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Evaluating the colour stability of esthetic resin composite: A study of Neospectra ST under different staining conditions

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Abstract

Background: There is a burgeoning interest in the colour permanence of aesthetic restorations, although only a handful of studies have been documented thus far.
Aim: To investigate the impact of various common staining solutions on nanohybrid composite resin..
Materials and methods: Forty disk-shaped specimens (10 X 2 mm) were fabricated with Neo SpectraST composite material. The specimens were divided into four groups with 10 specimens (n=10) in each, based on the staining solutions, Group I: Turmeric, Group II: Coffee, Group III: Coke, and Group IV: Distilled water. Baseline measurements were taken using an ultraviolet spectrophotometer. Each sample group was immersed in their respective staining solutions, and the colour changes were recorded after 1, 7, and 14 days of immersion using the same spectrophotometer. The absorption values were recorded within the 300 to 800 nm range at baseline and after the immersion. The data was collected and subjected to statistical analysis.
Results: Neo spectra ST composite showed the maximum staining capacity with the turmeric group compared to other staining solutions. One-way ANOVA showed significant differences (p=0.000) among the staining solutions at different time intervals. Repeated measures ANOVA displayed significant differences within the staining solutions (Turmeric: p=0.005; Coffee: p=0.001; and Coke: p=0.001) at different time intervals.
Conclusion: The nanohybrid composite resin showed a significant colour change to turmeric compared to other staining solutions.
Keywords: Neo spectra ST composite, Spectrophotometry, Staining.

1. Introduction

Cosmetic dentistry provides people with the option to select dental restorations that match the colour of their natural teeth [1]. Because of their superior aesthetic qualities, composite resins are extensively utilized in cosmetic dentistry [1-2]. They vary in the type of resin matrix, as well as in the size, type, and quantity of filler particles [2]. The success of restoration depends on several factors, including adequate strength, high aesthetic appearance, diametral tensile and flexural strengths, compressive strength, polish retention, and resistance to wear and fracture [3-4].

Furthermore, aesthetic materials should mimic the appearance of natural teeth, which is closely linked to the material's colour stability. However, despite recent advancements, the colour stability of composite resins after prolonged intraoral use continues to be a concern for dentists [5]. Due to the polymerization reaction and their interaction with the oral environment, these resins undergo a series of physical changes [6], leading to the softening of the resin matrix and reduced stain resistance [7]. Discoloration of tooth-coloured resin-based materials can be attributed to both intrinsic and extrinsic factors, as well as the interface between the matrix and fillers [7-8]. Extrinsic factors, such as the adsorption or absorption of stains, not only lead to discolouration but also impact the structure of the composite and its fillers [9]. The type of polymerization system and the conditions under which polymerization occurs are crucial factors that determine the colour stability of composite materials [2]. In addition, the colour stability of composites is also affected by the conversion of matrix monomers. A high-intensity light polymerization unit has been developed to achieve superior properties in direct resin composites [10]. The staining of tooth-coloured composite materials is a primary reason for replacing restorations in visible areas [11]. Several in vitro studies have examined the colour stability of various aesthetic restorative materials [12-14].

Staining can be assessed both visually and through instrumental methods such as spectrophotometry and colourimetry. Visual colour evaluations are often unreliable because of varying colour perception among observers. In contrast, instrumental measurements remove the subjectivity inherent in visual colour comparisons [15]. The most frequently employed methods for measuring the colour change in dental materials are colourimeters and spectrophotometers [16-17].

Spectrophotometers offer greater accuracy than colourimeters because they include monochromators and photodiodes that measure the reflectance curve of a product's colour at intervals of 10 nm or less [18]. A study assessed the colour stability of various composites in different drinking media and found that water caused the least colour change, while red wine resulted in the greatest colour change. Cola, tea, and coffee produced moderate colour changes [19].

Neo Spectra ST composite, introduced by Dentsply Sirona in 2020,[20] is a universal nanohybrid composite material. It features Sphere TEC™ filler technology, which involves spherical, pre-polymerized fillers that enhance handling, strength, and esthetics. This innovative technology improves the composite's adaptability and sculptability, making it easier to place and contour. Neo Spectra ST provides excellent polishability, wear resistance, and natural-looking aesthetics, making it suitable for both anterior and posterior restorations. Its optimized filler content ensures a balance between strength and workability, offering reliable performance for various restorative procedures. However, very limited literature available on the physical, mechanical, and optical properties of Neo Spectra ST composite. Hence, this study aimed to evaluate the colour stability of Neo Spectra ST composite exposed to different staining solutions at different time intervals.

2. Materials and methods

This study was conducted at GSL Dental College and Hospital, Rajahmundry, Andhra Pradesh, India. This in vitro study evaluated the influence of three different staining solutions, turmeric, coffee, and cola, on the colour stability of nanohybrid composite resin, NeoSpectra™ ST (Dentsply Sirona, USA), at three different immersion periods, 1, 7, and 14 days.

2.1 Sample preparation

A total of forty disk-shaped specimens were made using a nanohybrid composite, Neo Spectra™ ST. A stainless-steel mould with an inner diameter of 10 mm and a thickness of 2 mm was used to fabricate the composite specimens. The metal mould was placed over the glass slide, and the composite resin with A1 shade was condensed into it. The surface of the composite was covered with Mylar strips (Samit products, New Delhi, India) and another glass slide was placed over it. Then, the composite was cured on both sides for 40 seconds using a Blue LEX LED light curing unit (Monitex GT 1200, Taiwan) with a wavelength of 450-470 nm and a lamp intensity of 600 mW/cm2 in a normal mode. After curing, the specimens were retrieved from the mold and then stored in distilled water at 37°C for 24 hours to ensure complete polymerization. Specimens were polished using polishing disks (Sof-lexTM, 3M ESPE). Then, the baseline colour values were recorded using an ultraviolet spectrophotometer (Shimadzu, Japan) and absorption values were recorded at 300 to 800 nm.

2.2 Staining solutions preparation

Composite disks were prepared and exposed to various staining solutions—coffee, turmeric, and cola—over time intervals of 1, 7, and 14 days. A total of 40 samples were fabricated and divided into four groups (Figure 1) of 10 samples each (n=10) according to the staining solution used (Table 1). The turmeric solution (Group I) was made by dissolving 4 g of turmeric powder (Sakthi, Mallampati, India) in 200 ml of water. For Group II, the coffee solution was prepared by mixing 4 g of instant coffee powder (Hindustan Unilever Ltd, Maharashtra, India) into 200 ml of boiling water, stirring for one minute, and then filtering through a paper filter. Group III used 200 ml of commercially available Coca-Cola (Hindustan Coca-Cola Beverages Pvt Ltd, Thiruvallur, India), while Group IV used distilled water. The nanohybrid composite disks were immersed in their respective solutions (Figures 2a-d) and evaluated for colour stability using a spectrophotometer at specified time intervals. All solutions were freshly prepared and replaced daily.

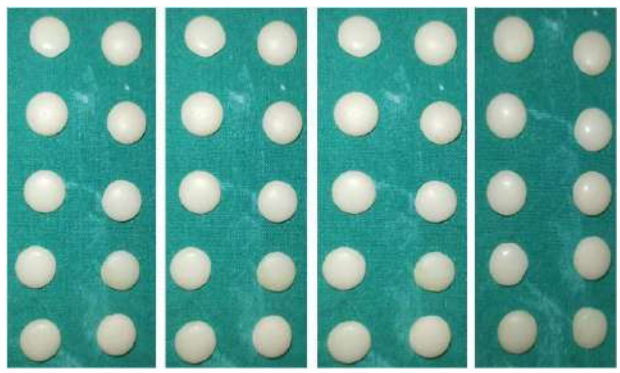

Figure 1. Composite Samples

2.3 Color stability evaluation

A spectrophotometer with a visible range of 300 to 800 nm was used to observe the amount of absorbance of colour (stain) of the samples. After removing the samples from their respective staining solutions, they were thoroughly washed under running water, dried with absorbent paper, and then placed in a viewing port for colour measurement in a spectrophotometer. The amount of absorbance was recorded at 300, 350, 400, 450, 500, 550, 600, 650, 700, 750 and 800 nanometres the value at 400-450nm wavelength was taken [21] (because it is in the visible light spectrum and is within the absorption range of many chromophores, which are molecules that absorb light at specific wavelengths) as standard value for each sample and compared to calculate the mean of colour change for every sample. These mean values were recorded on the 1st, 7th, and 14th days of an experiment to notice the colour changes. Hence, the percentage of absorbance of colour was selected as a criterion of colour change in a particular sample.

Table 1: Materials tested in the study

Material	Product	Composition	Manufacturer
Resin-based Composite	Neo Spectra™ ST	Organically modified ceramic- Methacrylate modified polysiloxanedimethacrylate resins, Ethyl-4 (dimethylamino) benzoate and Bis(4-methyl-phenyl) iodonium hexa-fluoro-phosphate. Filler load: 78–80% by weight Spherical, pre-polymerized Sphere TEC fillers (d3,50 ≈ 15 µm), non-agglomerated barium glass and ytterbium fluoride (≈0.6 µm)	DentsplyDeTrey, Konstanz, Germany
Staining Solutions	Sakthi Turmeric	Turmeric	Sakthi, Mallampati, India
	Coffee	Caffeine, melonoides, chlorogenic acids, N-methylpyridinium, diterpenes (cafestol and kahweol). Other components Crylamide, Furan, Ochratoxin-A.	Hindustan Unilever Ltd., Maharastra, India
	Cola	Carbonated water, sugar, acidity regulator, caffeine with natural coloring agents	Hindustan Cola-Cola Bevarages Pvt. Ltd, Thiruvallur, India

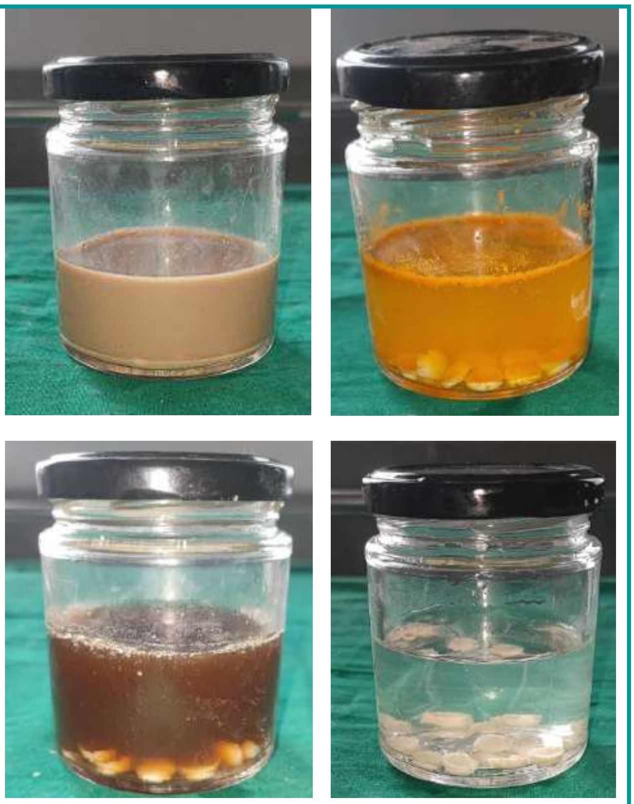

Figure 2. Composite Samples immersed in different staining solutions. Coffee (Top left), Turmeric (Top right), Coco-Cola (Bottom left), and Distilled water (Bottom right).

2.4. Statistical analysis

The obtained data was subjected to statistical analysis using the statistical package for social sciences (SPSS) 26.0 version, IBM, USA. One-way Analysis of variance (ANOVA) was used to compare the changes among the different staining solutions. Repeated measures ANOVA was used to compare among the different time intervals within each group, and Tukeys' test were performed at significance level of 0.05.

3. Results

The mean colour stability of the composite samples immersed in different staining solutions at different time intervals is presented in Table 2. The highest value of colour change was observed with the turmeric followed by coffee and Coke. The composite specimens stored in distilled water demonstrated the least colour changes compared to the other staining solutions. Maximum colour absorption on 1st day was seen in the turmeric followed by Coke and coffee, respectively. However, no significant colour absorption difference was observed after 7 and 14 days of immersion in turmeric and coffee. However, one-way ANOVA showed significant differences (p=0.000) among the staining solutions at different time intervals. Within each staining material, repeated measures ANOVA displayed significant differences (Turmeric: p=0.005; Coffee: p=0.001; and Coke: p=0.001) at different time intervals.

Table 3 presents the comparison between the different time intervals within each staining solution. In the turmeric group, 1-day immersion showed significant differences with the 7th day (p=0.028) and 14 days immersion (p=0.028). In the coffee group, significant differences were observed between all the time intervals (1- and 7-days: p=0.009; 1- and 14-days: p=0.013; and 7- and 14-days: p=0.013). Similarly, significant differences were also found in the Coke group between all the time intervals (1- and 7-days: p=0.013; 1- and 14-days: p=0.002; and 7- and 14-days: p=0.001).

Table 4 presents the intergroup comparison of colour changes between the different staining solutions at individual time intervals. After 1-day immersion, turmeric showed significant differences with the Coffee (p=0.001) and distilled water (p=0.000), and between Coke and distilled water (p=0.000). After 7 days of immersion, distilled water showed significant differences with the turmeric (p=0.000), Coffee(p=0.013) and Coke (p=0.000) staining solutions. Also, Coffee exhibited significant differences with the turmeric (p=0.006) and Coke (p=0.005). After 14 days of immersion, distilled water displayed significant differences with the turmeric (p=0.000) and Coffee (p=0.000) staining solutions. Also, significant differences were found between turmeric & coke (p=0.000); and coffee & coke (p=0.000).

Table 2. Comparison of absorption values during the different intervals

Groups	1st day Mean (SD#)	7th day Mean (SD#)	14th day Mean (SD#)	Repeated measures ANOVA
Turmeric	3.0188 (0.66)	1.9260 (0.09)	1.9260 (0.09)	F=11.4 p=0.005*
coffee	1.5840 (0.20)	1.884 (0.087)	1.88 (0.086)	F=19.7 p=0.001*
Coke	2.5140 (0.326)	1.930 (0.123)	1.40 (0.23)	F=39.7 p=0.001*
Control	1.28 (0.969)	1.28 (0.969)	1.28 (0.969)	
One-way ANOVA	F=20.23 P=0.000*	F=26.2 P=0.000*	F=28.07 P=0.000*	

#Standard Deviation

Table 3: Intra group comparison of absorption values among the different intervals

Groups	Intervals		p - value
Turmeric	1st day	7 days	0.028*
		14 days	0.028*
	7 days	14 days	-
Coffee	1st day	7 days	0.009*
		14 days	0.013*
	7 days	14 days	0.013*
Coke	1 day	7 days	0.013*
		14 days	0.002*
	7days	14 days	0.001*
Control	1 day	7 days	---
		14 days	---
	7 days	14 days	---

*Significant difference

Table 4: Inter group comparison of absorption values among the different intervals

Intervals	Groups		Mean Difference	Significance
After 1 day	Turmeric	coffee	1.1348	0.001*
		Coke	0.504	0.187 (NS)
		Distilled water	1.7388	0.000*
	coffee	Coke	0.63	0.07 (NS)
		Distilled water	0.604	0.09 (NS)
	Coke	Distilled water	1.23	0.000*
After 7 days	Turmeric	coffee	0.342	0.006*
		coke	0.004	1.000 (NS)
		Control	0.646	0.000*
	coffee	coke	0.346	0.005*
		control	0.304	0.013*
	Coke	control	0.65	0.000*
After 14 days	Turmeric	coffee	0.046	0.708(NS)
		Coke	0.526	0.000*
		Control	0.646	0.000*
	coffee	Coke	0.480	0.000*
		control	0.600	0.000*
	Coke	control	0.12	0.53 (NS)

*Significant difference, NS: No significant difference.

4. Discussion

Composite restorative materials are susceptible to colour change upon exposure to saliva, beverages, and food stains [22]. Compared to clinical studies, laboratory studies are easy to perform, could yield results at a faster rate, and help in predicting the colour changes in composite specimens [23]. Hence, this study assessed the colour change in dental resin materials by exposing them to turmeric, Coffee, Coke, and distilled water. Different studies have reported varying thresholds for colour difference values at which a colour change becomes perceptible to the human eye. These thresholds have been noted as ΔE values ranging from 1 [24] to between 2 and 3 [25], as well as greater than or equal to 3.3 [25] and 3.7[15]. Specifically, ΔE values between 0 and 2 are imperceptible, those from 2 to 3 are barely noticeable, values from 3 to 8 are moderately noticeable, and values above 8 are significantly noticeable [26]. A ΔE value of 3.7 or lower is generally considered clinically acceptable [15-23].

The staining of composites by all the immersion media used in this study can be explained by the staining susceptibility of composite resins, which may be related to their water sorption level and the hydrophilicity of the matrix resin [27]. Staining of resins by coloured fluids and beverages occurs due to the adsorption or absorption of colourants by the resins [17]. Composite resins that can absorb water are also capable of absorbing other pigmented fluids, leading to discolouration. It is believed that water serves as a vehicle [28] for stain penetration into the resin matrix. Conjugated diarylheptanoids, such as curcumin, are responsible for the orange colour and high staining potential of turmeric solution.[29] Coffee's staining is attributed to tannic acid and its discolouration results from both surface adsorption and absorption of colourants. This may explain why coffee tends to be less colour-stable compared to tea [17]. Despite containing phosphoric acid, cola drinks do not seem to significantly impact the colour change of composites. Different acids affect the dissolution and erosion of materials in various ways. Additionally, the phosphate ions present in Coca-Cola® may inhibit dissolution, as these ions have been shown to decrease the rate of calcium phosphate dissolution from teeth [30,31].

The stain resistance of the resin matrix is influenced by its degree of conversion [32] and water uptake [33]. In Bis-GMA-based composite resins, water uptake increases from 3% to 6% as the proportion of TEGDMA rises from 0% to 1% [34] UDMA appears to be more resistant to staining than Bis-GMA. Under standard curing conditions, UDMA-based composite resins show lower water sorption [35] and better colour stability.

The results of this study were consistent with the studies conducted by various researchers on the colour stability of dental composites. Like the present study, Stober et al. [36]also demonstrated that turmeric solution and red wine caused the most severe discolouration (ΔE >10) compared to tea, coffee, and mouth rinse over periods of 4 and 8 weeks. Scotti et al. [37] found that synthetic saliva and coffee caused more significant darkening than tea and artificial saliva over 10 and 30 days. Yannikakis et al. [38] used coffee and tea as staining agents and observed that coffee-stained provisional resin restorative materials more than tea. In a study by Fontes et al. [39], the authors evaluated colour changes at baseline and one week after storage in coffee, yerba mate, and grape juice. They found no significant difference in ΔE values from the baseline, except for grape juice.

The present in vitro study investigated the colour stability of composite resins exposed to different staining solutions over various time intervals. However, it did not fully replicate the complexities of the oral environment. Additional studies are necessary to achieve a thorough understanding of the colour stability of composite resin materials under real oral conditions.

5. Conclusion

The current study revealed that among the staining solutions tested, turmeric caused the most significant discoloration of Neo Spectra ST, followed by coffee and cola.

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Evaluation of stress distribution in an endodontically treated tooth restored with two different post and core systems in a maxillary central incisor: A finite element analysis study

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Abstract

Background: An endodontic post plays a crucial role in stabilizing and supporting a core restoration when insufficient coronal dentin remains after root canal treatment. It is inserted into the prepared root canal, strengthening the restoration and enabling it to endure chewing forces, thereby helping to preserve the tooth structure and overall durability of the restoration.
Aim: To evaluate the biomechanical behaviour and long-term safety of high-performance polymer PEEK as an intra-radicular dental post-core material through comparative finite element analysis (FEA) with other traditional (Nickel-Chromium) post-core material.
Materials and methods: CBCT scanning of a maxillary central incisor and its supporting structures was used to construct a two-3D solid model of endodontically treated teeth for finite element analysis (FEA). PEEK has a lower elastic modulus than root dentin and showed comparably more favourable stress distribution and high failure resistance than conventional post-core material. Two materials, Nickel-Chromium and PEEK, with the same crown design, were simulated to compare traditionally used post-core materials and evaluate their post-core properties. A 3D model of the maxillary central incisor area, including restorative components, was created. The masticatory load of 100 N was simulated at a 5 mm distance from the incisal edge and applied at a 45˚ angle to the long axis of the tooth.
Results: PEEK and metal post models demonstrated similar patterns and values of maximum equivalent stresses in the overall components of the model, except for the post and crown. In the apex region of the PEEK post-core case, the values of stresses were lower than those of metal posts.
Conclusion: PEEK post-core, with a lower elastic modulus than dentine, exhibited a favourable stress distribution profile at the intraradicular surface, indicating a lower possibility of root fracture than conventional post-core materials.
Keywords: Polyether ether ketone (PEEK), Nickel-Chromium, Finite element analysis, Post and core.

1. Introduction

Endodontically treated teeth exhibit the major loss of coronal dental tissues due to caries, fractures, and access cavity preparation procedures [1]. A successful restoration of endodontically treated teeth significantly affects their survival. The remaining coronal tooth structure, the tooth's position in the arch, and the esthetic requirements will determine the type of restoration indicated, whether it is restored directly or reinforced with a post, core, and crown [2,3]. Clinicians use posts and core foundations to support the final restorations of grossly destructed teeth [4]. Posts are usually classified into two major categories: custom-made and prefabricated posts [5]. Traditionally, custom-made posts were fabricated in dental labs from cast metals such as gold, palladium, silver, and base metal alloys [6].

Recently, however, they have increasingly made using Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) technology from materials like zirconia, glass-fibre reinforced composite, Nickel-chrome, hybrid ceramics, nano-ceramics, and Polyetheretherketone (PEEK) [7]. Custom-made posts adapt well to the root canal, have good mechanical proprieties, and have a long history of success in restoring endodontically treated teeth. Due to their high modulus of elasticity, these materials can withstand high occlusal forces before deformation occurs [8]. Prefabricated posts have gained popularity recently because they offer satisfactory results with minimal preparatory work, saving both time and cost [8].

However, due to a high elastic modulus difference between metal alloys and dentine, an excessive functional stress concentration may occur around the post, resulting in catastrophic root fracture [9]. Therefore, various post-core materials have been investigated to achieve long-term safety. Previous studies reported that a more favourable stress distribution is achieved using a post with a lower elastic modulus [10]. However, since fibreglass posts are generally supplied as ready-made products, they are limited in terms of their conformity to the shape of the root canal. In addition, although fibreglass posts have lower elastic moduli (from 45.7 to 53.8 GPa) than those of metal alloy posts (110.0 GPa for titanium and 95.0 GPa for gold), these are still approximately three times the elastic modulus of dentin (18.6 GPa) [11]. Employing post materials with an elastic modulus that is lower than that of dentin, like PEEK (Polyetheretherketone), promotes a more even distribution of stress across the dentin. This results in a failure type that is repairable at the neck of the tooth when a fracture occurs under excessive load [12].

PEEK is a tooth-coloured synthetic thermoplastic polymer, which exhibits suitable mechanical and shock-absorbing properties. Its ability to bond with both dentin and resin cement makes it an ideal material for use as a post. Using an adhesive luting cement for post retention, instead of threading, helps reduce the stress placed on the dentin [13,14]. PEEK is one of the organic thermoplastic polymers in the PolyArylEtherKetone (PAEK) family, best known as a high-performance polymer family, and mainly serves as an implantation material due its features and good biocompatibility in the medical field. It has been recognized as an adequate alternative biocompatible material for long-term proven titanium in orthopaedic applications. In dentistry, the main usage of the PEEK family has increasingly been as temporary implant abutments. In addition, it is used as dental clasps and frameworks for removable dental partial prostheses [15,16].

Advancements in dental materials and CAD/CAM technology enable clinicians to fabricate less time-consuming, highly accurate esthetic restorations. Posts and cores were not an exception as CAD/CAM technology permits the fabrication of custom-made PEEK posts and cores which can be used with full ceramic crowns thus overcoming the limitations of metal cast posts and cores [17,18].

Photoelastic stress analysis was also used to evaluate stresses responsible for the failure of a structure. The model needs to be made with similar conditions to the actual structure in terms of its geometry, support system, and the direction and strength of applied forces [19]. The distribution of internal stresses in the model should also be similar to those existing in the actual structure, regardless of the material. The calculations required to separate the principal stress values at a general interior point are very complicated. For precise stress analysis in large components, expensive equipment is needed. Also, 3D photoelasticity experiments are very time-consuming and tedious [20].

Fortunately, with rapid improvements in computer technology, finite element analysis (FEA) enables the user to accurately simulate a complex design like a post-crown endodontic restoration system and the natural condition of the oral cavity by entering various environmental parameters and tissue properties, overcoming the ethical issues and difficulties regarding medical studies [21].

The main objective of this study was to evaluate the biomechanical behaviour and long-term safety of high-performance polymer PEEK as an intra-radicular dental post-core material through comparative finite element analysis (FEA) with other traditional (Nickel-Chromium) post-core material.

2. Materials and methods

In this research, two types of custom-made posts and cores, PEEK and Nickel-Chrome, along with Zirconia full-coverage restorations, were utilized. The resin cement (Panavia F2.0, Kuraray, Japan) was employed for the bonding of the posts and full-coverage restorations.

2.1 Specimen preparation

A cone-beam computed tomography (CBCT) image of the right maxillary central incisor region was captured by a CBCT imaging machine (VGI Evo, Italy). The CBCT images were imported into the program MIMICS and materialized for segmentation. After segmentation, the polygonal model was saved in stereolithographic (STL) format and transferred to a reverse engineering program. The computer-aided three-dimensional interactive application (Hypermesh 19) was used for the generation of a solid model (Figure 1).

Two 3D Finite Element (FE) models of endodontically treated maxillary central incisor with two different posts & cores and the same full coverage restoration were designed for the analysis of stress distribution induced by applying the loads by using the ANSYS 17.0 software program, USA. The size and shape of the tooth were consistent with those of the anatomical atlas. The crown was 10.5 mm in length, with a medial distal width of 8.5 mm and a root length of 13 mm (the tooth was 23.5 mm long). A 0.2 mm thick periodontium was modelled around the root of the tooth. After creating the basic tooth model, an apical size of 40 and taper of 6% of the endodontic instruments and gutta-percha filling were simulated. Simulation of post space was done to a depth of 8 mm from the CEJ, leaving a minimum apical seal of 4–5 mm of gutta-percha in the canal space after post preparation and transversal tooth section 2 mm above the CEJ (ferrule effect) was made and the diameter of posts was 1.5 mm.

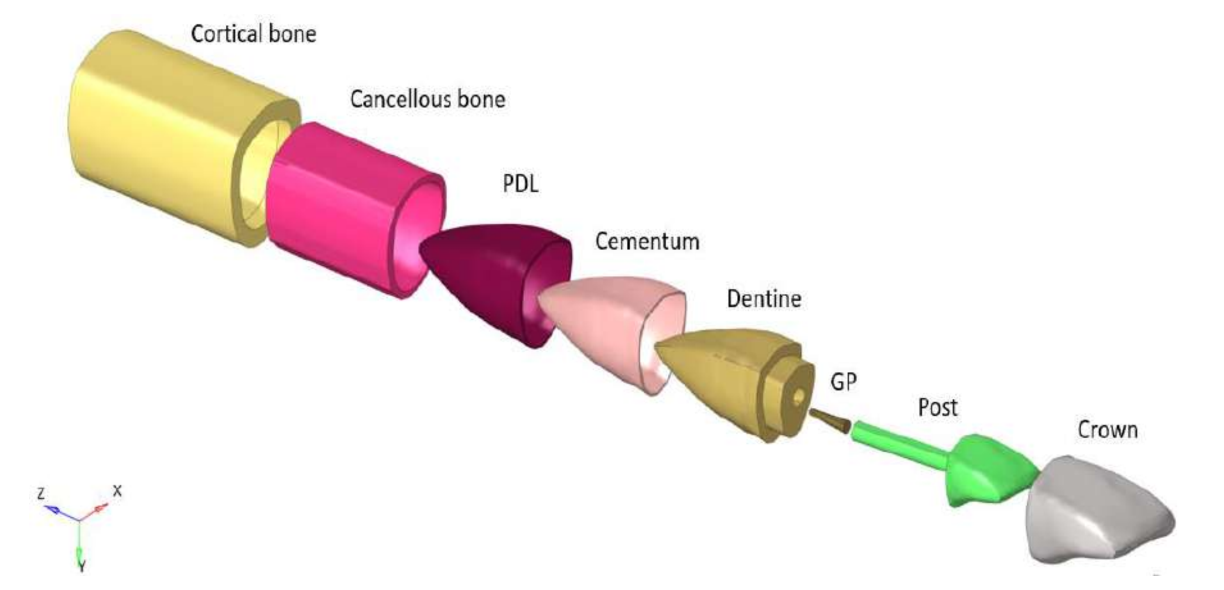

Figure 1. Different Components of constructed geometry models

Tooth Preparation was modelled according to the dimensions of the all-ceramic crown preparation for the full coronal coverage. Tooth reduction was modelled as 2 mm circumferentially and 2 mm incisally. The shoulder was kept as a finish line. The all-ceramic crown was modelled to fit the abutment. The all-ceramic crowns simulated in this study were Zirconia. All posts and crowns were cemented with Panavia F2.0 (Kuraray, Japan) with 0.1 mm thickness.

2.2 FE analysis

The 3D modelling of the maxillary central incisor region, along with restorative components, was done using the software, HyperMesh 19. The FE Models were obtained by importing the solid models into ANSYS17.0 FEM software, USA for stress analysis. All the materials were considered isotropic, homogeneous, and linearly elastic; these data were imported into the software program, together with the elastic modulus and Poisson's ratio values (Table 1). The models were then loaded with normal masticatory loads of 100 N at a distance of 5mm from the incisal edge, at an angle of 45 to the longitudinal axis of the tooth in coronal-apical and palatal-buccal directions (Figure 2). Meshing was conducted using quadratic tetrahedral elements, resulting in a total of 38189 nodes and 216854 elements in the study (Figure 3).

Table 1. Elastic modulus and Poisson's ratio of materials used in the current study

Materials	Elastic Modulus (GPa)	Poisson's Ratio
Cortical bone	13.7	0.3
Trabecular bone	1.37	0.3
Periodontal ligament	0.0689	0.45
Dentin	18.6	0.31
GUtta-percha	0.14	0.45
Zirconia	209.3	0.32
Resin cement	18.6	0.28
Nickel-Chromium alloy	205	0.33
PEEK	4.1	0.4

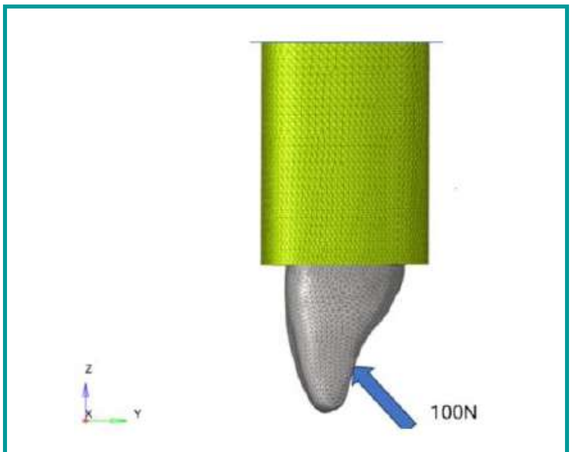

Figure 2. Force direction

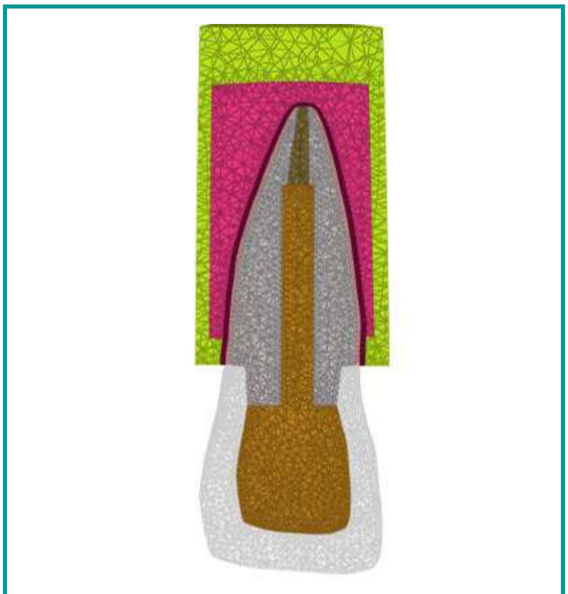

Figure 3. 3D Finite element meshing

Von Mises (Vm) stresses generated at the post and core assembly, coronal & radicular dentin were numerically recorded, colour-coded, and compared amongst the various models.

Model 1: Finite element analysis (FEM) of endodontically treated maxillary central incisors with Nickel-chrome post & core.

Model 2: Finite element analysis (FEM) of endodontically treated maxillary central incisors with PEEK post & core.

3. Results

The maximum von Mises equivalent stresses (MPa) of two FE models are presented in Table 2. The stress distribution in terms of colour contour patterns and the maximum value of VME stress of each component are shown in Figures 4 and 5. In Finite element analysis, Von Mises stress is a measure of the combined effect of different stress components. It's used to predict the yielding of materials under various loads. Peek and metal post models demonstrated similar patterns and values of maximum equivalent stresses in the overall components of the model, except for the post and crown.

On the other hand, the PEEK post-core model showed more stress concentration at the crown and the cervical area of the root. However, it showed significantly less stress concentration in the post-core component than in the metal post & core. In the metal post & core, the maximum stress values were located at the cervical region and 1/2 of the root. In the PEEK post-core case, the stress distribution and the maximum stress values were located at the core. In the apex region of the PEEK post-core case, the values of stresses were lower than those of metal posts. In addition, the stress in the cervical region of PEKK was dispersed in the mesio-distal direction.

Table 2. Comparative Evaluation of maximum von Mises equivalent stresses (MPa) within two FE models in this Study

von Mises Stress	PEEK Post	Ni-Cr Post
Crown	295	191
Post	32.72	118.62
Dentin	14.13	13.19
Cementum	13.92	13.01
PDL	3.08	3.03
Cement	2.12	1.39
Cancellous bone	2.075	2.064
Cortical bone	26.78	26.78

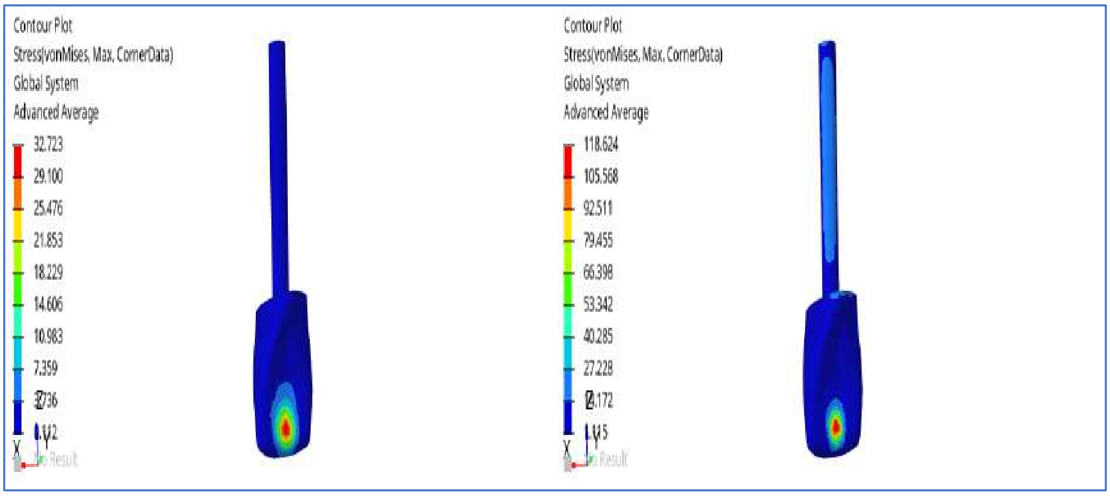

Figure 4. Stress distribution in PEEK and Ni-Cr post & core

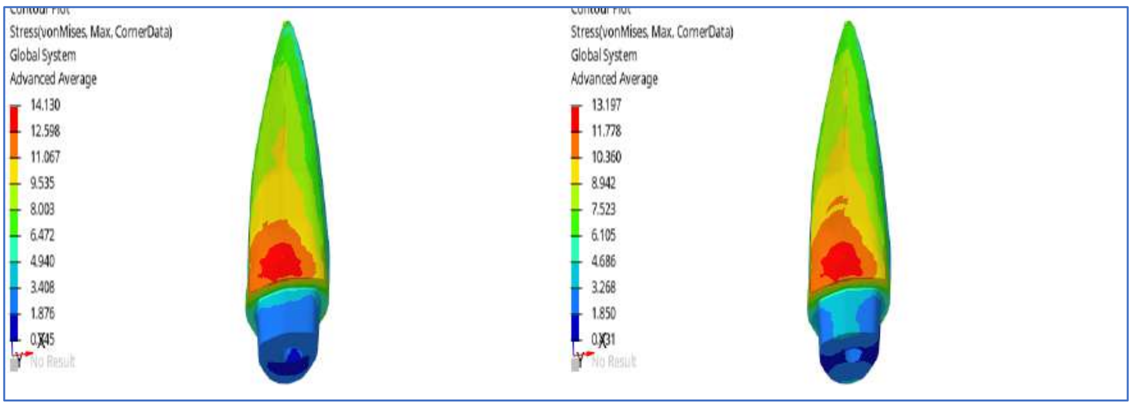

Figure 6. Stress distribution in Root dentin of PEEK and Ni-Cr post & core

4. Discussion

The risk of tooth fracture is an undesirable incident usually related to insufficient coronal tooth structure after endodontic treatment [22]. Rebuilding of the tooth structure by a post prior to crown restoration sometimes is mandatory to provide a stable and solid restoration of the tooth [23].

Analyzing stress distribution in post-core-restored endodontically treated teeth is challenging in vivo due to variations in mechanical and physical properties among different tooth tissues, which complicates the control of factors such as remaining tooth structure, load direction, and magnitude, as well as tooth position. In vitro tests also fall short as they cannot fully replicate the oral environment. To address these challenges, this study employed Finite Element Analysis (FEA) to simulate natural conditions within a complex design. Additionally, the Equivalent Von Mises (EVM) stress was utilized to assess stress distribution in critical areas, as it integrates both normal and shear stresses at specific points, which is crucial given the brittle nature of tooth tissues and the potential for failure [24,25]. So, in the current study, the models were studied as follows:
Model 1: An endodontically-treated maxillary central incisor with 2 mm ferrule and 1.5 mm diameter PEEK post & core. Model 2: An endodontically-treated maxillary central incisor with 2 mm ferrule and 1.5 mm diameter Nickel-chrome post & core.

This study evaluated the use of the high-performance polymer PEEK as an intraradicular post-core material by comparing it with conventional post-core materials. For a post-core restored endodontically treated tooth, a root fracture is an undesirable incident. According to previous studies, one of the causes of root fracture of post-restored teeth is stress concentration around the post-apex [26]. Clinically, the use of high elastic modulus metal posts and cores in endodontically treated teeth often leads to vertical root fractures, which can necessitate tooth extraction. To avoid these catastrophic fractures, prefabricated fibreglass posts and resin cores are now employed as post and core systems. Fibreglass, with its lower elastic modulus compared to metal but comparable strength, creates more favourable stress distributions within the root and typically results in repairable horizontal fractures if a root fracture occurs. However, despite having a lower elastic modulus than metal, fibreglass still has an elastic modulus several times greater than that of dentin. Recently, the high-performance polymer PEEK with an elastic modulus lower than that of fibreglass and similar to that of dentine has been introduced as an alternative intraradicular post-core material [27]. Therefore, the present study was performed to evaluate the biomechanical behaviour and long-term safety of the PEEK post-core system in the radicular tooth structure by using 3D FEA.

To assess the influence of a post-core material on the stress distribution of the restored tooth, the magnitudes of VME stresses under functional loading conditions were examined. In two experimental groups, the highest value of VME occurred at the zirconia crown among the overall components of each restored tooth model. This result is in agreement with the previous study of Sorrentino *et al.* [28], which conducted an FEA with a tooth model composed of a post, core, and crown, and it revealed that the crown component protects the whole system in the entire post-core restored tooth mode.

Regarding the effect of post-core material on the tooth root, the maximum VME stresses were observed at the outer labial region of the root's cervical area in both cases. When comparing these scenarios, it was found that as the elastic modulus of the post-core material decreased, stress concentration tended to increase, though the difference was not significant. This finding is consistent with previous research, indicating that more rigid post-core materials are better at resisting deflection forces, resulting in reduced maximum stresses on the root [29]. According to the study by Lanza *et al.* [10], the ideal materials of post-core systems should be sufficiently elastic to accompany the natural flexural movements of the tooth, which more rigid post-core materials cannot do. A post-core material with similar biomechanical properties to dentin could be advantageous in reducing the risk of root fractures. Therefore, a more rigid post-core working against the natural function of the tooth creates zones of tension and shear at the interface of dentine to the cemented post. These tensions, the intensities of which depend on the relative rigidity differences between the root and cemented post, can cause debonding or fractures.

In terms of stress distribution along the intraradicular labial root surface, where the dentine interfaces with the cemented post, the PEEK post-core—having an elastic modulus similar to that of dentine—demonstrated a lower stress distribution profile along the root mid-line compared to the post-core materials with higher elastic moduli. Metal post-cores showed generally higher stress distribution profiles, particularly in the cervical and post-apex regions. These findings indicate that a post-core material with a lower elastic modulus, such as PEEK, is advantageous for stress distribution at the dentine-post interface, potentially leading to a more repairable root fracture mode. This observation is consistent with previous studies highlighting the significance of stress distribution at the dentine-post interface.

Regarding the mechanical properties of PEEK, its flexural strength was similar to that of dentine and lower than the metal, and it had also a lower elastic modulus than dentine. As a result, the PEEK induced lower stresses in the post-core component, due to its flexibility. However, when the post made with PEEK material with lower elastic modulus was used, the post's stress distribution and safety factor were more favoured, but rather more stress was transferred to the adjacent crown and cement, which might indicate a higher probability of debonding of post and cement debonding resulting in crown fracture. In other words, using a post material with a low elastic modulus reduces the likelihood of vertical root fractures. However, this may increase the risk of post-core restoration failure due to cement debonding. Therefore, the elastic modulus and strength of the post-cement play a crucial role in maintaining the overall stability of a tooth restored with a low elastic modulus post-core material.

The distribution of mechanical and thermal stress in the complex geometry of an endodontically treated tooth, restored with a post, depends on the geometric, physical, and thermal properties of various materials and dental tissues. However, the variable stress gradient can contribute to damage to the bonding system resulting in the crazing of the filling material and remaining dental tissues [30].

In restorative dentistry, using PEEK for post and core represents a strategic approach to future dental health. The flexibility of PEEK material facilitates the correction of angulation issues ensuring precise alignment for optimal functionality and esthetics.

While the current study is a virtual experiment using 3D Finite Element Analysis (FEA), it highlights how the elastic modulus of post-core materials can impact the likelihood of vertical tooth fractures and post-core debonding. Therefore, a thorough understanding of stress distribution and the long-term stability of the post-core restored tooth system can aid dental professionals in making informed decisions about post-core material selection, considering the amount of remaining tooth structure. It should be noted that the simulation materials of the restorative parts and oral structures used in this study were considered to be linearly elastic, homogeneous, isotropic, and ideally bonded, which is not the same as that of natural tooth structure and supporting tissues which they present heterogeneous and anisotropic behaviours [31]. However, to guarantee the accuracy of the finding, a direct comparison between the results of the FEA study and clinical trial with in-vitro studies is necessary to support or modify the outcome of the present study and evaluate the combined effects of thermal changes and mechanical loading. Therefore, further laboratory and clinical studies, including ageing effects, are required to verify and supplement the present study.

5. Conclusion

Based on the results of this study, the following conclusions may be drawn:

- PEEK post-core, with a lower elastic modulus than dentine, exhibited a favourable stress distribution profile at the intraradicular surface, indicating a lower possibility of root fracture than conventional post-core materials.
- PEEK models transferred higher stresses to the interface material and restorative crown than the other models due to its flexibility. The probability of debonding and crown failure in a PEEK post-core system may be higher than that of rigid post-core systems.

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Effect of preoperative analgesics and cooled Lidocaine with Epinephrine on the anesthetic efficacy of inferior alveolar nerve block in patients with symptomatic irreversible pulpitis: A single-blind, randomized controlled trial

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Abstract

Background: Treating mandibular molars with symptomatic irreversible pulpitis poses challenges, as achieving anaesthesia in “hot teeth” is difficult. Epinephrine aids anaesthesia by reducing blood absorption through local vasoconstriction. However, when epinephrine is contraindicated, cooling the anaesthetic may provide effective vasoconstriction in cutaneous arteries and inhibit sensory nerve action potentials, enhancing anaesthetic efficacy.
Aim: To evaluate the effectiveness of preoperative analgesics and cooling of 2% lidocaine solution with 1:200,000 Epinephrine on the efficacy of Inferior alveolar nerve block (IANB) during root canal treatment in patients with symptomatic irreversible pulpitis of the mandibular molars.
Materials and methods: This study was conducted on 36 subjects diagnosed with symptomatic irreversible pulpitis. Participants were randomly assigned into one of three groups, each consisting of 12 patients (n=12). The subjects in Group A (Control) received Vitamin E 400 mg tablets as premedication and Local Anaesthetic injection of 2% Lignocaine at room temperature. The subjects in Group B received Piroxicam 20 mg tablets as premedication and local anaesthetic injection of 2% Lignocaine at Room Temperature. The subjects in Group C received Piroxicam 20 mg tablets as premedication and local anaesthetic injection of 2% Lignocaine at 4° Celsius. The patient’s preoperative pain levels before and after administering the analgesic, before and after the administration of local anaesthesia and intraoperative pain levels were recorded using the Heft-Parker visual analogue scale. Anaesthetic success was again evaluated after re-initiation of the endodontic treatment. The heart rates of the patients were measured using a finger pulse oximeter.
Results: The patients in group C showed the highest mean difference in pain levels followed by group B and A. However, the Group A patients displayed the highest heart rates followed by Groups B and C. One-way ANOVA showed a significant differences in the pain levels (p=0.0002) and heart rates (p=0.0004) among the groups.
Conclusion: This study showed that Piroxicam effectively achieved IANB in patients with symptomatic irreversible pulpitis of mandibular molars. Cooling 2% lidocaine with 1:200,000 epinephrine to 4°C significantly reduced post-injection heart rate and enhanced anesthetic success.
Keywords: Pulse oximeter, Intraoperative pain, Visual Analogue Scale.

1. Introduction

Mandibular molars experiencing symptomatic irreversible pulpitis present a challenging treatment situation. Dentists often face difficulties in achieving anaesthesia in a hot tooth. Epinephrine decreases the absorption of local anaesthesia in blood by local vasoconstriction [1]. However, in situations where Epinephrine is not advisable, cooling the dental anaesthetic may be more effective in inducing vasoconstriction in the skin's arteries and preventing sensory nerve action potentials. Research in recent years has explored various strategies to enhance the efficacy of local anaesthesia, particularly in cases of symptomatic irreversible pulpitis, which can be challenging to anaesthetize effectively. Goto et al. [2] demonstrated that cooling induces vasoconstriction in cutaneous arteries via activation of α1-adrenoceptors and α2C-adrenoceptors, which may prolong anaesthetic action by slowing blood flow in treated areas. Supporting this, Butterworth et al. found that cooling lidocaine solutions with ice significantly decreased sensory nerve action potential compared to solutions at room temperature, suggesting an increased numbing effect through cooling.

Similarly, Dabarakis et al. [4] reported that 3% plain mepivacaine solution at 4°C had a notably extended duration of action relative to the same solution at 20°C. Furthermore, Mishra et al. [5] observed that clinical success rates in achieving anaesthesia in patients with symptomatic irreversible pulpitis can be as low as 43-83%, underscoring the difficulty of anaesthetizing "hot" teeth. Given these challenges, nonsteroidal anti-inflammatory drugs (NSAIDs) are frequently prescribed as preoperative analgesics to reduce mild to moderate pain associated with symptomatic irreversible pulpitis. Therefore, the present study investigated and compared the effects of preoperative analgesics and cooling of Lidocaine on the anaesthetic efficacy of inferior alveolar nerve block in patients having symptomatic irreversible pulpitis..

2. Materials and methods

This study was conducted in the Department of Conservative Dentistry and Endodontics at GSL Dental College and Hospital and received approval from the institutional ethics committee (GSLDC/IEC/2023/063).

This randomized, single-blinded trial employed a parallel design and included 36 participants diagnosed with symptomatic irreversible pulpitis. A power analysis determined the necessary sample size, and participants were randomly assigned to one of three groups, with 12 individuals in each group (n = 12). The groups including, group A (Control, Vitamin E 400 mg with 2% Lignocaine at Room temperature), group B (Piroxicam 20 mg with 2% Lignocaine at Room Temperature), and group C (Piroxicam 20 mg with 2% Lignocaine at 4° Celsius).

All 36 participants received a detailed explanation of the study and provided written informed consent. Participants in Groups B and C were given a 20 mg dose of piroxicam one hour before local anaesthetic administration to initiate root canal treatment. To monitor baseline heart rate, a finger pulse oximeter was placed on the index finger of either hand before administering the anaesthetic. A pressure-type syringe was used with anaesthetic cartridges, which were cooled to 4°C to achieve the desired temperature of the local anaesthetic solution. Inferior alveolar nerve block (IANB) injections containing 2% lidocaine at room temperature were administered using a pressure-type syringe (Osung Deosy, Pearland, TX, USA) with 30-gauge short needles (Septojet needles, Septodont). For the preparation of the cooled anaesthetic cartridges, standard anaesthetic cartridges were placed in ice coolant boxes maintained at a temperature of 4°C, verified with a digital thermometer at 4±2°C. Cartridges were kept in the ice bath for 15 minutes before injection.

Patients in Group C were given IANB injections using cooled lignocaine. To maintain blinding, cartridges for the control group were placed in a similar container filled with water at room temperature. After one hour, a standard IANB was carefully administered using the Halsted technique, with 1.8 ml of 2% lidocaine containing epinephrine at a 1:100,000 concentrations, using an aspirating syringe (DentArt Instruments Mfg. Co.) and a long 30-gauge needle (Septodont). Ten minutes following the initial IANB, patients' subjective lip numbness was assessed. Endodontic access was then performed under a rubber dam. The Heft Parker Visual Analogue Scale (HP VAS) was utilized to evaluate patients' pain levels. A dental intern monitored the heart rate every 30 seconds for a total of 5 minutes following the IANB injections, while intraoperative pain levels were simultaneously assessed using the HP VAS. Afterwards, endodontic treatment was resumed under a rubber dam. The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS, version 25.0; IBM Corporation, USA). A one-way analysis of variance (ANOVA) was conducted to assess statistical significance.

3. Results

Patient recruitment began in August 18, 2023 and the study was conducted over a 3-months period. Of the randomly included patients, 53.3% were female and 46.7% were male. Effectiveness of the Preoperative analgesic was determined by the difference in preoperative and intraoperative HP VAS scores.

The differences in pain levels from preoperative to intraoperative stages, alongside changes in heart rate measured before and after IANB injections of Groups A, B and C are presented in Tables 1, 2, and 3, respectively. In Group A, pain differences range from 10 to 31, suggesting variability in patients' pain reduction following the anesthesia. The largest pain reduction is observed in Patients 2 and 9, both with a difference of 31, while the smallest pain reduction is seen in Patients 4 and 7, with a difference of 10 (Table 1). Heart rate differences between pre- and post-injection measurements vary from 16 to 22, indicating slight changes in physiological response to the anesthetic. Most patients show an increase in heart rate, with Patient 12 having the largest increase (22 beats), while Patient 11 shows the smallest increase (16 beats) (Table 1).

In Group B, the difference in pain levels from preoperative to intraoperative ranges from 45 to 70, indicating significant variability in pain relief among the patients. The highest pain reduction is observed in Patient 16, with a difference of 70, while the lowest pain reduction is noted in Patient 22, with a difference of 45. In terms of heart rate changes, the differences range from 14 to 20 beats per minute. Most patients exhibit moderate increases in heart rate post-injection, with Patient 18 showing the highest increase of 20 beats, while Patient 19 shows the smallest increase of 14 beats (Table 2).

Table 1. Preoperative and Intraoperative Pain, and Heart Rate Differences for Patients Undergoing IANB Treatment in Group A (Vitamin E 400 mg, 2% Lignocaine at room temperature)

S. No.	Patients	Difference between Preoperative and Intra-operative pain	Difference between Pre injection and Post injection Heart rates
1	Patient 1	18	19
2	Patient 2	31	21
3	Patient 3	13	17
4	Patient 4	10	20
5	Patient 5	18	18
6	Patient 6	13	19
7	Patient 7	10	18
8	Patient 8	24	20
9	Patient 9	31	17
10	Patient 10	21	21
11	Patient 11	18	16
12	Patient 12	15	22

Table 2. Preoperative and Intra-operative Pain, and Heart Rate Differences for Patients Undergoing IANB Treatment in Group B (Piroxicam 20 mg, 2% Lignocaine at room temperature)

S. No	Patients	Difference between Preoperative and Intra-operative pain	Difference between Pre injection and Post injection Heart rates
1	Patient 13	58	17
2	Patient 14	49	19
3	Patient 15	62	15
4	Patient 16	70	18
5	Patient 17	51	16
6	Patient 18	58	20
7	Patient 19	67	14
8	Patient 20	49	17
9	Patient 21	62	15
10	Patient 22	45	19
11	Patient 23	63	16
12	Patient 24	62	18

In Group C, the differences in pain levels range from 10 to 31, indicating variability in pain relief among the patients. The greatest reduction in pain is seen in Patients 2 and 9, both showing a difference of 31, while the least pain relief is noted in Patients 4 and 7, with a difference of 10. Regarding heart rate changes, the differences range from 4 to 10 beats per minute. Patient 34 shows the smallest change in heart rate with a difference of 4, indicating minimal physiological response to the treatment. Patient 35 exhibits the largest change in heart rate with a difference of 10, suggesting a more significant physiological reaction to the injection (Table 3).

The patients in group C showed the highest mean difference in pain levels followed by group B and A. One-way ANOVA demonstrated a significant difference in the pain levels among the groups (p=0.0002) (Table 4). However, the Group A patients displayed the highest heart rates followed by Groups B and C. One-way ANOVA showed a significant difference among the groups (p=0.0004) (Table 4).

Table 3: Preoperative and Intraoperative Pain, and Heart Rate Differences for Patients Undergoing IANB Treatment in C (Piroxicam 20 mg, 2% Lignocaine at 4° Celsius)

S. No.	Patients	Difference between Preoperative and Intra-operative pain	Difference between Pre injection and Post injection Heart rates
1	Patient 25	18	7
2	Patient 26	31	5
3	Patient 27	13	9
4	Patient 28	10	7
5	Patient 29	18	8
6	Patient 30	13	6
7	Patient 31	10	9
8	Patient 32	24	5
9	Patient 33	31	7
10	Patient 34	21	4
11	Patient 35	18	10
12	Patient 36	15	7

Table 4. Comparison between the groups (One-way Analysis of Variance)

Groups		Mean Difference	Standard Deviation	Significance
Pain levels	A	18.5	7.17	0.0002
	B	58	7.85	
	C	70	10.31	
Heart rates	A	19	1.85	0.0004
	B	17	1.90	
	C	7	1.81	

4. Discussion

Pain is a common and distressing experience for dental patients, particularly during invasive treatments such as root canal therapy. By investigating the effects of preoperative analgesics and the cooling of local anaesthetics, this study addresses a critical gap in dental anesthesiology. The results may contribute to better pain management strategies, thus increasing patient comfort and decreasing anxiety during dental treatments. Furthermore, understanding the interplay between preoperative medications and the temperature of local anaesthetics may help clinicians make informed decisions that optimize pain control, ultimately contributing to better clinical outcomes and patient satisfaction. Therefore, the present study investigated the effects of preoperative analgesics and cooling of lidocaine on the anaesthetic efficacy of inferior alveolar nerve block in patients having symptomatic irreversible pulpitis.

In this study, blinding of the participants was implemented to eliminate any potential bias. The dosage of 20 mg of Piroxicam was selected based on findings from Pulikottil *et al.* (2018), which demonstrated that pre-anaesthetic analgesics significantly enhanced anaesthetic success [6]. Additionally, previous research by Kim *et al.* (2016) indicated that Vitamin E helps mitigate the systemic side effects of lidocaine [7]. Pain levels were recorded using the Heft-Parker Visual Analogue Scale due to its proven reliability in endodontic studies. Piroxicam's anti-inflammatory action, which inhibits the synthesis of arachidonic acid, cyclooxygenase, lipoxygenase, prostaglandins, and leukotrienes, likely contributed to the observed improvement in anaesthetic efficacy.

The clinical outcomes of this study indicated that Piroxicam served as an effective preoperative analgesic, significantly enhancing both clinical and statistical success rates of IANB compared to the control group. These findings are consistent with prior studies by Wali *et al*. (2012) [8] and Deepankar Shukla *et al*. (2022) [9], which reported Piroxicam's 90% efficacy in IANB. Additionally, this study found Piroxicam to be clinically effective with minimal adverse effects; no side effects were reported, likely due to the single preoperative dosage. Future research may investigate variables like age, ethnicity, and body weight that could influence Piroxicam's efficacy in IANB applications.

Local Anaesthetic failure may be due to various reasons. In Clinically normal teeth, there is a 75%-90% success rate of anaesthesia, whereas, in the case of inflamed tissue (irreversible pulpitis), anaesthesia is ineffective in 30%-80% of patients. According to Hargreaves *et al*. (2001) [10] in Irreversible pulpitis, there is an 8-fold higher failure of local anaesthetic injections. Tetrodotoxin-resistant receptors get activated by the presence of inflammatory mediators, and exhibit resistance to the local anaesthetic solutions. As the local anaesthetic solution is subjected to rapid uptake by blood circulation, it is absorbed in the blood circulation, thus decreasing the concentration and the amount of the anaesthetic solution.

Individuals receiving IANB injections without a vasoconstrictor reported either no anaesthesia or only brief anaesthesia lasting just 1 to 2 minutes. Epinephrine, which activates both alpha and beta-adrenergic receptors, can pose certain complications due to beta-receptor stimulation. As a natural hormone from the adrenal medulla, epinephrine is secreted at a basal rate of approximately 0.17 to 0.54 µg/min in a healthy adult weighing 70 kg, a standard still applicable today. When administered with a single dose of lidocaine, the risk of adverse reactions remains low, though it increases with multiple lidocaine-epinephrine injections. To reduce the uptake of local anaesthetic in IANB injections without increasing epinephrine levels, cooling the anaesthetic solution offers a practical solution by inducing local vasoconstriction, thus inhibiting sensory nerve fibres. Butterworth et al. [3] found that cooling the anaesthetic delays its uptake by peripheral circulation. Lowering the temperature of lidocaine increases its pKa, ionic strength, and buffering capacity, as shown by Sanchez *et al*. [11]. Rosenberg and Havener [12] also noted that cooling lidocaine extended anaesthesia duration in rat sciatic nerves, while Dabarakis et al. [4] observed a significantly prolonged anaesthetic effect in maxillary premolars with 3% mepivacaine at 4°C versus 20°C (22.3 minutes vs. 17.3 minutes). Since cooling the anaesthetic solution may extend its duration and potency, this study assessed the efficacy of 2% lidocaine with 1:200,000 epinephrine cooled to 4°C in inferior alveolar nerve blocks. Results revealed an improved anaesthetic success rate with cooling, consistent with studies by Aggarwal *et al*. (2023) [13] and Riaz *et al*. (2023) [14].

This study focused on a randomly selected patient group rather than targeting individuals with cardiac health concerns, where epinephrine use in local anaesthesia is often restricted. Future research could involve patients with systemic conditions that contraindicate epinephrine to provide a clearer understanding of the benefits of cooling anaesthetic solutions before administration. These findings could ultimately help improve local anaesthesia effectiveness, allowing dental practitioners to manage "hot teeth" cases more effectively and reduce instances of anaesthesia failure.

5. Conclusion

In conclusion, cooling 2% lidocaine with 1:200,000 epinephrine to 4°C reduced post-injection heart rates and improved anaesthetic success rates. Additionally, preoperative Piroxicam was highly effective for achieving IANB in patients with symptomatic irreversible pulpitis in mandibular molars. Using a cooled anaesthetic combined with Piroxicam as a premedication offer a promising approach to enhance the efficacy of local anaesthesia, particularly for difficult cases like "hot teeth." This approach may lead to better pain management and improved patient satisfaction during root canal treatments.

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Exploring non-antimicrobial agents as antibiotic alternatives: an *in vitro* study

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Abstract

Background: Microorganisms cause periapical and pulpal disorders, making root canal treatment (RCT) essential. Due to complex canal anatomy, bacteria may persist despite cleaning. Intracanal medicaments, such as calcium hydroxide and chlorhexidine, help eliminate residual bacteria, reduce inflammation, and enhance treatment outcomes by improving disinfection and compatibility.
Aim: To assess the antimicrobial effectiveness of Triple Antibiotic Paste (TAP), Modified TAP, Sertraline (SSRI), Atorvastatin and the combination of Atorvastatin and Sertraline against *Enterococcus faecalis*.
Materials and methods: A total of 30 samples were made, with 6 samples from each group: TAP, Sertraline, Atorvastatin, Modified TAP, and Sertraline + Atorvastatin. The antimicrobial efficacy of the medicaments was evaluated using an agar well diffusion test by measuring inhibition zones around the medicaments. Statistical analysis included one-way ANOVA, with significance set at $p < 0.05$.
Results: A significant difference ($p=0.001$) in the diameter of growth inhibition zones was observed. The maximum inhibitory zone was found in Group 5: Sertraline+Atorvastatin.
Conclusion: The combination of sertraline and atorvastatin demonstrated superior antimicrobial efficacy compared to modified TAP, TAP, sertraline, and atorvastatin used alone.
Keywords: Neo Atorvastatin, *Enterococcus faecalis*, Selective Serotonin Reuptake Inhibitor, Triple antibiotic paste.

1. Introduction

Microorganisms are integral contributors to the onset of periapical and pulpal disorders [1]. The root canal treatment procedure eradicates bacteria residing within the infected root canal. The intricate anatomy of root canals often poses challenges in achieving thorough disinfection of the entire canal system. Consequently, employing antibacterial agents in the form of intracanal medicaments becomes necessary to effectively eradicate endodontic microflora [2].

Enterococcus faecalis, a Gram-positive facultative anaerobe, is a vital constituent of the microbial flora found in unsuccessfully treated endodontic teeth. Demonstrating resilience in harsh environments, it possesses the capability to develop biofilms [3]. In recent studies, calcium hydroxide ($Ca(OH)2$) has been disregarded as an efficient intracanal medicament due to its inability to eradicate the biofilm of E. *faecalis*. Consequently, newer antibacterial compounds are being suggested as alternatives [4].

Triple antibiotic paste (TAP), comprising metronidazole, ciprofloxacin, and minocycline, stands out as a widely employed intracanal medicament in endodontic therapies. Research findings indicate that TAP effectively eliminates bacteria up to a depth of 400 μm within the dentin, surpassing the reach of $Ca(OH)2$, which extends only up to 200 μm [5,6]. The overutilization of TAP may foster bacterial resistance, diminishing its efficacy as a medicament. Consequently, there has been a quest for non-antibiotic compounds possessing potent antibacterial attributes that operate via alternative mechanisms [7]. Some non-antibiotic drugs, such as antihistamines, antipsychotics, tranquillizers, and statins, have demonstrated antibacterial properties. Research has revealed that certain selective serotonin reuptake inhibitors (SSRIs) also possess antibacterial characteristics. Notably, Sertraline, which is classified as an SSRI, has shown significant bactericidal effects against both Gram-positive and Gram-negative bacteria by inhibiting bacterial DNA synthesis [7,8].

To our knowledge, the antimicrobial efficacy of modified TAP and Sertraline in combination with Atorvastatin remains unexplored. Therefore, the present in vitro study was conducted to evaluate the antibacterial efficacy of Sertraline (SSRI), TAP, Modified TAP, Atorvastatin and the combination of Sertraline with Atorvastatin against E. *faecalis*.

2. Materials and methods

This protocol was approved by the Institutional Ethics Committee (IEC number O.R.: GSLDC/IEC/2024/024), GSL Dental College and Hospital, Rajahmundry, Andhra Pradesh, India. A total of 30 samples were made and divided into 5 groups with 6 (n=6) in each. The study assessed the antibacterial effectiveness of TAP, Modified TAP, Atorvastatin, and Sertraline. These medications were sourced in their pure forms from Sigma-Aldrich, India.

2.1 Bacterial strains and media

The E. *faecalis* strain ATCC 29212 from the American Type Culture Collection (ATCC) was acquired. Their growth was confirmed on Bile esculi medium (Figure 1) and cultivated in blood agar. Inoculum density was standardized at 0.5 McFarland units (equivalent to 1.58 X 108 bacteria/ml) to account for turbidity [9]. The strains were isolated from a blood agar plate inoculated in peptone nutrient broth and were again incubated for 24 hours at 37 degrees centigrade in the incubator. The antibacterial activity of materials was assessed using the agar diffusion test method.

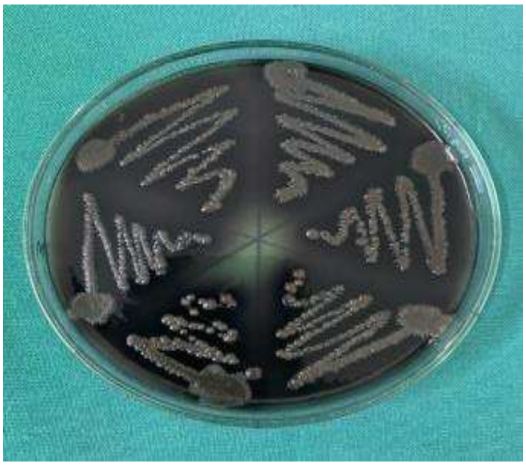


Figure 1. Bile esculin medium with *Enterococcus faecalis* growth

2.2 Preparation of medicament

Ciprofloxacin, metronidazole, and minocycline were used for TAP, while ciprofloxacin, metronidazole, and clindamycin were used for Modified TAP. Sertraline and atorvastatin were obtained in powder form from Sigma-Aldrich, India (Figure 2). A total of 30 specimens were prepared and divided into five groups, each containing six samples (n=6) from each medication. The samples were grouped as described below.

Group 1: TAP (1:1:1 w/v) – Equal amounts of metronidazole, ciprofloxacin, and minocycline were mixed with distilled water (1 mg/mL).

Group 2: Sertraline (1:1 w/v) – One millilitre of distilled water was mixed with 60 µg powder to attain a concentration of 60 µg/ml.

Group 3: Atorvastatin (1:1 w/v) –One millilitre of distilled water was mixed with 80 µg powder to attain a concentration of 80 µg/ml.

Group 4: Modified TAP (1:1:1 w/v) – Equal amounts of Metronidazole, Ciprofloxacin, and Clindamycin were mixed with distilled water (1 mg/mL).

Group 5: Sertraline+Atorvastatin (1:1 w/v) – Equal amounts of Sertraline and Atorvastatin were mixed with distilled water.

2.3 Agar well diffusion assay

A total of 5 Mueller-Hinton agar plates (Figure 7) were taken for the experiment, with 1 plate allocated to each group, ensuring 80% power and 95% confidence intervals. A total of six wells, each measuring 5 mm in diameter and 2 mm in depth, were made on the Mueller-Hinton agar plates (Figure 3a). Approximately 30 µl of the test material was dispensed into each well (Figure 3b). In order to achieve a uniform distribution of the cultured bacteria on the agar plates, cotton swabs were utilized (Figure 3c). The plates were then aerobically incubated at 37°C for 24 hours. Following incubation, a blinded examiner utilized an inhibition zone measuring scale to gauge the zone of bacterial inhibition surrounding each well, measuring from the initial point of bacterial growth to the outer margin of the well (Figure 3d).

2.4 Statistical analysis

The obtained data were analysed using Statistical Package for Social Sciences, SPSS version 25.0, Chicago, IL, USA. One-way ANOVA was employed to compare the diameter of growth inhibition zones across different groups. A significance level of p-value less than 0.05 was considered statistically significant.

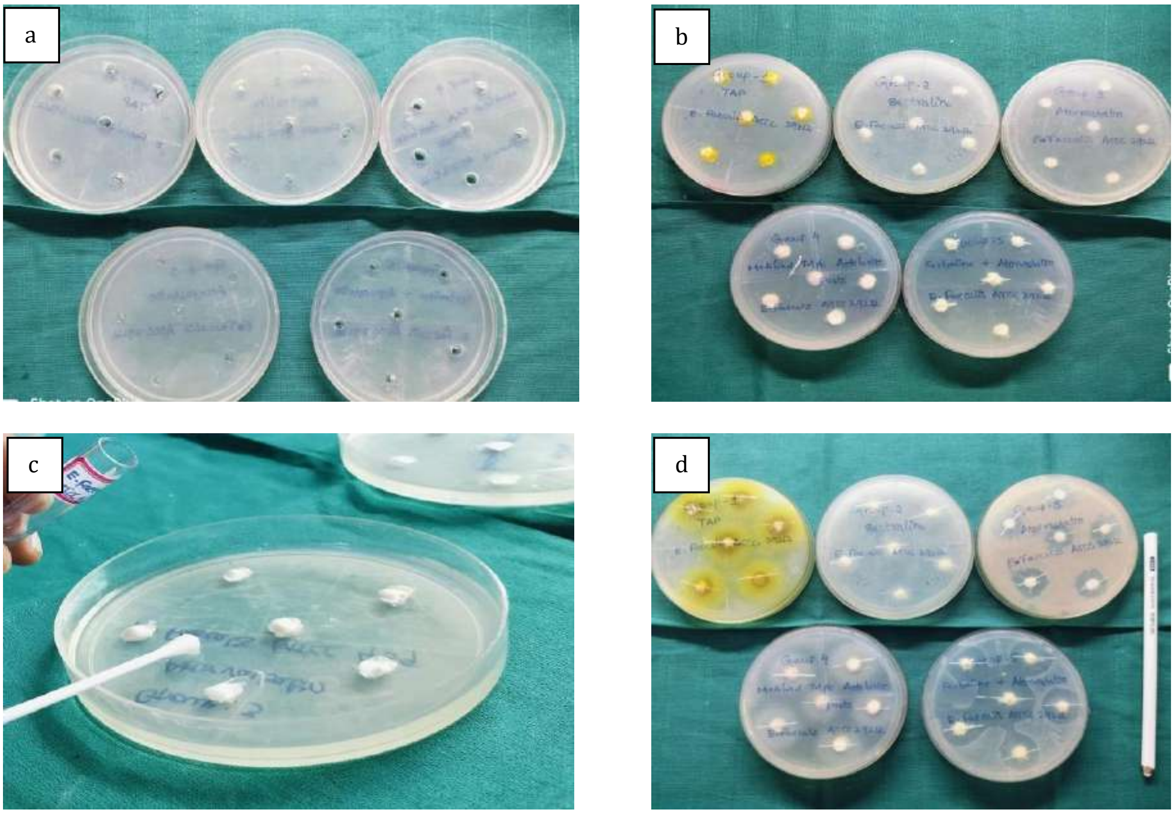
Figure 2. Powdered form of drugs

3. Results

Table 1 provides a comparative analysis of the inhibitory zones formed against E. *faecalis* in the 5 groups after incubating for 24hrs. The highest inhibitory zone was observed in Group 5, Sertraline+Atorvastatin, (23.500±1.516 mm) followed by Group 4, Modified TAP, (23.333±1.966 mm), Group 1, TAP (22.666±3.077 mm), and Group 2, Sertraline (19.166±2.787 mm). The least zone of inhibition was observed in Group 3, Atorvastatin (18.333±1.366 mm). One-way ANOVA displayed a significant difference among the groups for all five categories of the bacterial inhibition zones against E. *faecalis* (Table 1).

4. Discussion

It's fascinating how research is exploring alternative methods for disinfection in situations where antibiotic resistance poses challenges. Evaluating the antimicrobial effectiveness of statins and SSRIs alongside conventional methods such as Triple Antibiotic Paste (TAP) and Modified TAP against E. *faecalis* in root canal treatments appears to be a novel approach. Statins and SSRIs have primarily been associated with cardiovascular health and mood disorders respectively, so seeing them being investigated for their antimicrobial properties in dentistry is intriguing. Root canal infections, often caused by bacteria like E. *faecalis*, require effective treatment to prevent complications, so finding new approaches is crucial [7,8].



Figures 3 a-d. Assessment of antimicrobial activity. Where a. Mueller-Hinton agar plates with 6 wells, b. Wells with 30 µl of the test material, c. Distribution of the cultured bacteria on the agar plates, and d. Zone of inhibitions around the specimens.

Table 1. Mean zone of inhibitions (mm) around the specimens against E. *faecalis* (One-way ANOVA)

Groups	N	Mean	Standard Deviation	Significance (p-Value)
1	6	22.666	3.077	
2	6	19.166	2.787	
3	6	18.333	1.366	0.001
4	6	23.333	1.966	
5	6	23.500	1.516	

This study investigated the effectiveness of various alternative methods for combating *Enterococcus faecalis*. It is crucial to identify which of these alternative approaches have shown particular efficacy against E. *faecalis*. Additionally, a comparative analysis of these methods against traditional treatments regarding efficacy and safety is needed.

The resilience of E. *faecalis*, as highlighted by Haapasalo and Orstavik, underscores its designation as one of the most resistant intracanal bacteria, thereby emphasizing the critical need to evaluate and compare these alternative treatment strategies. It possesses the remarkable capability to endure within dentinal tubules for up to 10 days without external nourishment. These bacteria are responsible for persistent apical periodontitis due to their adeptness in adhering, aggregating, and forming biofilms, attributes that enhance their survival and amplify their resistance to antibiotic treatments [10].

The antimicrobial efficacy of dental materials and medications has long been assessed by dentists and pharmaceutical companies through the agar diffusion method. This approach enables a direct comparison of the effectiveness of various medicaments against specific pathogens, aiding in the identification of the most potent medicament for eradicating bacteria within the pulp space [11]. TAP has garnered widespread usage as an intracanal medicament against E. *faecalis* [12]. Comprising metronidazole, minocycline, and ciprofloxacin, TAP harnesses the non-cytotoxic properties of the tetracycline drug group to inhibit collagenases and matrix metalloproteinases. Notably, these antibiotics have demonstrated the capacity to elevate interleukin-10 levels, an anti-inflammatory cytokine. Additionally, metronidazole and ciprofloxacin have been shown to stimulate fibroblast production [13]. Various researchers substantiated the efficacy of MTAP through in vitro studies [14]. In clinical practice, the inclusion of minocycline has been observed to correlate with specific complications, such as tooth structure discoloration, antiangiogenic effects, and the chelation of radicular dentin, which can result in demineralization and compromised root integrity [15]. Karczewski *et al.* conducted a recent in vitro study examining the antimicrobial effectiveness, dentin discolouration potential, and cytotoxicity of Clindamycin MTAP. Their findings suggested that clindamycin has the potential to be a suitable substitute for minocycline within TAP formulations [16].

In this study, a blend of ciprofloxacin, metronidazole, and clindamycin was utilized. This particular drug combination was selected due to its broad spectrum of activity against endodontic pathogens. Considerable evidence substantiates the notion that serotonin reuptake inhibitors, the primary class of antidepressant medications, exhibit notable antimicrobial efficacy [7]. In 2015, Ayaz *et al.* [8] investigated the potential activity of sertraline against ATCC strains and clinical isolates of S. aureus, E. coli, and P. aeruginosa. They examined its effects both independently and in conjunction with seven different antibiotics. To assess the inherent antibacterial properties of sertraline against S. aureus, agar dilution and well assay methods were employed. The diameter of inhibitory zones (DIZ) increased proportionally with higher concentrations of sertraline. To enhance the understanding of sertraline's antimicrobial potential, the researchers investigated 28 bacterial strains, comprising 3 ATCC strains and 25 clinical isolates, along with 13 fungal strains. Sertraline demonstrated a 50% inhibition rate against clinical isolates of E. coli at a concentration of 60 μg/mL [7]. Statins, a group of drugs used to lower lipid levels and decrease the risk of heart-related issues, have shown additional benefits in reducing inflammation and modulating the immune system over time. Moreover, researchers have proposed that statins may offer protection against various infectious diseases. Atorvastatin and simvastatin, in particular, have been studied for their potential antimicrobial properties among the different types of statins [7]. The results of the current study aligned with the above study findings, demonstrating that the antimicrobial efficacy of sertraline is enhanced when combined with other drugs rather than used alone.

In this study, sertraline was administered both alone and in combination with atorvastatin, showing a larger inhibitory zone in the group that received the combination, which illustrates the concept of drug synergism. The comparison of growth inhibition zone diameters revealed that the values for Modified TAP were significantly greater than those for TAP. These findings are consistent with the study by Cunha *et al.* (2021) [18], which assessed the antibacterial efficacy of Triple Antibiotic Medication with Macrogol (3Mix-MP), traditional Triple Antibiotic Paste, calcium hydroxide, and ethanol extract of propolis, concluding in the above study that MTAP was more effective than TAP. The growth inhibition zones' diameters were notably larger when sertraline was combined with atorvastatin compared to when each medicament was used alone. This suggests a potential synergistic effect of combining these two substances. However, additional research is needed to explore various combinations of antibiotics and non-antibiotics against E. *faecalis*. Thus, the null hypothesis was rejected, indicating a significant variance in the growth inhibition zones' diameters across the five groups.

The main limitations of this study include it's *in vitro* design, which may not fully replicate the complex root canal environment, and its focus solely on E. *faecalis*, limiting the assessment of efficacy against other endodontic pathogens. The sample size, while statistically adequate, could be expanded for greater generalizability. Additionally, the antimicrobial efficacy was evaluated only after 24 hours, leaving questions about long-term effects and resistance development. Future research should focus on in vivo studies, testing a broader range of bacterial strains, and exploring synergistic combinations of antibiotics and non-antibiotic agents to enhance endodontic treatment outcomes.

5. Conclusion

This study found that the combination of sertraline and atorvastatin was more effective against E. *faecalis* than modified TAP, TAP, sertraline, or atorvastatin used alone. Hence, in clinical scenarios, employing medication combinations instead of single agents should be advocated for more effective control of endodontic biofilms. Additionally, utilizing non-antibiotic intracanal medications mitigates the potential for systemic complications and curbs the development of antibiotic resistance.

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The effect of immediate dentin sealing on the bond strength of resin composite to dentin bonded with universal bonding agent: An *in vitro* study

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Abstract

Background: Dentin hypersensitivity is a common scenario encountered in dental practice. This issue can be treated by reducing dentin permeability and dentinal fluid flow. However, the desensitizing agents used may adversely affect the bonding of composite restorations to dentin.
Aim: To evaluate the shear bond strength of restorative composites to dentin treated with silver diamine fluoride and self-etch bonding agent bonded using a universal bonding agent.
Materials and methods: A total of 30 teeth were selected, and their occlusal surfaces were ground to expose a flat dentin surface. The teeth were then embedded in cold cure resin blocks. Depending on the treatment, the samples were randomly divided into three groups, with 10 in each. The samples in the group were untreated, in group 2 were treated with Silver Diamine Fluoride (SDF), and in group 3 with the sixth generation bonding agent (self-etch primer). After the treatment, the composite is bonded to the dentin surfaces and subjected to shear bond strength using the universal testing machine (UTM). The specimen was mounted on the custom-made jig and placed over the UTM. The load was applied at a cross-head speed of 1mm/min until debonding occurred at the dentin and composite interface, and the bond strength was computed in MPa. Overall comparisons were analyzed using the Kruskal-Wallis test. The Mann-Whitney U-test was used for pair-wise comparisons, and the significance level was set at $p < 0.05$.
Results: The lowest bond strength was observed with the dentin surfaces treated with silver diamine fluoride (Group 2), and the highest bond strength was for dentin treated with self-etch bonding agent (Group 3). Significant differences ($p=0.003$) were observed between the groups. In pair-wise comparisons, group 3 showed significant difference with group 1 ($p=0.007$) and group 2 ($p=0.002$). However, no significant difference was observed between groups 1 and 2 ($p=0.197$).
Conclusion: The shear bond strength varies with different desensitizing treatments. This study reported more SBS with sixth-generation bonding agent followed by untreated dentin and SDF.
Keywords: Dentin, Silver Diamine Fluoride, Dentin Hypersensitivity, Shear bond strength.

1. Introduction

Hypersensitivity is a multi-etiological clinical problem. Dentin hypersensitivity is a common and painful condition encountered in clinical practice. It is characterized by sharp, short pain triggered by thermal, tactile, chemical, evaporative, or osmotic stimuli on exposed dentin [1]. Various factors cause dentin hypersensitivity, including loss of enamel, denudation of root surface, gingival recession resulting from periodontal disease, inappropriate brushing habits, and periodontal treatment. In such cases, the underlying dentin is exposed to external stimuli, resulting in hypersensitivity. Hydrodynamic theory is the most widely accepted theory for explaining dentinal hypersensitivity. This states that pain is due to the deformation of sensory nerves in the pulp, caused by peripheral stimuli, which are generated by the movement of fluids or semi-fluid material in dentin tubules [2].

Traditionally home-use desensitizing toothpastes are considered the first choice because of their advantages of wide availability, cost-effectiveness and convenient application. However, they have a short life due to daily tooth brushing, saliva dissolving and an acidic diet [3]. Professional chair-side desensitizing solutions such as Silver diamine fluoride (SDF) [4] and self-etch bonding agents [5] as immediate dentin sealing (IDS) are commonly used to treat dentin hypersensitivity clinically. Immediate dentin sealing (IDS) is also called prehybridization, dual bonding technique, or resin coating technique [6]. This appears to achieve improved bond strength, fewer gap formations decreased bacterial leakage, and reduced dentin sensitivity [7].

Silver Diamine Fluoride (SDF) provides desensitization by precipitating proteins from dentinal tubules [8]. The use of self-etch adhesives for treating hypersensitivity has become increasingly popular in recent years. These systems use hydrophilic acidic monomers, which demineralize dentin and form a hybrid layer incorporating smear plugs which reduce post-operative sensitivity [9]. The recently introduced universal adhesive systems have gained popularity due to their ease of application in self-etch & etch and rinse modes. This adhesive also contains10-MDP (10-Methacryloyloxydecyl dihydrogen phosphate), which is a monomer with mild acidity and has water-insoluble salt formation capacity with dentin and adhesive versatile to bond resin composites to metals and ceramics [10,11]. Furthermore, short and medium-term clinical evaluations seem promising [12].

This study aimed to assess the adhesiveness of composite resin to surface-treated desensitizing agents. The impact of these desensitizing agents on the bond strength of adhesive restorations has been the subject of numerous studies, yielding inconsistent and sometimes contradictory results. So, the purpose of this study was to statistically analyze the shear bond strength of restorative composite resin to dentin after treatment with silver diamine fluoride and self-etch bonding agent, bonded using a universal bonding agent. The null hypothesis posted that desensitizing treatments would not affect the bond strength of resin composite to dentin.

2. Materials and methods

Thirty freshly extracted human molars were collected and thoroughly cleaned, with all hard and soft tissue residues carefully removed. The teeth were then preserved in saline solution until they were needed for the study. Only teeth extracted for periodontal or orthodontic reasons were included, while those with caries or visible cracks were excluded from the study. The materials used in the study are presented in Table 1.

2.1 Specimen preparation

The occlusal surfaces of the teeth were ground to expose a flat dentin surface. The flat dentin surface was polished with 600-grit silicon carbide paper to create a uniform smear layer and smear plug. Subsequently, they were embedded in cold-cure resin (Dental Products of India, India) blocks. The samples were organized into three groups of ten (n=10) each: Group 1 consisted of Untreated Dentin (UT), Group 2 was treated with Silver Diamine Fluoride (SDF), and Group 3 received a sixth-generation bonding agent (Self-etch Primer, Clearfil SE Bond, Kurary Japan).

2.1.1 Specimen preparation in Group 1 (Untreated dentin): A Universal bonding agent (Clearfil Universal, Kurary, Japan) was applied to the dentin surfaces for 10 sec. Air dried for 5 seconds and then light cured for 10 sec. Then, the Universal composite was placed using a mold of 4 X 5mm and light-cured for 40 seconds with an LED light curing unit (Woodpecker, Guilin, China).

2.1.2 Specimen preparation in Group 2 (Silver diamine fluoride): SDF was applied to the dentin surface using a micro brush and allowed to soak for 1 to 3 minutes. A Universal bonding agent (Clearfil Universal) was applied to the dentin surfaces for 10 sec. Mild air was blown for 5 sec and then light cured for 10 sec. Then, the Universal composite was placed using a mold of (4 X 5)mm and light-cured for 40 sec with an LED light curing unit (Woodpecker, Guilin, China).

2.1.3 Specimen preparation in Group 3 (Clearfil SE Bond): The primer was applied and left for 20 seconds on the prepared teeth as per manufacturer instructions. After drying, the bonding agent was applied and distributed evenly with mild airflow. Then, these samples were light-cured for 10 seconds. A Universal bonding agent (Clearfil Universal, Kurary, Japan) was applied to the treated dentin surfaces for 10 seconds. Then Universal composite was placed using a cylindrical mold light-cured for 40 seconds with LED curing light (Woodpecker, Guilin, China).

2.2 Evaluation of shear bond strength

The specimen was placed on a custom-made jig and was mounted on the universal testing machine (Instron, USA). The load was applied at the dentin-composite interface at a crosshead speed of 1mm per minute until debonding occurs. The debonding load was recorded in Newtons (N) and the shear bond strength (MPa) was calculated using the following formula:

Shear bond strength = Debonding load (N) / Bonded area (mm^2).

Table 1. Materials used in the study

Product name	Company
Silver Diamine Fluoride	E-SDF (Kids – e – Dental (LOT : JK138))
Sixth Generation Bonding Agent	Clearfil SEBond, Kuraray Co Ltd, Osaka, Japan (LOT : 620409)
Universal bonding agent	Clearfil Universal Bond, Kuraray Noritake Dental Inc., Kurashiki, Okayama, Japan (LOT: AU0054)
Universal Composite	Plafique Omnichroma, Toukyama Dental corporation, Tokyo, Japan (LOT: 2831).

2.3 Statistical analysis

Data analysis was done using the Statistical Package for Social Sciences (SPSS version 26.0, IBM Corporation, USA). Overall comparisons were analyzed using the Kruskal-Wallis test. Pair-wise comparisons were done using the Mann-Whitney U test. The level of significance was set at $p < 0.05$ for all tests.

3. Results

The overall comparison of SBS between the three groups is presented in Table 2. The highest bond strength was found with the group 3 specimens (0.51 ± 0.22 MPa), which were treated with the self-etch bonding agent. The control group demonstrated a mean SBS of 0.32+0.09 MPa. The lowest bond strength (0.26 ± 0.10 MPa) was observed with the dentin surface treated with silver diamine fluoride, Group 2. Significant differences (p=0.003) were found among the groups (Table 2). Pair-wise comparisons of SBS between the three groups are presented in Table 3. In pair-wise comparison, group 3 showed a significant difference with group 1 (p=0.007) and group 2 (p=0.002). However, no significant differences were observed between groups 1 and 2 (p=0.197).

Table 1. Overall comparison of shear bond strength (MPa) between three groups

Groups	Mean ± SD	Mean Ranks	Kruskal-Wallis Value	p-Value
Group 1	0.32 ± 0.09	13.75	11.783	0.003*
Group 2	0.26 ± 0.10	9.80		
Group 3	0.51 ± 0.22	22.95		

***Significant difference**

Table 2. Pair wise comparison of shear bond strength

Groups	Mean +SD	Mean Ranks	Mann-Whitney Value	p-Value
Group 1	0.32 + 0.09	12.20	33.000	0.197
Group 2	0.26 + 0.10	8.80		
Group 1	0.32 + 0.09	7.05	15.500	0.007*
Group 3	0.51 + 0.22	13.95		
Group 2	0.26 + 0.10	6.50	10.000	0.002*
Group 3	0.51 + 0.22	14.50		

***Significant difference**

4. Discussion

Dentin forms the major bulk of the tooth. It is traversed by dentinal tubules that extend from the pulp to the enamel–dentin or cement-dentinal junction. Dentin is a highly mineralized tissue and is permeable. Once the dentin is exposed, it causes sensitivity due to the permeability of dentinal tubules. Dentinal hypersensitivity is treated using different desensitizing agents. However, these agents may interfere with the bonding of composite restorations to the tooth. In this study, different desensitizing agents produced different shear bond strength values.

In the present study, the dentin surfaces treated with a self-etch bonding agent demonstrated more SBS followed by the control and the dentin treated with the SDF. In the control group, the composite was bonded to untreated dentin using UAS and the result was 0.32±0.09 MPa. The effective chemical interaction may occur between long-chain molecule MDP and hydroxyapatite forming a stable Nano layer that could form a stronger phase at the adhesive interface, which increases the mechanical strength of the adhesive. The results of this study are in accordance with previous studies [13]. In addition, stable MDP-Ca salt deposition along with Nano layering may explain the high bond stability, which has previously been proven by laboratory and clinical research [14]. According to the adhesion-decalcification concept, the MDP-Ca salt complex is highly insoluble, and stable, and forms strong molecular bonds to hydroxyapatite-based substrates.

SDF is a colourless alkaline solution with a pH between 9 and 10. 38% SDF solution contains 253,870 ppm silver and 44,800 ppm fluoride ions. In other words, a 38% SDF solution is composed of 25% silver ions and 5% fluoride ions dissolved in an 8% ammonia solution. The main disadvantage of SDF therapy is permanent black staining. SDF also stains the skin, working tables, dental instruments and clothes if handled carelessly. Patients must be well-informed before treatment to avoid patient dissatisfaction [15].

The bond strength of the SDF group was the lowest with an SBS of 0.26 ± 0.10 MPa. The SBS was 18% less in group 2 compared to group 1. This is because SDF can interfere with the penetration of primer and bonding into the intertubular and peritubular dentin which leads to less hybrid layer formation with the lower collagen matrix because of the formation of acid-resistant fluoro-hydroxyapatite crystals [16]. Silver ions have an inhibitory effect on cysteine cathepsin enzymes that degrade dentinal collagen matrix proteins, leading to bonding loss [17]. SDF produces desensitization by occluding dentinal tubules and promotes tertiary dentine formation. Silver precipitates as silver salts on the dentine surface and within the dentinal tubules after SDF application [18]. After SDF application the fluoro-hydroxyapatite is produced. This promotes remineralisation. This can block or decrease tubule diameter, resulting in relief of dentine hypersensitivity [19].

The dentin surface treated with the self-etch bonding agent showed the highest bond strength, 0.51 ± 0.22 MPa. The percentage increase in SBS from group 1 to group 3 was 66.9%. The percentage increase in SBS from group 2 to group 3 was 51%. The bonding mechanism of self-etch adhesives is based on changing the chemical composition of the substrate surface, commonly referred to as hybridization [20], the surface layer of dentin is partially dissolved and the resultant porosity is filled with resin. The self-etch adhesives dissolve the smear layer and preserve smear plugs [21]. The coagulation of plasma proteins by primer components contributes to the reduction in dentin permeability.

Previous studies suggested that doubling the number of adhesive layers improves bond strength by enhancing monomer penetration into hybrid layers and increasing chemical interactions [22]. Therefore, an additional layer application should be considered as a crucial clinical step. This also explains the highest bond strength of group 3. All universal adhesives were based on the functional monomer 10-MDP (methacryloyloxydecyl dihydrogen phosphate) imperative to obtain a stable nanolayer structure (10-MDP/Ca salts) in the hybrid layer and adhesive layer [23]. This study reported significant differences between the groups, so the null hypothesis was rejected.

This *in vitro* study had certain limitations, as it could not replicate in vivo conditions. Additionally, the sample size was limited, and only one type of adhesive and composite resin was tested. Thermal cycling and aging processes were not applied, and the reduction of dentin hypersensitivity was not assessed. Future research could address these limitations by incorporating larger sample sizes, multiple adhesives and composite resins, and including thermal cycling and aging protocols to better simulate clinical conditions. Evaluating the effect on dentin hypersensitivity could also enhance the clinical relevance of the findings.

5. Conclusion

Within the limitations of the study, it can be concluded that shear bond strength (SBS) differs across various desensitizing treatments. Results indicate that the sixth-generation bonding agent demonstrated superior SBS compared to both untreated dentin and Silver Diamine Fluoride (SDF).

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