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Effect of different intracanal medicaments on the fracture resistance of single rooted permanent human teeth: A comparative invitro analysis.

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Thechiefaimofrootcanaltherapyisthecompleteeradicationofmicroorganismsfrom therootcanalsystem,preventingreinfectiontherebyachievingcompleteperiradicular healing[1].Combineduseofadequateisolationtechniques,biomechanicalpreparation, effective irrigating solutions and techniques, along with a proven disinfecting medicament play a major role in determining the success of a root canal therapy . Medicaments play a major role in preparing the root canals for long term treatment protocols.[2]

Calciumhydroxide(CH)isthemostoftenutilizedintracanalmedication.Antimicrobial activityandtheabilitytopromotehardtissue formationareamongitsadvantageous qualities. Nevertheless, its poor dentinal tubule penetration, diminished effectiveness against Enterococcus faecalis, and detrimental effects on radicular dentin microhardnessandfractureresistanceafterprolongedusecontinueto beaconcern.[3]

Chlorhexidine (CHX) possesses broad-spectrum antimicrobial activity, therefore, the combined use of CHX and CH has been proposed as an intracanal medicament strategytoenhanceantimicrobialefficacyandreduceteriskofpersistentendodontic infection. Beyond its disinfecting properties, CHX may also contribute to the preservation of dentinal integrity by acting as a collagen cross-linking agent and inhibitingmatrixmetalloproteinaseactivity.Thiscanhelpstabilizethedentinalcollagen matrix and potentially enhance the fracture resistance of dentin.[3]

Triple antibiotic paste (TAP) is a blend of three antibiotics namely metronidazole, ciprofloxacin,anddoxycycline.[4]Itpenetratesbetterintodentinaltubulesascompared with CH to attain a sterile environment.[5]

Nano-silver, a widely recognized nanoparticle in nanotechnology, has garnered attentionforitsexceptionalantimicrobialeffectiveness,makingitadvantageousinroot canal procedures.[5]

Bio-CTemp,acalciumsilicate–basedintracanalmedicament,hasbeenintroducedto overcome the limitations of conventional dressings. Owing to its biocompatibility, bioactivity, and sealing ability, it is especially indicated in cases of perforations and internal or external resorption, and represents a promising alternative for effective intracanal disinfection while preserving the structural integrity of radicular dentin.[4]

MATERIALSANDMETHODS

Selection Criteria

Extractedhumanpermanentsingle-rootedpremolarteethwithpatentrootcanalswere included in the study. Teeth with caries, open apices, calcified canals, cracks or fractures, existing

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restorations, or internal or external root resorption were excluded.

SpecimenPreparationandRootCanalInstrumentation

Atotal of 48 extracted human permanent single-rooted premolars with single canals were selected. The specimens were cleaned of soft-tissue remnants using an ultrasonic scaler and stored in 0.1% thymol solution until use.
Access cavities were prepared using a round bur in a high-speed handpiece under continuous water cooling. Apical patency was established using a #10 K-file. The working length was determined by introducing a #15 K-file until its tip was visible at the apical foramen, followed by subtracting 1 mm from the recorded length.
RootcanalpreparationwasperformedusingtheProTaperrotarysystemuptosizeF3 withanendodonticmotor.Duringinstrumentation,thecanalswereirrigatedwith2mL of5.25%sodiumhypochloritebetweeneachinstrument. Finalirrigationwasperformed with2mLof17%ethylenediaminetetraaceticacidtoremovethesmearlayer,followed by a final flush with 5 mLof sterile saline using a 27-gauge needle.The canals were subsequently dried with sterile paper points.

Grouping and Medicament Application

The specimens were randomly divided into four groups (n = 12) according to the intracanal medicament used:

- **Group I:** Tripleantibioticpaste(TAP)
- **GroupII:**Calciumhydroxide+2%chlorhexidine(CH+CHX)
- **GroupIII:**0.02%silvernanoparticlegel(AgNP)
- **Group IV:** Bio-CTemp

For **Group I**, TAP was prepared by mixing metronidazole, ciprofloxacin, and minocycline powdersin equalproportions,using polyethyleneglycolasthevehicleto obtain a consistent paste-like formulation.
For**GroupII**,calciumhydroxidepowderwasmixedwith2%chlorhexidinegeltoobtain a homogeneous paste.
For **Group III**, a commercially available 0.02% silver nanoparticle gel was used in its ready-to-use form.
For**GroupIV**,apremixedcalciumsilicate-basedintracanalmedicament(Bio-CTemp) was used according to the manufacturer's instructions without further modification.
The respective intracanal medicaments were placed into the prepared root canals usingaLentulospiralmountedinaslow-speedhandpiecetoensureuniform

distribution up to the working length.The medicaments were gentlycompacted using sterile pluggers, and the access cavities were sealed with a temporary restorative material with a minimum thickness of 3 mm.
Allspecimensweremaintainedinanincubatorat37°Cand100%humidityfor4weeks before evaluation·

Fracture Resistance Testing

Following the storage period for 4 weeks, the temporary restorations were removed, and the roots were embedded in self-cure acrylic resin blocks, leaving 3 mm of the coronalportionof therootexposed. Fractureresistancetestingwascarried outusing auniversaltestingmachine.Eachspecimenwaspositionedvertically,andaspherical steel tip of approximately 2 mm diameter was aligned with the long axis of the tooth. A compressive load was applied at a crosshead speed of 0.5 mm/min until fracture occurred. The maximum load required to fracture each specimen was recorded in Newtons (N).

Statistical Analysis

DatawereanalyzedusingSPSSsoftware(version23).One-wayanalysisofvariance (ANOVA) was used for intergroup comparison, followed by Tukey's post hoc test for pairwise comparisons.Avalue of $p < 0.05$ was considered statistically significant.

Results

One-way analysis of variance (ANOVA) demonstrated a statistically significant difference in fracture resistance among the four intracanal medicament groups ($P < 0.05$). The mean fracture resistance values for each group are presented in Table 1 and Figure 1.

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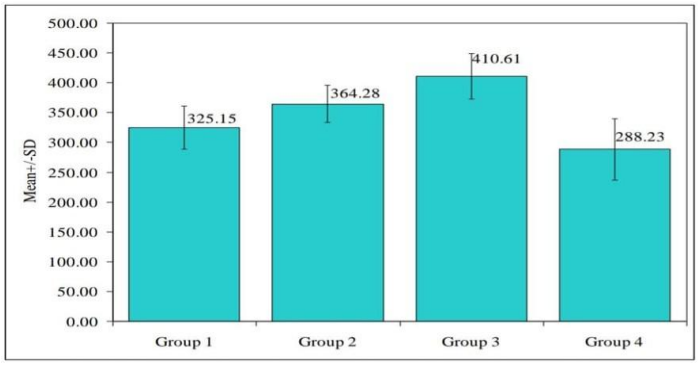

Groups	Mean Difference	SE	p-value	95% Confidence Interval	
				Lower Bound	Upper Bound
Group 1 with Group 2	-39.13	16.30	0.0920	-82.66	4.39
Group 1 with Group 3	-85.47	16.30	0.0001*	-128.99	-41.94
Group 1 with Group 4	36.92	16.30	0.1220	-6.61	80.44
Group 2 with Group 3	-46.34	16.30	0.0330*	-89.86	-2.81
Group 2 with Group 4	76.05	16.30	0.0001*	32.52	119.57
Group 3 with Group 4	122.38	16.30	0.0001*	78.86	165.91

*p<0.05

The silver nanoparticle gel (AgNP) group demonstrated the highest mean fracture resistance,followedbythecalciumhydroxide+chlorhexidine(CH +CHX)groupand the triple antibiotic paste (TAP) group. The Bio-C Temp group exhibited the lowest mean fracture resistance among the four groups.

Post hoc analysis using Tukey's multiple-comparison test demonstrated statistically significant differences between theAgNP group and each of the other experimental groups.Significantdifferenceswerealsoobservedbetween theCH+CHX,TAP,and Bio-C Temp groups ($P < 0.05$).

Thus,thefracture resistance values followed the order: AgNP > CH + CHX > TAP > Bio-C Temp.

DISCUSSION

The present study evaluated the effect of different intracanal medicaments on the fracture resistance of single-rooted permanent teeth. The results demonstrated that silver nanoparticle gel (AgNPs) exhibited the highest fracture resistance, followed by calcium hydroxide combined with chlorhexidine (CH+CHX), triple antibiotic paste (TAP), and Bio-C Temp, which demonstrated the lowest fracture resistance. These findings suggest that the effect of intracanal medicaments on radicular dentin is dependent on the chemical composition and physicochemical characteristics of the medicament.

Theultimateobjectiveofendodontictreatmentistheeradicationofmicrobialinfection withinthecomplexanatomyoftherootcanalsystemtopromoteperiradicularhealing.[1] Consequently,theadjunctiveplacementofintracanalmedicaments(ICMs)isessential duringinterappointmentvisitstosuppressbacterialregrowthandeliminatepersistent pathogens, primarily *Enterococcus faecalis*.[3,4]Despite their therapeutic advantages, prolonged exposure of radicular dentin to chemical agents can induce significant structural alterations, affecting mechanical integrity, microhardness, and fracture resistance.[5,6]

Root fracture represents one of the most undesirable complications following endodontic intervention, significantly compromising tooth prognosis.[7]In the present study, the structural integrity of

endodontically treated teeth was influenced by the interplay between chemomechanical preparation and the biochemical nature of the medicaments. Endodontic procedures alter dentin biomechanics, modulus of elasticity,andmineralcontent;sodiumhypochloritede gradestheorganiccollagenous matrix via non-specific proteolysis, whereas chelating agents like EDTA reduce calciumconcentration,softeningdentinalwalls.[5,8,9] Whenintracanaldressingsare subsequentlyplaced,theirdurationofcontactandchemi calnaturedictatetheoverall alteration in fracture susceptibility.[5,6]

Calcium hydroxide is one of the most extensively used intracanal medicaments becauseofitshighalkalinityandantimicrobialactivity. However,prolongedexposure to its highly alkaline environment has been associated with alteration of the organic component of dentin. High concentrations of hydroxyl ions can affect organic phosphateandcarboxylategroupsthatcontributetothei nteractionbetweencollagen and hydroxyapatite, potentially resulting in reduced dentin strength and increased susceptibility to fracture.[2,10] Varma et al. similarly reported that prolonged calcium hydroxide application may weaken radicular dentin because of alteration and denaturation of the organic matrix.[2]

Inthepresentstudy,theCH+CHXgroupdemonstratedh igherfractureresistancethan TAP and Bio-C Temp but lower values thanAgNPs. The addition of chlorhexidine to calcium hydroxide has been proposed to improve antimicrobial coverage because chlorhexidinepossessesbroadantimicrobialactivityan dcanbindtodentin,providing prolonged antibacterial activity.[1] Rahimi et al. reported that the addition of chlorhexidine to calcium hydroxide did not adversely affect root fracture resistance within 1 month.1 The relatively higher fracture resistance observed with CH+CHX in thepresentinvestigationmaythereforeindicatethatthei ncorporationofchlorhexidine didnotproduceanadditionaldetrimentaleffectonthem echanicalintegrityofradicular dentin under the conditions tested. Nevertheless, the precise mechanism by which chlorhexidine may influence the collagenous component of dentin was not directly evaluated in the present study and should therefore be interpreted cautiously.

The AgNP group demonstrated the highest fracture resistance in the present investigation. The favorable performance of nano-silver may be associated primarily with its antimicrobial characteristics and interaction with dentinal surfaces. Silver nanoparticles possess oligodynamic antibacterial activity and have demonstrated potential for disinfection of infected root canals.[3] Their nanoscale dimensionsprovide a large surface area for interaction with microorganisms and dentinal surfaces. Alshamrani et al. reported that nano-silver treatment produced higher dentin microhardness than calcium hydroxide and TAP, and suggested that deposition of activated silver nanoparticles on the dentin surface and within dentinal tubules could contribute to the observed increase in surface hardness.[3] The present finding of increasedfractureresistancewithAgNPsmaytherefore berelated,atleastinpart,to their favorable interaction with dentin and their ability to provide antimicrobial activity without the pronounced alkaline effect associated with calcium hydroxide. However, because the present study did not directly assess nanoparticle penetration, collagen degradation,mineralchanges,ordentinaltubuleocclusi on,thesemechanismsshould be regarded as possible explanations rather than definitive causes of the increased fracture resistance.

Thus, the increased fracture resistance observed in the present study should not be interpreted as evidence that AgNPs universally improve all mechanical or adhesive propertiesofrootdentin. Rather, the results indicate afavorableeffect specificallyon the fracture-resistance outcome evaluated in the present experimental model.

TAPdemonstratedlowerfractureresistancethanAgNP sandCH+CHXinthepresent study.TAPcontainsmetronidazole,ciprofloxacin,and minocyclineandiswidelyused because of its broad antimicrobial activity and ability to penetrate dentinal tubules.[3] However,theacidicenvironmentassociatedwithantibi oticformulationshasraised concerns regarding alteration of the chemical and mechanical properties of dentin. The relatively lower fracture resistance ofTAP in the present study may therefore be related to chemical alteration of the mineralized dentin matrix during medicament exposure.Bio-CTempdemonstratedthelowestfractureresistanceam ongthetested medicamentsinthepresentinvestigation.Bio-CTemp isapremixed calciumsilicate-basedintracanalmedicamentwithantimicrobialandbio activeproperties.Itshydration involves the release of calcium and hydroxyl ions, which may promote calcium-containing deposits and increase dentin surface hardness.[3] Interestingly,Alshamrani etal.reportedthehighestdentinmicrohardnessandpush

-outbondstrengthwithBio-C Temp among the groups evaluated.[3]Therefore, the lower fracture resistance observedforBio-CTempinthepresentstudycannotbeexplainedsolelyon thebasis of surface hardness. This apparent difference highlights the distinction between surface microhardness and the overall fracture resistance of the root. Fracture resistance represents the response of the entire root structure to a load and may be influenced by dentin thickness, canal preparation, material–dentin interaction, exposure time, and the distribution of stresses within the root. 11

Thediscrepancybetweenthepresentfindingsandthose ofAlshamranietal.mayalso be related to differences in study design. Their investigation evaluated dentin microhardness and push-out bond strength following 2 weeks of medicament exposure, whereas the present study assessed fracture resistance as the primary outcome. In addition, differences in tooth selection, instrumentation protocols, medicamentformulations,exposureconditions,andmechanicaltestingmethodsmay influence the measured response.Alshamrani et al. themselves emphasized that the effectofintracanalmedicamentsmayvaryaccordingto exposuretimeandspecimen characteristics.[3] Consequently, direct comparison between studies should be made cautiously.

LIMITATIONS

This study has certain limitations. As an in vitro investigation, the experimental conditionscouldnotcompletelyreplicatetheclinicalenvironment,includingfunctional occlusal loading, temperature fluctuations, and the complex oral environment. The effect of the medicaments was evaluated over a 4-week period; therefore, the long-term effects of prolonged medicament exposure could not be assessed. Cyclic or occlusalloading was not simulated, and the studyevaluated onlyfractureresistance. Furthermore, variations in the structural characteristics of extracted teeth and the presence of residual medicament within the root canal system may have influenced the observed results.

CONCLUSION

Withinthelimitationsofthisinvitrostudy,thetypeofintracanalmedicamentinfluenced thefractureresistanceofrootdentin.Silvernanoparticlegeldemonstratedthehighest fracture resistance, whereas Bio-C Temp exhibited the lowest fracture resistance among the tested medicaments. These findings highlight the importance of considering the effects of intracanal medicaments on dentinal integrity in addition to their antimicrobial properties. Further long-term studies incorporating cyclic loading and clinical simulation are warranted to validate these findings.

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