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Comparatative Evaluation of the Effect of *Punica granatum*, *Cinnamomum zeylanicum* , and Sodium Hypochlorite on the Flexural Strength of Root Canal Dentin - An In Vitro Study

T K Krishnameera[1,*], Moksha Nayak[2], E Narendra Babu[1]

[1] *PG Student, KVG Dental College and Hospital, Kurunjibagh, Sullia, Dakshina Kannada, Karnataka, India*
[2] *Principal and Professor, KVG Dental College and Hospital, Kurunjibagh, Sullia, Dakshina Kannada, Karnataka, India*

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[*] *Corresponding author.*
T K Krishnameera
drkrishnameerathachattil96@gmail.com

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ABSTRACT

The choice of irrigants in root canal therapy can influence the flexural strength of dentin. Herbal irrigants have gained attention as alternatives due to their antimicrobial efficacy, cost-effectiveness, and sustainability. The main objective of the study was to compare and evaluate the effect of *Punica granatum, Cinnamomum zeylanicum*, and sodium hypochlorite on the flexural strength of root canal dentin. Thirty two human non caries single-rooted maxillary and mandibular premolars were included in the study. The teeth were randomly distributed into four experimental groups based on the irrigant used. Group 1 (n=16): Aqueous extract of 20% pomegranate peel; Group II (n =16): 25% Cinnamon ethanolic extract; Group III (n=16): 2.5% Sodium hypochlorite; Group IV (n =16): normal saline (control). Each tooth was decoronated. Decoronated roots were sectioned longitudinally into buccal and lingual halves, yielding a total of sixty-four specimens. Each segment was embedded in auto-polymerizing acrylic resin and polished with fine emery papers moistened with distilled water. Then these segments are divided into groups based on the irrigant used. All specimens are treated with 5 ml of each irrigant for 10 minutes and rinsed immediately. The flexural strength of dentin is tested using the digital universal testing machine. Statistical analysis was performed using one way ANOVA test. The experimental groups demonstrated a significant enhancement in flexural strength compared to the control group. Among the experimental groups, pomegranate peel extract and cinnamon ethanolic extract showed the highest mean flexural strength, whereas sodium hypochlorite recorded comparatively lower values ($p < 0.001$). Within the limitations of this study, it can be concluded that herbal irrigants were less detrimental to root dentin compared to the conventional irrigant, as both herbal agents produced a comparable increase in flexural strength. Further research is required to optimize their concentration and clinical applications.

Keywords: Flexural strength; Sodium hypochlorite; Pomegranate peel; Cinnamon extract; Root canal dentin

1 INTRODUCTION

Effective endodontic treatment necessitates the complete elimination of microorganisms and their toxic byproducts from the infected root canal system. This objective is primarily achieved through the use of antimicrobial irrigants, which play a crucial role in canal disinfection and treatment success[(1)]. Irrigation is a critical step in root canal therapy, as it enables cleaning and disinfection of areas of the canal wall that are inaccessible to mechanical instrumentation[(2)]. Root canal irrigants may adversely affect the mechanical properties of dentin, including microhardness and flexural strength[(3)]. A reduction in flexural strength increases the susceptibility to root fractures, which can ultimately compromise the success of endodontic treatment[(4)]. Contemporary medicine increasingly incorporates herbal extracts derived from natural plants due to their ready availability, affordability, low toxicity, and prolonged shelf life. Moreover, these extracts are rich in bioactive compounds—such as alkaloids, flavonoids, and terpenoids—which confer diverse therapeutic properties including antioxidant, anti-inflammatory, antimicrobial, immunomodulatory, and adaptogenic effects. Pomegranate peel extracts exhibit notable antibacterial activity against

various bacterial strains, primarily attributed to the presence of bioactive constituents such as tannins and phenolic compounds, including punicalagin[5]. Cinnamon (*Cinnamomum zeylanicum* L.), a member of the Lauraceae family, is widely recognized not only as a culinary spice but also for its traditional medicinal applications, owing to its antimicrobial, anti-inflammatory, and analgesic properties[6]. A 25% concentration of cinnamon ethanolic extract (CEE) demonstrated strong antimicrobial activity, comparable to that of 5.25% sodium hypochlorite, against microorganisms isolated from nonvital teeth[7]. At present, there is limited evidence directly comparing the effects of pomegranate peel extract and cinnamon extract as root canal irrigants on dentin. Therefore, the aim of this study was to evaluate the influence of *Punica granatum, Cinnamomum zeylanicum* and sodium hypochlorite on the flexural strength of root dentin.

2 MATERIAL AND METHODS

2.1 *Sample Selection*

For this in vitro study, thirty-two intact, non-carious, single-rooted mandibular and maxillary premolars extracted for orthodontic purposes were collected from the Department of Oral and Maxillofacial Surgery, KVG Dental College. Teeth exhibiting caries, restorations, surface alterations, stains, craze lines, white spot lesions, developmental anomalies, hypoplasia, hypocalcification, or erosive defects were excluded. All selected samples were stored in 0.1% thymol solution until further testing.

2.2 *Preparation of Specimens*

All teeth were decoronated at the level of the cementoenamel junction using a water-cooled diamond disc. Each tooth was then sectioned longitudinally into two halves, yielding a total of sixty-four specimens.

The root segments were mounted horizontally in auto-polymerizing acrylic resin blocks with the dentin surface exposed. The mounted specimens were subsequently ground and polished using a series of fine-grit emery papers to obtain a smooth, standardized surface for testing.

2.3 *Preparation of irrigants*

2.3.1. *Preparation of Pomegranate Peel Extract:*

A 20% (w/v) aqueous extract of pomegranate peel was prepared by dissolving 20 g of dried peel powder in 100 mL of distilled water. The solution was thoroughly mixed to ensure complete extraction.

2.3.2. *Preparation of Cinnamon Extract:*

Cinnamon bark was first crushed into smaller fragments to increase the surface area for extraction. Approximately 400 mL of 90% ethanol was then used as the extraction solvent. Following the extraction process, the solvent was removed, and the concentrated extract was collected from the bottom of the boiling flask.

2.4 *Grouping of Samples*

All specimens were randomly divided into four groups (n = 16 per group) according to the irrigant used.

- Group I (n=16): Aqueous extract of 20% pomegranate peel.
- Group II (n =16): 25% Cinnamon ethanolic extract.
- Group III (n=16): 2.5% Sodium hypochlorite.
- Group IV (n =16): Normal saline (control).

2.5 *Specimen Treatment and Flexural Strength Testing*

All specimens were treated with 5 mL of the respective irrigant for 10 minutes, after which they were immediately rinsed with distilled water. Flexural strength testing was performed using a miniature three-point bending apparatus. Each specimen was positioned on the supporting span and subjected to loading until fracture using a universal testing machine (UTM 2011N) operating at a crosshead speed of 1 mm/min. The flexural strength of each sample was subsequently recorded.

To minimize bias, all specimens were coded by an independent operator before testing. The examiners responsible for measurements were blinded to the group allocation, and data entry was performed without disclosure of treatment identity until the completion of statistical analysis.

2.6 *Statistical Analysis*

- Statistical analysis was done using one way ANOVA test.
- Independent sample test were used to bring about the comparison with control group.
- P-value < 0.05 was considered statistically significant.
- All analyses were performed using SPSS v26 (IBM Corp., Armonk, NY, USA) and R v4.3.

3 RESULTS

Table 1 represents the descriptive values of flexural strength among the groups.

Among the experimental groups, both pomegranate peel extract and cinnamon extract demonstrated an increase in flexural strength, whereas sodium hypochlorite resulted in a reduction. Statistical analysis using one-way ANOVA revealed a highly significant difference among the groups ($p < 0.001$). Notably, the herbal irrigants exhibited the least adverse effect on flexural strength.

Table 1: Descriptive values of flexural strength of dentine among studied groups

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	p value
					Lower Bound	Upper Bound			
Group 1 Aqueous extract of 20% pomegranate peel	16	4.5400	.00000	.00000	4.5400	4.5400	4.54	4.54	<0.001**
Group 2 25% Cinnamon ethanolic extract	16	4.4256	.01590	.00398	4.4172	4.4341	4.40	4.45	
Group 3 2.5% Sodium hypochlorite	16	3.2619	.01328	.00332	3.2548	3.2689	3.24	3.28	
Group 4 Normal saline	16	1.7219	.04475	.01119	1.6980	1.7457	1.62	1.78	

*One way ANOVA test
** p value <0.001 was considered statistically very significant.

Table 2: Significance level of group wise comparison between the studied groups

Groups	Group 4 (CONTROL) Normal saline	Group 1 Aqueous extract of 20% pomegranate peel	Group 2 25% Cinnamon ethanolic extract	Group 3 2.5% Sodium hypochlorite
Group 1 Aqueous extract of 20% pomegranate peel	<0.001	—	<0.001	<0.001
Group 2 25% Cinnamon ethanolic extract	<0.001	<0.001	—-	<0.001
Group 3 2.5% Sodium hypochlorite	<0.001	<0.001	<0.001	—

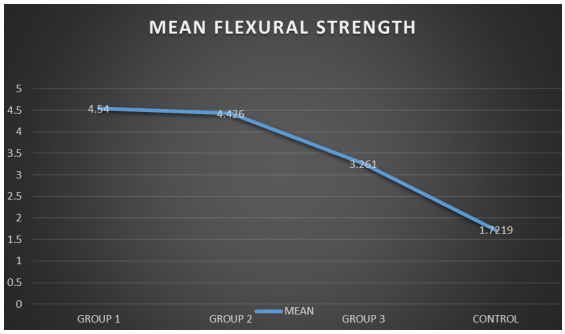

Fig. 1: Graph representing mean flexural strength among groups

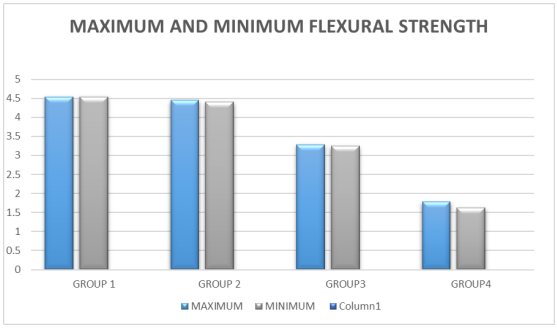

Fig. 2: Bar graph representing maximum and minimum flexural strength

4 DISCUSSION

The present study evaluated the effect of pomegranate peel extract and cinnamon extract on the flexural strength of root canal dentin, as assessed using a universal testing machine. The findings of the present study suggest that both pomegranate peel extract and cinnamon extract improved the flexural strength of root dentin, aligning with results reported in earlier studies[8].

Endodontically treated teeth are generally more prone to fracture compared to vital teeth. This increased susceptibility has been attributed to several factors, including the loss of tooth structure due to caries, cavity preparation, and access cavity design, as well as alterations in the biomechanical properties of dentin following endodontic therapy. Removal of the pulp and subsequent dehydration may also reduce dentin toughness, rendering the tooth less resistant to

occlusal and lateral forces[9,10]. Furthermore, endodontically treated teeth often require extensive restorative procedures, which may further weaken the remaining structure if not appropriately designed[11]. Preservation of coronal and radicular tooth structure, therefore, plays a critical role in enhancing the longevity and resistance of these teeth to fracture[12].

The application of endodontic irrigants, although essential for disinfection and smear layer removal, is associated with alterations in both the organic and inorganic components of dentin. These chemical and structural modifications may occur regardless of the therapeutic benefits of the irrigants, potentially influencing the mechanical and bonding properties of the tooth structure[13]. Pomegranate peel extract (PPE) has gained attention in dentistry due to its rich content of polyphenols, flavonoids, and hydrolyzable tannins such as ellagitannins and punicalagins, which possess potent antioxidant and collagen cross-linking properties. These bioactive compounds interact with the organic matrix of dentin, particularly type I collagen, leading to the formation of additional intermolecular cross-links. This biochemical modification increases the stiffness and resistance of the dentin matrix to enzymatic degradation, thereby contributing to improved mechanical properties, including flexural strength[14].

Cinnamon extract, derived primarily from *Cinnamomum zeylanicum* and *Cinnamomum cassia*, contains bioactive compounds such as cinnamaldehyde, eugenol, proanthocyanidins, and flavonoids, which exert antimicrobial, antioxidant, and collagen-stabilizing effects. When applied to dentin, these constituents can enhance the organic matrix integrity and improve mechanical properties such as flexural strength[15]. Proanthocyanidins and cinnamaldehyde in cinnamon extract act as natural collagen cross-linkers, promoting the formation of stable hydrogen and covalent bonds within the collagen fibrils of root dentin. This additional cross-linking enhances the stiffness of the dentin matrix, reduces enzymatic collagen degradation, and improves resistance to fatigue under stress, thereby leading to increased flexural strength[16].

NaOCl acts as a strong proteolytic agent. Its hypochlorous acid and hypochlorite ions degrade the collagen network within dentin by breaking peptide bonds and oxidizing amino acids. This leads to the removal of the organic phase, which is crucial for dentin's toughness and resistance to fracture. The resultant deproteinization decreases the ability of dentin to withstand functional stresses[17]. Prolonged or high-concentration exposure to NaOCl reduces dentin's flexural strength, modulus of elasticity, and microhardness. Use of sodium hypochlorite as irrigant leads to formation of a "ghost mineral layer" of sparse collagen generating a friable mineral matrix which results in reduction of flexural strength[18].

Flexural strength evaluation is done using a digital universal testing machine. Flexural strength was measured using a digital UTM (e.g., UTM-2011N) equipped with a miniature three-point bending fixture. The support span (L) was set to X mm (report exact value; commonly 10–20 mm for dentin beams). The loading nose and supports had rounded edges to minimize stress concentrations. Each specimen was centered on the supports (tension side down), aligned perpendicular to the span, and loaded at a crosshead speed of 1 mm/min until fracture. The maximum load at failure (F, in Newtons) was automatically recorded by the UTM software.

The primary limitation of the present study lies in its in vitro design, which cannot fully reproduce the complex and dynamic conditions of the oral cavity, including variations in salivary flow, pH fluctuations, microbial biofilm interactions, and masticatory stresses. In addition, only a single concentration of each irrigant was tested; different formulations, concentrations, or application protocols may influence the outcomes. Another limitation is that the analysis was restricted to flexural strength, which, although valuable, does not comprehensively represent the full spectrum of dentin's mechanical behavior.

Future research should therefore incorporate in vivo models to better simulate clinical conditions, evaluate a wider range of concentrations and treatment protocols, and include assessments of biocompatibility. The use of advanced characterization tools such as scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDX), and micro-computed tomography (micro-CT) is also recommended to provide deeper insight into the morphological and compositional changes in dentin induced by different irrigant

5 CONCLUSION

Within the limitations of this in vitro investigation, both pomegranate peel extract and cinnamon extract demonstrated a capacity to enhance the flexural strength of root dentin. Among the irrigants tested, the herbal agents produced favorable outcomes, whereas sodium hypochlorite was associated with a reduction in flexural strength. Further in vivo studies with longer observation periods, varied treatment protocols, and advanced analytical approaches are necessary to validate these findings and establish their clinical relevance.

6 DISCLOSURE

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Conflict of Interest: Nil

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