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" From Chemistry To Clinic: The Importance Of Irrigant Properties In Root Canal Treatment"

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Abstract
Endodontic irrigants are solutions used in root canal treatment to disinfect the root canal system, dissolve organic tissue, and remove debris. They exhibit various physicochemical properties that contribute to their effectiveness in root canal therapy. Some key properties of endodontic irrigants include antimicrobial activity, tissue compatibility, wettability, surface tension, Viscosity, pH level etc. This review outlines the role of surface tension and viscosity of endodontic irrigants in root canal shaping and cleaning. The results in this review is gathered from Scopus, Google Scholar, Research Gate and PubMed databases by searching the keywords like viscosity, surface tension, root canal irrigants, properties of endodontic irrigants. The present work concludes low surface tension and low viscosity of root canal irrigants greatly effect root canal cleaning and shaping process which turns the endodontic outcome magically.

Keywords: *Viscosity, Surface tension, Root canal irrigants, Properties of endodontic irrigants.*

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I. Introduction

It is truly said, "Instruments shape, irrigants clean." Every root canal system has spaces that cannot be cleaned mechanically. The bacteria located in areas such as isthmuses, ramifications, deltas,[1] irregularities and dentinal tubules will not be eliminated by mechanical means alone.[2] In a study of micro-CT images obtained before and after root canal shaping, 35% or more of the root canal surface (including the isthmus) was found to be untouched, regardless of the canal preparation technique.[3] Literature evidences that the number of infected tubules and depth of penetration of bacteria are highly variable and may range from 150 µm to 50 percent of the distance between the main root canal and cemento-dentinal junction.[3] Even in small and/or rounded canals, micro-tomographic studies report that different instrumentation systems leave approximately 10% to 50% of the total surface area unprepared. These numbers can be even higher when only the apical surface of the canal is evaluated. In more complex canals such as oval/flat canals, the amount of intact surface area after preparation can vary from 10% to 80%.[4] In addition, a smear layer is produced on the walls of the instrumented root canal. It is composed of inorganic and organic constituents from dentinal filings and pulp tissue debris. The smear can be penetrated by bacteria, while offering protection to the biofilms that are adhering to the root canal walls and interfering with the adaptation of endodontic cements to the dentin walls.[4]The microorganisms that persist inside the root canal and un-instrumented portion of the root canal and/or microbes that recolonize the previously filled root canal system, are considered as the main cause of persistent or secondary apical periodontitis.[5]The irrigation effectiveness depends on the working mechanisms of the irrigants and the ability to bring the irrigants in contact with microorganism and tissue debris in the root canal.[6-7] The intimacy of this contact is associated to the wettability of the dentin surface where the drop of irrigant is applied. The term "wetting ability" refers to the ability of a liquid to wet a solid surface while the term "wettability" is defined as the ability of the surface of a material to be wet in a uniform and stable way by a liquid substance.[8-9] The wetting ability of a solution influences its penetration ability into the main and lateral canals as well as into the dentinal tubules. It strictly correlated to its surface tension.[10-11] Surface tension and viscosity are critical factors influencing fluid flow, significantly impacting an irrigant's ability to penetrate dentine and its efficacy in spreading across dentin surfaces. Traditionally, instrumentation was primarily seen as a method to access the apical anatomy, with the expectation that irrigants would carry out most cleaning and disinfection tasks. This shift in approach has sparked a renewed interest in root canal irrigation, evident in the surge of research studies over the past two decades. However, conflicting study outcomes often create confusion among clinicians, researchers, and decision-makers due to information

overload. Consequently, this review aims to outline the challenges at hand, discuss prevalent irrigants, identify knowledge gaps, and offer guidance for future advancements in this field.

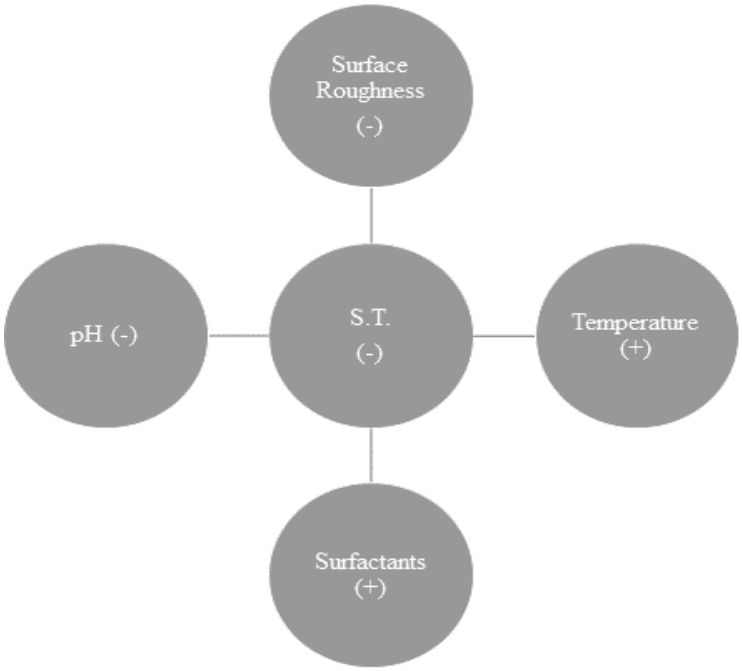
II. Methodology

Database systems Pubmed, Google Scholar and Research Gate were used to extract the articles. In regards to inclusion criteria, only those articles (original research/ basic research/ case studies/ review aricles) were selected which shows direct or indirect effect of surface tension and viscosity on endodontic treatment. Keywords to search the article was Viscosity, Surface tension, Root canal irrigants, Properties of endodontic irrigants. Exclusion criteria were all other articles which do not end on key point.

III. Review

Surface Tension

Very early, Zoethout and Tuttle[12] defined surface tension as a condition of intramolecular attraction at the surface of a liquid in contact with a solid tending to pull the molecules inward from that surface. When that intramolecular attraction is destroyed, the surface tension is decreased. Philips[13] also defined surface tension can be defined as the force between molecules which produces a tendency for the surface area of a liquid to decrease. The irrigating solution must be brought into intimate contact with the dentin wall and the debris. Generally, when the surface tension is decreased, the solution can spread more extensively on solid surface.[14]



(Diagram 1: showing the factors effecting the surface tension of an endodontic irrigant)

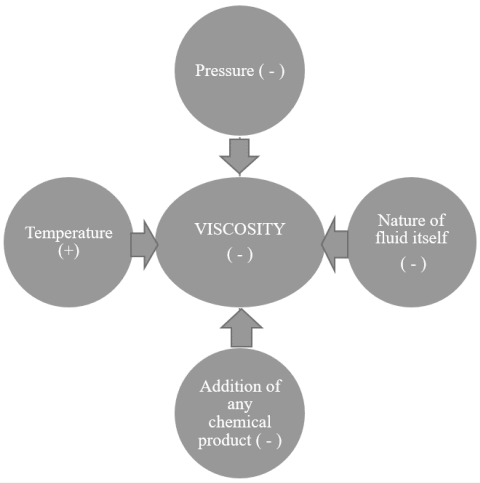
To reduce surface tension of substances, in order to get a better contact of them with the dentin wall, surfactants can be used[15-16], as well as changes in pH values and in temperature[17]. Bukiet et al[18] states that adding surfactants to irrigants, the surface tension decreases until reaching the critical micellar concentration (CMC). Above the CMC, the addition of surfactant provokes formation of micelles in the liquid, keeping constant the surface tension. The best wetting properties of the irrigants are obtained at this concentration. Iglesias JE, Pinheiro LS, Weibel DE et al[19] concluded that the addition of surfactants to the Ca(OCl)2 solution reduced its surface tension, possibly enhancing its wetting ability, which may enable a better diffusion of the irrigant on dentin walls, leading to improved action of the solution during endodontic treatment. Similar fndings were also supported by Hernan Coaguila-Llerena, Julia da Silva Toledo, Ana Paula Ramos, et al[20]. Yılmaz Z[16] also advocated that the surfactant added both EDTA solutions showed lower surface tension levels than that of dentin in all pH and temperature variations. Our previous study[17] revealed that the addition of surfactant to the EDTA solution significantly increased the wettability of root canal dentin surfaces. Hence, it might improve the adhesive properties of dentin. Naumovich D.B [21] tried to find out the relationship between pH and surface tension of 22 endodontic but he was unable to establish a concrete relation between these two properties. However, he concluded that the drugs which showed low surface tension values spread more easily in the root canals than those which showed higher values. Calve, Medina, Shnchez[22] reported that among the major factors affecting root

canal cleansing by EDTA solutions, acidity can be mentioned playing an important role in three possible ways. First, the chelating ability of EDTA increases as acidity decreases[23]. Second, solubility of teeth mineral (hydroxyapatite, HA) increases as pH decreases (on acid medium).[24] Third, pH enhances "the penetrability of EDTA" into small spaces.[25] Xiaoli Hu, Junqi Ling, Yan Gao[26] stated the increased wettability of the dentin surface is the result of this acidic property of H_2O_2. Meenu G Singla, Ashima Garg, Sumit Gupta[27] stated that MTAD has a low pH and acts as a calcium chelator and causes enamel and root surface demineralization[28] and because of the low surface tension of MTAD (34.5 mJ/m2),[29] the intimate contact of irrigant solutions with the dentinal walls might increase, which may permit deeper penetration for effective smear layer removal and thereby disinfection. Luciano Giardino, Flaviana Bombarda de Andrade, Riccardo Beltrami[30] also reported the better antibacterial action of Tetraclean NA can be explained by its low pH, low surface tension and better removal of the smear layer, all of which improves its penetration into the root canal and the dentinal tubules.

Root canal irrigants with lower surface tension can more effectively wet and penetrate the complex root canal anatomy. This allows for better lubrication and flow of the irrigant within the canal, facilitating its access to areas that are difficult to reach, such as lateral canals, isthmuses, and fins. Improved wetting helps in effective removal of debris, biofilms, and residual pulp tissue. These findings are supported by Abou-Rass and Patonai[31] and Yılmaz et al[17]. Luciano Giardino[29-30], Generali, L.[32] and Peters OA[3] supported that lower surface tension enables the irrigant to penetrate into dentinal tubules, microscopic irregularities, and accessory canals. This is important for thorough disinfection, as it allows the irrigant to reach areas where bacteria and their byproducts may reside, preventing reinfection. Mohammadi Z and Abbott PV.[33] supported that Low surface tension irrigants are more likely to dislodge and carry away debris, bacteria, and pulp remnants from the root canal system. Torabinejad M, Handysides R, Khademi AA, Bakland LK[34] stated that the low surface tension of irrigants aids in the removal of the smear layer that forms during instrumentation. y Mohammadi Z, Shalavi S, Jafarzadeh H and Abbott PV[35] stated that irrigants with low surface tension can access dentinal tubules more effectively, increasing the potential for reaching bacteria residing within these microstructures. This results in improved disinfection of the root canal system. Al-Jadaa A, Paqué F, Attin T and Zehnder M[36] supported the argument that Low surface tension irrigants are less likely to create excessive pressure within the root canal system, reducing the risk of irrigant extrusion beyond the apex, which could cause discomfort or complications.

Viscosity

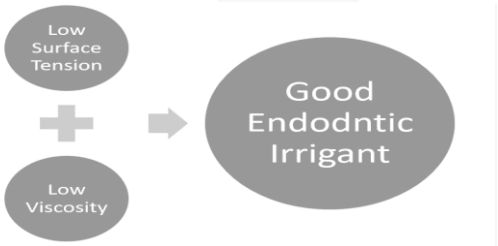
Viscosity can be described as the internal resistance to root canal irrigant flow deformed by either shear or tensile stress. Viscosity is a property arising from collisions between neighbouring particles in a fluid that are moving at different velocities.[37] Viscosity is effected by temperature, pressure, by addition of other chemical in root canal irrigant and by the nature of fluid itself. Poggio, et al.[38] stated that when temperature was increased, the coefficients of viscosity decreased in a similar way for all irrigants and at room temperature the higher viscosity would inhibit fluid dynamics and elevating temperature reduces viscosity and enhances fluid properties. This reduction in viscosity is explained by the thermal agitation of the fluid molecules, which move more easily resulting in an improvement of rule, with increasing pressure and this expectation has been confirmed in a variety of experimental studies.[39-43] Arathi, et al[44] stated that reduced molecular size of an irrigant allows better penetration into the dentinal tubules, thus improving its antibacterial efficacy. Bukiet et al.[45] conclude that adding chemical products such as surfactants, often displaying viscous properties, may increase the viscosity but there is decrease in irrigant viscosity by adding surfactants with a concentration close to their critical micellar concentration (CMC).



(Diagram 2: showing the factors effecting the viscosity of an endodontic irrigant)

The viscosity of an irrigant influences its flow characteristics within the root canal system. A proper viscosity is necessary to ensure adequate distribution of the irrigant throughout the entire canal space, including complex anatomical variations. Appropriate flow and distribution contribute to better disinfection and debris removal. It is supported by Boutsioukis C, Verhaagen B, Versluis M, Kastrinakis E, Wesselink PR and van der Sluis LW.[46] Low-viscosity irrigants can more effectively carry away debris, pulp remnants, and biofilm from the root canal walls and dentinal tubules. This reduces the chances of reinfection and contributes to a cleaner root canal system. This finding is supported by Haapasalo M, Shen Y, Qian W and Gao Y.[47] Controlling the viscosity of an irrigant can also help in the precision and control of the irrigation process. Varying the viscosity can influence the irrigant's ability to remove debris, aid in the negotiation of narrow canals, and improve the overall effectiveness of the procedure. Same thing stated by Zehnder M.[48] Moreover, low-viscosity irrigants are less likely to cause excessive pressure buildup within the root canal system during irrigation, reducing the risk of irrigant extrusion beyond the apex and subsequent discomfort or complications. It is also stated by Al-Jadaa A, Paqué F, Attin T and Zehnder M.[49]

IV. Conclusion



From the various literature review, studies and researches, it can be concluded that low surface tension and low viscosity are the important properties of a root canal irrigant. These properties must be kept in mind while selecting an endodontic irrigant because these directly effects the outcome of an endodontic procedure. However, more research is still needed to explore this field further.

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