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Irrigating Needle Designs in in Primary tooth Endodontics: A Narrative Review

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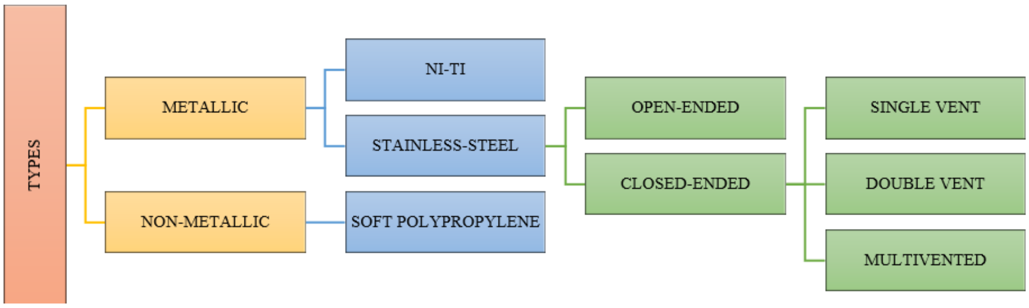
Abstract: *For a successful endodontic treatment in primary molars, it is important to decontaminate morphologically complex root canals with lateral fibrils and interconnecting branches between canals. During instrumentation, formation of smear layer is inevitable, which makes irrigation protocol necessary to ensure biological sealing and for treatment success. This review deals with mechanical and fluid dynamics of various irrigation needle designs, specifically comparing traditional metallic needles and advanced soft polypropylene needles. Also describes about factors affecting irrigation, depth of penetration of needles, canal sizing, wear analysis, tip geometry and its complications. In conclusion, use of soft polypropylene needles, with passive placement in root canal and low-concentration irrigating solution is recommended for the protection of underlying permanent tooth germ and ensuring the preservation of primary dentition.*

I. Introduction

Pulpectomy is the most effective method for treating primary molars with irreversible pulpitis and traumatic injuries. Preserving primary dentition is essential as they act as biological space maintainers, help masticatory function and guide the physiological eruption of their permanent successors.[1] The ultimate goal of endodontic therapy is the total decontamination of root canal system, which requires the meticulous removal of organic tissue, biofilm, and the microscopic "smear layer" that builds up during the procedure. Instrumentation, Disinfection/Irrigation and Obturation are three main steps that eliminate micro-organisms and seal the canal against further bacterial invasion.[2]

During the instrumentation of primary root canal systems, the formation of a smear layer is an inevitable consequence. It is tenacious including of organic and inorganic film, which is made of tooth structure (root dentine), necrotic tissue and microorganisms which coats the root canal walls and occludes into the dentinal tubule orifices. Hence, this layer acts as a physical and biological barrier, sequestering pathogens and which prevents the deep penetration of antibacterial irrigants. Persistent debris of this nature compromises the seal between the filling materials and the dentinal wall, increasing the risk of post-treatment failure.[3]



Hence, irrigation plays a vital phase of endodontic therapy. While various irrigating solutions, such as sodium hypochlorite and chlorhexidine, have proven successful due to their superior antimicrobial and tissue-dissolving properties, the clinical technique of application is equally critical. Most commonly, delivery is achieved through the use of specialized hypodermic irrigation needles, available in various designs attached to a syringe. As the Root canal morphology of multi-rooted primary teeth is often complex, due to deposition of secondary dentin which leads to the development of narrow fins, lateral fibrils, and interconnecting branches between canals. This results in irregular and atypical canal configurations which are difficult to identify through clinical examination, hence it is essential for the clinician to understand the specific details and mechanical dynamics of the needles used to ensure both safety and efficacy.[4,5]

Classification of Irrigating Needles

Metallic Needles in Endodontic Irrigation (Fig 1)

Metallic needles are generally categorized into two primary types based on their tip geometry: open-ended and closed-ended designs.

Open Vented Needles

It includs beveled or non-beveled types, are designed to express irrigants directly toward the apex of root. Helps the irrigating solution to reach apex of the canal, disadvantage is that it carries a risk of increasing apical pressure during irrigation. According to study by Boutsioukis et al., these needles should be positioned at least 2–3 mm short of the working length to mitigate the risk of irrigant extrusion into the periapical tissues. Interestingly, despite the pressure risks, some by Topcuoglu et al 2020, have associated this design with less post-operative pain, possibly due to more effective debris clearance at the apical third.

Closed Vented Needles

They may be single, double, or multi-vented and are designed to express irrigants laterally against the canal walls rather than directly toward the apex. This design of needle creates pressure towards the lateral walls, thereby reducing the risk of apical extrusion of irrigating solution. Due to this safety, clinicians can safely position closed-ended needles closer to the apex, around 1 mm short of the working length. However, that some clinical studies suggests that these designs may result in comparatively more post-operative pain after endodontic treatment, potentially due to differences in effectively of biofilm sheared from the canal walls**.**

Disadvantage: Vapor lock phenomenon, air bubbles get entrapped at apical part of root canal, because of anatomy of root canals are closed-ended cavities. These can block penetration of irrigant in apical area. Hence, sufficient irrigation debridement is not possible in apical area with needle irrigation.

Non- metallic Soft polypropylene Needles (Fig 1)

These are flexible, multivented needle tips. Study by Sheth M et al, concluded that soft polypropylene needle tips reached areas some areas of cracks, crevices, isthmus, accessory canals and apical delta were manual or rotary instruments failed to reach. These needles exhibit highest pressure and axial velocity near the apex, which leads to greater canal coverage compared to metallic needles.

Disadvantage: Higher risk of apical extrusion of irrigating solution.

Factors affecting Irrigation

For the safety of needle irrigation two main factors are that interplay between needle geometry and fluid dynamics. Mainly needle factors are penetration depth, diameter, and bevel orientation. Physical properties of the irrigant like its viscosity, velocity, and pressure tells how effectively the irrigating solution debrides the space. Studies have shown that surface irregularities on irrigation needle disturbs flow pattern, which compromises on delivery in anatomically challenging areas like S-shaped or double-curved canals. Also restricted penetration leads to inadequate apical cleaning.

A critical factor is the design of the needle tip, as it directly influences the balance between effective cleaning and safety of periapical tissues. Open-Ended Needles (OENs) produce higher apical pressure and therefore increase the risk of irrigant extrusion to the periapical tissues, while paradoxically limiting replenishment of the solution in the apical third. On the other hand, Side-Vented Needles (SVNs) change the flow direction towards the canal walls rather than to the apex. This design increases safety by limiting epidemic extrusion and debris displacement and improves chemical debridement of the apical third. Such safety measures are particularly vital when treating primary teeth; the presence of physiological root resorption and the proximity of permanent tooth germs necessitate a strictly controlled irrigation protocol to prevent collateral damage.[6,7]

Mechanical Properties

Diameter of Needle (Srivastava I etal 2021)[8]: The clinical selection of irrigation armamentarium depends on a precise understanding of needle dimensions and their mechanical behaviour within the root canal system. According to ISO 9626 standards, the needles commonly recommended for endodontic irrigation use, range from 21G to 30G, with external diameters decreasing from 0.8 mm to 0.3 mm, respectively. These dimensions are critical because they dictate the depth to which a needle can safely navigate.

Depth of Penetration: The physical reach of an irrigation needle is a primary determinant of cleaning efficacy, particularly in the apical third. Sheth et.al 2025 evaluated penetration depth of various irrigating needles using 3D-printed transparent canal models demonstrate that material composition significantly influences accessibility:[6]

- Soft Polypropylene: 20.09 mm
- Stainless-Steel: Double-vented needle at 18.85 mm, Single-vented needle at 17.07 mm.
- Ni-Ti Needles: 14.65 mm.

Soft polypropylene exhibits highest penetration depth due to its flexibity. Ni-Ti needles recorded a shallower penetration depth.

Fluid Dynamics and Flow Rates: The gauge of the needle also directly impacts the delivery speed of the solution. Gopikrishna et al 2015 highlights that flow rates decrease significantly as the needle diameter narrows:[9]

- 26G: 0.27 mL/s
- 27G: 0.19 mL/s
- 30G: 0.09 mL/s

These variations emphasize the need for clinicians to adjust manual pressure based on the needle gauge to ensure consistent debridement without risking apical extrusion.

Canal Sizing: To ensure the irrigant reaches the apex, the canal must be sufficiently prepared to accommodate the chosen needle gauge. It is generally recommended that the minimum canal preparation should reach a size 25 K-file.[10]

- 27G Needle: Requires canal enlargement to at least a size 45 K-file for apical access.
- 30G Needle: Compatible with preparations shaped to a size 35 K-file.
- 31G Needle: Specially for narrow preparations, reaching the apex in a size 30 K-file canal.

Wear Analysis: The SEM findings reveal distinct wear patterns across different needle materials after copious irrigation with 5.25% of Sodium hypochlorite (Naocl) and 0.9% saline solution with irrigation rate at 1ml/min:[6]

- Metallic Variations**:** Nickel-Titanium (Ni-Ti) Open-ended needle showed superficial wear like scratch marks, voids and abrasive wear. Stainless-steel double-vented needles exhibited crack initiation and "buckling" fractures due to low ductility and high axial compressive stress. In contrast, single-vented steel needles showed branching cracks resulting from a combination of compressive stress and corrosion.
- Polymer Resilience: Soft polypropylene needles demonstrated a unique wear mechanism—periodic shedding of the outer layer—but avoided cracking entirely due to their high elasticity.

Evaluation of irrigation: Iohexol (Omnipaque) is often preferred as a contrast medium due to its non-ionic nature, water solubility, and low osmolarity for clinical assessment of irrigation.[10]

Clinical Considerations[11]

While treating primary molars, the current gold standard protocol for irrigation involves 1-minute rinse with 5–10 ml of a chelating agent. Common irrigants include:

- Sodium Hypochlorite: Low concentration of 0.5%.
- Organic Acids: 6% Citric Acid, 5–7% Maleic Acid.
- Other Antimicrobials: 0.2% Chlorhexidine, 3.8% Silver Diamine Fluoride, or Tetraclean (a combination of doxycycline, citric acid, and cetrimide).

Complications of needle irrigation:[12,13]

Most commonly, complications occur due to incorrect determination working length, of iatrogenic widening of the apical foramen, lateral perforation or wedging of the irrigating needle. Sodium hypochlorite accident and fracture of irrigation needle are the complications seen. Sodium hypochlorite accident occurs due to inadvertent injection of sodium hypochlorite beyond the apical foramen can occur in teeth with wide foramina or when the apical constriction is destroyed by resorption or during root canal preparation. Furthermore, applying excessive pressure during irrigation or allowing the needle tip to bind within the canal without coronal reflux can force large volumes of irrigant into the apical tissues. When this happens, the potent tissue-dissolving properties of sodium hypochlorite result in localized tissue necrosis. Therefore, mild concentration of 0.5% NaoCl is recommended which is non-toxic to vital tissues and washed away by circulating blood (Spangberg et al. 1973, Baumgartner 1992) and irrigation must be done with low and constant pressure, making sure it leaves coronally from acess cavity. Irrigation needle fracture is rare, Ultrasonic tips can be used for retrival. Advance technologies like, 3D-printed guides and CBCT can be used to retrieve separated instruments with minimal dentin loss.

Recommendations for primary teeth during irrigation with needles:[14,15]

- For determination of working length, prioritize electronic apex locators as they more accurately detect physiological root resorption than radiographs. Sathorn et al. in their study concluded that rotary systems provide more cleaner canals and are less time-consuming during canal preparation in deciduous teeth when compared to hand files, hence irrigation can be done better.
- Irrigation solution recommended, low concentration of sodium hypochlorite- 1% with saline solution.
- Needle position should be 1-2mm short of working length.
- Soft polypropylene needle or Closed end double side vented needles are preferable for safety.
- Maintain passive placement of needle tip, with withdrawing action slightly from binding point.

- Due to vapour lock mechanism with conventional needles, irrigation agitation methods like Passive Ultrasonic Irrigation (PUI), EndoActivator, Laser-Activated Irrigation (LAI) can be used.

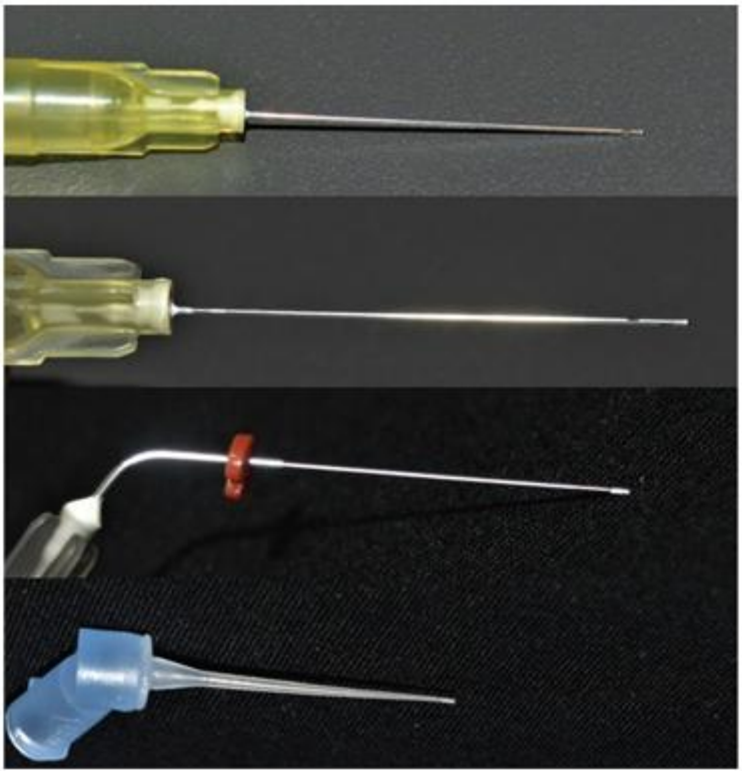


Fig 1: Refrence of image (Sheth M et al)[6] Stainless steel single-side vented needle, stainless steel double-side vented needle, NiTi open-ended notched needle, soft polypropylene multi-vented needle. (from top to bottom)

II. Conclusion:

Advance irrigating non-metallic needles made of soft polypropylene having superior flexibility, penetrate into atypical canal configurations also they have shown higher resilience against mechanical failure when compared to traditional metallic needles.
By selecting appropriate irrigating needles and following safety protocols clinicians can significantly improve success rates for endodontically treated primary molars.

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