, the open-tip needle resulted in the highest amount. Therefore, a double-side-vented needle is recommended for irrigating teeth with intact apical constrictions. Given its statistical similarity to the double-side-vented needle, the one-side-vented closed-tip needle can be considered a secondary option. Conversely, open-tip needles should be avoided whenever possible.

In the over-instrumented teeth group, the one-side-vented needle extruded the least amount of irrigant, whereas the open-tip needle extruded the greatest amount. Therefore, one-side-vented needles should be preferred for irrigating apically disrupted teeth, as they demonstrated greater safety, while open-tip needles should be avoided.

Within the limitations of this study, the lateral single-vented closed-tip needle may be recommended for irrigation procedures in over-instrumented teeth. However, there is a notable scarcity of literature addressing the irrigation procedures applicable to over-instrumented teeth. Further research is warranted to clarify methods and materials, particularly by exploring different needle sizes and flow dynamics.

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