

“Assessment Of Human Root Dentin's Fracture Resistance To Intra-Canal Calcium Hydroxide, Mineral Trioxide Aggregate, And Calcium Phosphate Cement”.

Dr Akhilesh Singh Parate^{1*}, Dr. Pauravi Hegde², Dr Surabhi Duggal³, DR. ASHTHA ARYA⁴, Dr. Pawan Anil Pawar⁵, Dr. Ratheesh M. S.⁶

¹(M.D.S.)Senior resident in Department of Dentistry, Government medical College, SHAHDOL (MP)
E-mail: drakhileshortho@gmail.com

²MDS (Conservative Dentistry and Endodontics) Consultant Endodontist Mumbai , E-mail: pauravi.hegde@gmail.com

³Assistant Professor, Department of Prosthodontics and Crown & Bridge School of Dental Sciences, Sharda University, Greater Noida.
E-mail: surabhiduggal92@gmail.com

⁴PROFESSOR, Dept. Of Conservative Dentistry and Endodontics, Faculty of Dental Sciences, SGT University, Gurgaon. , E-mail:
DRASHTHAARYA@YAHOO.CO.IN

⁵Senior lecturer Department of Conservative Dentistry and endodontics M.G.V.'s K.B.H. dental College and Hospital, Nashik , E-mail:
drpawanpawar18@gmail.com

⁶ Professor, Department of Pediatric and Preventive Dentistry Sree Anjaneya Institute of Dental Sciences, Calicut Kerala ,E-mail:
dr_ratheeshms@yahoo.co.in

*Corresponding Author:- Dr Akhilesh Singh Parate
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Abstract

Background: The use of Ca(OH)₂ in Endodontics was undisputed till date. Amidst its various merits, recently it has been observed that Ca(OH)₂ treated teeth for extended periods show high failure rate because of unusual preponderance to root fracture. Newer materials like MTA and CPC have shown promising results in multiple endodontic applications including apexification.

Objective: The aim of the present study is to compare the in vitro changes in the fracture resistance of human root dentin when exposed to intracanal Ca(OH)₂, MTA and CPC.

Methodology: 60 freshly extracted single rooted teeth were selected and divided into four following groups of 14 teeth each Group I – saline group (control group) Group II - Ca(OH)₂ group Group III – MTA group Group IV – CPC group Coronal access and endodontic instrumentation was done using specified instruments and techniques. The prepared canal was filled with saline solution, Ca(OH)₂ paste, MTA and CPC and sealed with bonded composite resin and teeth were immersed in saline. After 30 days and 180 days the roots of 7 teeth from each group were sectioned horizontally into 1mm thick disks depending upon length of root into 4-5 sections and each disk was placed under a universal testing machine and the peak load at fracture was recorded.

Results: Results showed that the mean peak load at fracture of Group I (saline group) was higher in both 30 days and 180 days specimen. Ca(OH)₂ group showed a decrease in the fracture resistance as compared to all other groups in 30 and 180 day specimen.

Conclusion and Interpretation: Based on results, both MTA and CPC can be efficiently used as an alternative to Ca(OH)₂.

Key words: Calcium hydroxide; mineral trioxide aggregate; calcium phosphate cement; fracture resistance.

INTRODUCTION

Modern dentistry incorporates endodontics as an integral part of restorative and prosthetic treatment. Any tooth with pulpal involvement, provided that it has adequate periodontal support, can be a candidate for root canal treatment.¹ Effective cleaning and shaping is the foundation of successful root canal treatment. However because of the complexity of the root canal systems, complete cleaning and shaping with presently available irrigants and instruments is difficult. Therefore intracanal medication has been advocated to further reduce the number of microorganisms between appointments. A wide range of chemicals have been used to disinfect the root canal system including formocresol, cresatin, phenolic compounds, aldehydes, antibiotics, steroids and Ca(OH)₂.²

Ca(OH)₂ has been used in various formulations as liner beneath restorations, pulp capping agent, intracanal medicament, apexification, antibacterial agent, used for control of inflammatory root resorption after luxation and avulsion injuries.³

Despite its efficacy, this dressing has several disadvantages such as variability of treatment time, number of appointments and radiographs, difficulty in patient follow up, delayed treatment and possibility of increased tooth fracture after Ca(OH)₂ used for extended periods.⁴ It is also postulated that due to its strong alkalinity Ca(OH)₂ may denature the carboxylate and phosphate groups leading to a collapse in the dentin structure and thus leading to decreased fracture resistance.⁵

Alternatives to Ca(OH)₂ have been proposed, the most promising being a recently developed material, MTA.⁶ The material has been shown to have excellent biocompatibility, antimicrobial properties, low cytotoxicity, and low microleakage.⁷

On the other hand are the emerging trends towards use of CPC which are a class of self setting biocompatible bone substitute materials, with potential applications in dentistry. However, its clinical use has been challenged by poor rheological properties. The set cement provides good and stable sealing. The osteoconductive property is an added advantage. FI-CPC proves to be an ideal material for endodontic sealing/filling and periodontic repair.⁸

Thus it was hypothesized that the newer materials like MTA and CPC have shown promising result in increasing fracture resistance than the conventional Ca(OH)₂. This invitro study was carried out to evaluate the fracture resistance of human root dentin when exposed to intra-canal Ca(OH)₂, MTA and CPC at 30 and 180 day intervals under Universal testing machine.

MATERIALS AND METHOD

Evaluation of fracture resistance of human root dentin when exposed to intracanal Ca(OH)₂, MTA, and CPC. An invitro study was undertaken in the Department of Conservative Dentistry and Endodontics using the following materials and methods.

Methodology

60 freshly extracted single rooted human teeth were selected for the study on the basis of the following criteria- no root caries, resorption or fracture, mature, fully formed apices, were stored in normal saline. The teeth were sorted by size and type and subsequently randomly assigned to one of the four groups so that each group comprises of 15 similar teeth.

Group I – Saline group (control group)

Group II – Ca(OH)₂ group

Group III – MTA group

Group IV – CPC group

Each tooth was accessed coronally with endo access bur and the canals were instrumented to a size of 20 stainless steel K-file, so that the file extended beyond the apical foramen by 1mm, followed by copious irrigation with NaOCl followed by sterile saline using 25 gauge needle, subsequently the canals were dried using paper points.

Group I

The root canals of the teeth in this group were filled with normal saline using syringe of 25 gauge needle. The coronal portion was sealed by placing a small cotton pellet into the pulp chamber and then single step self-etching dental adhesive (XENOIII) was used. According to manufactures recommendation, liquid from both Bottle A and Bottle B in equal amounts (approximately a drop each) was dispensed in the CliXdish Light-Protective Dispensing Dish and mixed for approximately 5 sec. Generous amount of the mix was applied onto the cavity surfaces and left for 20 sec and then cured for 10 sec. Apical seal was done by application of self etch bonding agent followed by composite restoration. The teeth were soaked in saline-soaked gauge throughout the preparation procedures and then stored in 0.9% saline at room temperature in a beaker. Group I formed the control group of the study.

Group II

The root canals of teeth in Group II were filled with Ca(OH)₂ paste – Metapex (META) by using a disposable tip supplied with the syringe and by inserting the tip into the root canal. Excess Ca(OH)₂ paste was intentionally extruded past the apex. As with Group I, the teeth in Group II were sealed apically and coronally by placing a small cotton pellet into the pulp chamber and then applying self-etching dental adhesive (XENO III) followed by composite restoration. The teeth were then stored in 0.9% saline at room temperature in a beaker.

Group III

As per the manufactures instruction the Pro Root MTA powder and liquid were mixed on the mixing pad and the canals of the teeth in this group were densely filled taking the mixed MTA on the tip of finger plugger (size 20). The teeth in this group were sealed apically and coronally like the previous groups and stored in 0.9% saline at room temperature in a beaker.

Group IV

The canals of the teeth in this group were densely filled with CPC (Chitra CPC) using a disposable syringe. Powder and liquid were mixed with according to the manufacturer's instructions. The teeth were sealed as that of the control group and stored in 0.9% saline at room temperature in a beaker.

After 30 days seven teeth from each group were sectioned horizontally into 1 mm thick discs starting from apical 1/3rd into 3-4 sections using microtome and each horizontal section was placed under universal testing machine and a mounted punch with 1.2mm cross section was centered between the canal and the outside edge of the dentin disc and lowered onto the specimen at a cross head speed of 2.5mm/min until the specimen fractured. The test machine software automatically recorded the peak load at fracture and values noted. Similarly after 180 days, the remaining seven teeth from each group were taken from the saline storage containers and tested in the same manner as that of 30day's group. The mean peak load at fracture for each group was calculated and the results from all groups were compared by one-way ANOVA and a Post-hoc student- Newman-Keuls test.

RESULTS

The aim of the present study was to evaluate the fracture resistance of root dentin when exposed to intracanal Ca(OH)₂, MTA and CPC. The peak load for fracture was measured for each dentin disk under universal testing machine for both 30 and 180 day specimen, where p-value of 0.05 or less was considered statistically significant. The mean peak load at fracture for each group was calculated and results from all the groups were compared by one-way ANOVA and a Post hoc student- Newman- Keuls test for pair wise comparison. Results showed that the mean peak load of fracture of control group (group I) was higher in both 30 day and 180 day specimen. Although the mean peak load of fracture of CPC (group IV) was greater than MTA (group III) in 30 day specimen, it wasn't statistically significant. The mean peak load of fracture of MTA (group III) was greater than CPC (group IV) in 180 day specimen which wasn't statistically significant either.

During intra group comparison the reduction of fracture strength of CPC from 30 day – 180 day specimens was statistically significant with p-value < 0.05.

Statistical analysis of 30 day specimen

Inter group comparison

One way ANOVA reveals that the pattern of peak load of fracture was different with different groups. When Group I (saline/control group) was compared with Group II (Ca(OH)₂ group) there was a significant reduction of fracture strength with p-value being < 0.01. When Group I was compared with Group III (MTA group) there was significant reduction of fracture strength with p-value being < 0.01. Although the fracture strength of Group IV (CPC group) was found to be reduced in comparison with Group I, it wasn't statistically significant with p-value of 0.07.

When Group II (Ca(OH)₂ group) was compared with Group III (MTA group) the reduction of fracture strength of Ca(OH)₂ group was not statistically significant. Reduction of fracture strength of Group II (Ca(OH)₂ group) in comparison with Group IV (CPC group) was statistically significant with p-value of < 0.01. When Group III was compared with Group IV the reduction of fracture strength of MTA was not statistically significant, the p-value being 0.19.

Variation of fracture strength: Group I > Group IV > Group III > Group II

Statistical analysis of 180 day specimens

Inter group comparison

One way ANOVA reveals that the pattern of peak load of fracture was different with different groups. Significant reduction of fracture strength was noticed when Group II, III and IV was compared with the control group of p-value being < 0.01. Group II showed significant reduction of fracture strength when compared with Group III and Group IV with a p-value of < 0.01.

Comparison between Group III and Group IV revealed that the MTA group showed a marginal increase of fracture in comparison with CPC which was statistically not significant.

Variation of fracture strength: Group I > Group III > Group IV > Group II

Table 1 : Mean, SD And Range Values Of Peak Load At Fracture And Their Comparison Between 30 And 180 Days Intra Group Comparison

		Saline	Ca(OH) ₂	MTA	CPC
30 days	Mean ±SD	18.22 ± 2.34	10.12 ± 2.34	12.11 ± 2.22	15.23 ± 3.23
	Range	11.20– 30.12	2.34 – 21.23	6.67– 21.22	6.23– 22.11
180 days	Mean ±SD	15.34 ± 2.12	9.99 ± 2.45	13.89 ± 2.05	12.11 ± 2.22
	Range	11.23 – 22.34	2.67 – 19.12	10.02 - 20.07	6.55 – 19.87
30 vs 180	Mean diff	0.67	1.11	0.56	1.89
	t*	0.56	0.67	0.76	2.11
	p	0.45,ns	0.34,ns	0.48,ns	<0.01,s

*unpaired t test

Table 2 : Statistical Analysis Of 30 Day Specimen Inter Group Comparison

Groups	Mean ± SD
1. Saline	18.56 ± 3.45
2. Ca(OH) ₂	10.34 ± 4.11
3. MTA	12.11 ± 2.34
4. CPC	15.34 ± 3.23

Difference between groups *		
Groups compared	Mean Difference	p-value
1-2	7.67	< 0.00, s
1-3	5.67	< 0.00, s
1-4	2.34	0.06, ns
2-3	1.67	0.08, ns
2-4	3.87	< 0.00, s
3-4	2.11	0.23, ns

Table 3: Statistical Analysis Of 180 Day Specimens Inter Group Comparison

Groups	Mean \pm SD
1. Saline	17.34 \pm 2.34
2. Ca(OH) ₂	11.23 \pm 2.65
3. MTA	13.89 \pm 2.12
4. CaPO ₄	12.78 \pm 2.34

ANOVA, F=22.1 p<0.01, s

Difference between groups *		
Groups compared	Mean Difference	p-value
1-2	7.67	< 0.00, s
1-3	4.54	< 0.00, s
1-4	4.89	< 0.00, s
2-3	3.87	< 0.00, s
2-4	2.45	< 0.01, s
3-4	1.11	0.67, ns

DISCUSSION

Originally Endodontics was mainly a therapeutic procedure in which the drugs were used to destroy micro organisms, fix or mummify vital tissues, and affect a sealing of the root canal space.⁹

A variety of intracanal medicaments have been used between appointments for complete disinfection of root canals.¹⁰ Among the number of materials that have been advocated, Ca(OH)₂ has been considered as the material of choice as an intracanal medicament. Ca(OH)₂ has a special position in endodontics.¹¹

Commonly used as a short term or long term intracanal dressing material, Ca(OH)₂ dissociates into calcium and hydroxyl ions on contact with aqueous fluids. Hydroxyl ions are believed to be responsible for the highly alkaline nature of the Ca(OH)₂. Both the bactericidal and osteogenic potential are derived from the ability of the material to release calcium and hydroxyl ions at a slow and constant pace over a long period of time. The rate at which the ions of calcium hydroxide are released from the products and their ability to overcome neutralizing agents are significant because a high sustained alkalinity between appointments is very important for a potent action.¹² Ca(OH)₂ in itself is a white odorless powder with a molecular weight of 74.08. It has a low solubility in water and a high pH (12.5-12.8). When the powder is mixed with suitable vehicle, a paste is formed. Ca(OH)₂ is thus available in the powder form or in various commercial preparations. VITAPEX/METAPEX (Meta Biomed, Korea) – one such commercial preparation contains both Ca(OH)₂ and iodoform. The hard tissue barriers produced by long-term Ca(OH)₂ therapy consists of irregularly arranged layers of coagulated soft tissue, calcified tissue and cementum like tissue. Also included are islands of soft connective tissue, giving the barrier a “swiss cheese” consistency, because of the irregular nature of the barrier it is not unusual for cement or softened filling material to be pushed through it into the apical tissues during filling.¹³

Recently, Torabinejad and colleagues at LOMA LINDA University in the 1990’s introduced a cement called mineral trioxide aggregate (MTA, Dentsply Tulsa Dental) which appears to have all the characteristics of an ideal cement, above all, it is hydrophilic in nature which makes it compatible with moisture and also challenges to seal communication between the root canal system and oral cavity and between root canal system and the periodontium. Recent studies on the material constituents have clarified that MTA is a silicate cement rather than oxide mixture.¹⁴

Scanning electron microscopy (SEM) and electron probe micro analysis found that the major difference between GMTA and WMTA is in the concentration of Al₂O₃, MgO, FeO. The concentration of FeO in WMTA is 90.8% less than GMTA which is the likely cause for the color change.¹⁵

CPC have attracted much attention in medicine and dentistry because of their excellent biocompatibility and bone replacing behavior, and their ability to conform to the defects in hard tissue (tooth structure, bone, etc.), which allows them to be placed close to native bone. This is a result of their self hardening capability which occurs through a setting reaction that leads to the formation of a solid piece of precipitated calcium phosphate at room or body temperature.¹⁶

Although little is known about this material in the dental community, in vivo and in vitro studies show calcium phosphate cement as a promising material for grafting applications. Further research is necessary to take advantage of the excellent biological properties of this cement under clinical applications.¹⁷

As per the manufacturer’s information the CPC is intended for the repair of dentinal or bony defects.

It is an ideal material for

- Furcation perforation sealing
- Root apexification
- Extraction socket filling
- Periodontal defect repair
- Pulpotomy medicament¹⁸

Due to its excellent biological properties and noncytotoxicity MTA and CPC have been hypothesized to be a replacement for Ca(OH)₂ in apexification cases. Thus the aim of the present study was to evaluate the fracture resistance of root dentin when exposed to intracanal Ca(OH)₂, MTA and CPC at various intervals mimicking the clinical time interval.

Fifty six freshly extracted single rooted human teeth were selected for the study on the basis of the following criteria-

- No root caries,
- Resorption or fracture,
- Mature,
- Fully formed apices,
- Were stored in normal saline.

The teeth were sorted by size and type and subsequently randomly assigned to one of the four groups so that each group comprises of 14 similar teeth.

Group I – Saline group (control group)

Group II – Ca(OH)₂ group

Group III – MTA group

Group IV – CPC group

Each tooth was accessed coronally with endo access bur the canals were instrumented to a size of 20 stainless steel K-file, so that the file extended beyond the apical foramen by 1mm, followed by copious irrigation with NaOCl followed by sterile saline using 25 gauge needle, subsequently the canals were dried using paper points.

The prepared canal were filled with saline solution, Ca(OH)₂, MTA and CPC and sealed with bonded composite resin both coronally and apically and teeth were immersed in saline.¹⁹

After 30 days, the roots of 7 teeth from each group were sectioned horizontally²⁰ into 1mm thick disks depending on length of root into 4-5 sections and each disk were placed in an universal testing machine and the peak load at fracture were recorded.

After 180 days, the remaining 7 teeth from each group were removed from the saline storage containers and tested in the same manner as the 30 day group.

The mean peak loads at fracture for each group were calculated and the results from all groups were compared by a one-way ANOVA and a post hoc student-Newman-Keuls test.

Results showed that the mean peak load of fracture of control group (group I) was higher in both 30 day and 180 day specimen. Ca(OH)₂ (Group II) showed a decrease in the fracture resistance as compared to all the other groups in both 30 and 180 day specimens.

Though the fracture resistance of CPC (group IV) was greater than MTA (group III) in 30 day specimens, an unexpected finding appeared, the fracture resistance of MTA (group III) was greater than CPC (group IV) in 180 day specimens. Either of them weren't statistically significant.

The recent studies of immunofluorescence imaging revealed that the mechanical properties of dentin are fundamentally determined by dentin matrix which is mostly composed of collagen type I.

Matrix metalloproteinase (MMP)-2,-14 and membrane type 1 (MT1) are found to play an important role in the degradation of collagen matrix of dentin. On the other hand the tissue inhibitor of metalloproteinase (TIMP) inhibit the active forms of MMPs, especially TIMP-2 inhibits MMP-2. It is speculated that both calcium hydroxide and MTA in the root canals of dentin may affect the activities of MMP and TIMP-2, thus influence the mechanical properties of dentin.

According to histological analysis, except for TIMP-2 MMP-2,-14 were clearly observed in the dentin matrix of calcium hydroxide treated group, resulting in the degradation of organic matrix, thus reducing the fracture strength.

Expression of collagen type I, MMP-2,-14, and TIMP-2 on the dentin were noticed in MTA treated teeth. TIMP-2 prevented the organic matrix from degradation caused by MMP-2,-14.

Therefore, the reason for high fracture resistance of dentin at long term might lie in the inhibitor activities of TIMP-2. Reduced expression of MMP-2, -14 for the MTA treated teeth may also contribute to the high fracture strength at the end.⁷ As mentioned earlier MTA reacts with water forming calcium oxide and calcium phosphate, so in the light of the present study where CPC group showing increased fracture resistance in comparison to Ca(OH)₂ in 30 and 180 day specimens and MTA in 30 day specimens may be hypothesized to have an expression of TIMP similar to that of MTA in inhibiting the degradation of dentin organic matrix.

The findings of the study appears to support the speculation/contention that long term exposure to Ca(OH)₂ alters the physical properties of dentin, which may be due to the change in the organic matrix. On the same lines the recent materials like MTA and CPC that can provide a reliable outcome and long term prognosis can be considered as an alternative to Ca(OH)₂.

CONCLUSION

On the basis of the procedure performed and the results obtained using intracanal Ca(OH)₂, MTA and CPC under universal / Instron testing machine to check the fracture resistance suggested that there was a subtle decrease in the fracture strength of root dentin when exposed to Ca(OH)₂ in comparison to the other materials used in the study.

Based on the results of this study it can be concluded that both MTA and CPC can be efficiently used as an alternative to Ca(OH)₂ although further studies have to be conducted as there is limited information in the dental literature concerning the long term effects of the newer materials such as MTA and CPC.

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