Review Article

Effect of calcium hydroxide on fracture resistance and microhardness of dentin in human teeth: A systematic review

Simar Sethi, Alpa Gupta, Ansy Hanna Kurian, Dax Abraham, Parul Chauhan, Kritika Aneja, Sucheta Jala, Arundeep Singh

Department of Conservative Dentistry and Endodontics, Manav Rachna Dental College, Faridabad, Haryana, India

ABSTRACT

Aim: Calcium hydroxide to date is a widely used intracanal medicament during endodontic treatment. Long duration of exposure of dentin to calcium hydroxide may influence the fracture resistance and microhardness of dentin thereby affecting the tooth. The aim of this review was to identify and systematically analyze the effect of calcium hydroxide on fracture resistance and microhardness of dentin in human teeth.

Methods: A PubMed and Scopus search was performed using keywords 'fracture resistance' and 'microhardness' along with Medical Subject Heading (MeSH) terms 'Calcium hydroxide' and 'dentin' and 'tooth' till 12th March 2022. The reference list of each selected article was also explored to identify additional articles. An inclusion criteria was set that had to be met by each study for it to be selected for the review. Only articles written in English language were included in this systematic review. The review was conducted according to the PRISMA checklist.

Results: Ten in-vitro studies that fulfilled the inclusion criteria were included in this review. The findings of majority of studies showed that an exposure duration of more than one month to calcium hydroxide decreased the fracture resistance and microhardness of dentin thereby affecting the strength of the tooth. Further, one week of exposure to calcium hydroxide did not show any significant change in fracture resistance.

Conclusion: Based on the analysis of the studies included in this review, it can be concluded that increased duration of exposure of dentin to calcium hydroxide negatively affects the fracture resistance and microhardness, thereby weakening the tooth.

Keywords: Calcium hydroxide, dentin, fracture resistance, microhardness, tooth

INTRODUCTION

Calcium hydroxide has been successfully used in endodontic therapy since its introduction in 1920 by B. W. Hermann.[1] It is a white, odorless powder with a pH of 12.5–12.8.[1] The alkaline nature of calcium hydroxide accounts for its mechanism of action, attributing to its ability to stimulate hard tissue formation and induce antimicrobial properties.[2] The ionic dissociation of calcium hydroxide releases hydroxyl ions that account for its antimicrobial action. The hydroxyl ions further cause lipid peroxidation that induces the destruction of phospholipids and structural changes in the cellular membrane of the bacterial cell.[3] These peroxides act as free radicals and result in extensive membrane damage through the initiation of autocatalytic chain reactions. The high pH of calcium hydroxide, causes alkalization of the narrow range of pH of bacterial cellular enzymes that bring about denaturation of the protein structure of these enzymes.[3,4] Moreover, the hydroxyl ions are also efficient to react with bacterial DNA and result in splitting of the strands inhibiting DNA replication and disarranging the cellular activity.

In endodontics, calcium hydroxide is widely employed as an intracanal dressing, for apexification and apexogenesis

Submitted: 19-Dec-2021 **Revised:** 12-Mar-2022
Accepted: 13-Apr-2022 **Available Online:** 28-Dec-2022

Access this article online	
Website: www.endodontologyonweb.org	Quick Response Code
DOI: 10.4103/endo.endo_225_21	

Address for correspondence: Dr. Simar Sethi, Department of Conservative Dentistry and Endodontics, Manav Rachna Dental College, Sector - 43, Delhi - Suraj Kund Badkhal Road, Faridabad - 121 004, Haryana, India.
E-mail: ksimar096@gmail.com

How to cite this article: Sethi S, Gupta A, Kurian AH, Abraham D, Chauhan P, Aneja K, *et al*. Effect of calcium hydroxide on fracture resistance and microhardness of dentin in human teeth: A systematic review. Endodontology 2022;34:223-8.

procedures, wherein it induces dentin bridge formation, for direct and indirect pulp capping, as well as pulp regeneration procedures.[2]

Today, calcium hydroxide has been replaced for various endodontic procedures by mineral trioxide aggregate, due to a high success rate, less pulpal inflammation and more predictable formation of a hard dentin bridge of the latter.[5] However, Kawashima *et al*. suggested the use of calcium hydroxide as a short-term intracanal medicament which is still a preferred approach in endodontics and dental traumatology.[6]

It has been proposed that the link between hydroxyapatite and collagenous fibrils determine the strength of dentin.[7] The soaring pH of calcium hydroxide may cause the dentinal structure to collapse owing to the destruction of carboxylate and phosphate groups.[8,9] This destruction and dissolution within the dentinal structure reduces the hardness of the treated tissue. Various studies that have been conducted draw attention to the fact that root canal medicaments may affect the physical and chemical properties of radicular dentin.[2,4,10-12]

Past literature also reveals that long-term exposure to calcium hydroxide may weaken the dentin, thereby increasing the susceptibility of the tooth to fracture.[2,13] The difference in findings of the previously conducted studies indicates an obvious controversy regarding the negative reverberation of calcium hydroxide on the mechanical properties of dentin that may impact the fracture resistance of teeth, or how long calcium hydroxide can be exposed to radicular dentin without compromising its mechanical properties.[2]

The last systematic review was published in 2013, in which all studies that had an impact on the mechanical properties were included.[2] This review included the literature on animal as well as human teeth.[14] A review was conducted on the reliability of bovine teeth as a substitute for human teeth in dental research.[14] The findings indicated that there exists inconsistent data in regard to whether bovine teeth can be used as a substitute for human teeth in dental research.[14] This outcome pinpoints to the fact that there is a need to narrow down literature and focus exclusively on studies conducted on human dentition so as to replicate clinical scenarios and obtain a scientifically acceptable end result. Subsequently, new studies have been conducted which immensely contribute to the literature and need to be amalgamated to provide an updated overview.

Therefore, the aim of this review is to provide an update on the effect of calcium hydroxide on the fracture strength and microhardness of dentin in human teeth on the basis of recent available literature.

MATERIALS AND METHODS

Research question

What will be the effect of calcium hydroxide on fracture resistance and microhardness of dentin in human teeth?

Protocol and registration

The protocol of the review is registered with Open Science Framework (OSF) with DOI No. 10.17605/OSF.IO/ZU8V4 and registered from osf.io/7quh2.

Literature search process

PubMed and Scopus were searched for articles till March 12th, 2022. Using the search keywords, Calcium Hydroxide, dentin, dentine, intracanal medicament, metapex, medicament, tooth, fracture, hardness, microhardness, fracture strength, and root dentin, 556 and 627 articles were found for PubMed and Scopus databases, respectively. The review was conducted according to the preferred reporting items for systematic reviews and meta-analyses checklist.[15]

Selection criteria

Only those studies were selected in a systematic review that have one control group, are based on human dentition only, have taken any time of duration of exposure taken into consideration, have at least five samples per group, have at least one experimental group with root/radicular dentin filled or exposed to calcium hydroxide and fracture resistance checked before obturation. The minimum number of required samples for a statistically accurate result is five to six, therefore, this is the rationale behind having to include studies with at least five samples per group.[16] Only the articles written in English were considered to be included in the systematic review. Studies having no control group, conducted on bovine and/or ovine teeth, not having a calcium hydroxide group, aim of the study not matched as per the aim of the review, fracture resistance checked after obturation and case reports, letters, short communications, case series, reviews were excluded.

Study selection

According to the defined inclusion/exclusion criteria, articles were screened based on the title, abstracts and full-text analysis. Articles were also selected from the citation list in order to ensure to identify studies that might have been missed by the database search.

Quality assessment

The methodological quality of the included studies was evaluated using an adaptation of the parameters used

in a previous systematic review performed with *in vitro* studies.[17,18] The data parameters of the included studies will be evaluated using the following parameters: (a) teeth randomization, (b) standardization of tooth type, (c) teeth free of caries/restoration/cracks, (d) standardization of duration of exposure, (e) standardization of type of testing machine used, (f) single operator protocol execution, and (g) statistical analysis.

Data extraction

Data extraction from the included studies was performed, and data were tabulated under the headings as author and year, type of teeth used, standardization of teeth, presence of any restorations, cracks, fractures, type of mechanical test used, duration of exposure, and pertinent outcome of the study [Table 1].

RESULTS

A total of 1183 articles were retrieved from PubMed and Scopus databases, including articles that were hand searched [Figure 1]. After exclusion of duplicates, the title/abstract evaluation of the remaining articles was done that yielded 39 articles. Of these 39, 29 studies were excluded and the remaining ten studies were included in this review. Table 2 shows the number of studies and their reason for exclusion.

The methodological quality of included studies was assessed under the following sub-headings: teeth randomization, standardization of tooth type, teeth free of caries/restoration/cracks/fractures, standardization of duration of exposure, standardization of type of testing machine used, single operator protocol execution, and statistical analysis. From the ten included studies, five studies were estimated to have a low risk of bias, and five were judged as to have a moderate risk of bias [Table 3].

Due to the heterogenicity in the types of groups, methods, and techniques, the pertinent outcomes could not be standardized, and therefore, conducting a meta-analysis was not possible. In this review, ten studies that evaluated fracture resistance and microhardness of dentin in human teeth, majority studies indicated that prolonged exposure of calcium hydroxide to dentin had a negative impact, thereby affecting the strength of the tooth. The studies included in the systematic review indicate that exposure of more than 30 days (1 month) of calcium hydroxide to dentin increases the fracture susceptibility of teeth. In four of the six experiments that evaluated the microhardness of dentin on exposure to calcium hydroxide, an inverse relationship was observed between the duration of exposure to calcium hydroxide and the microhardness of dentin.

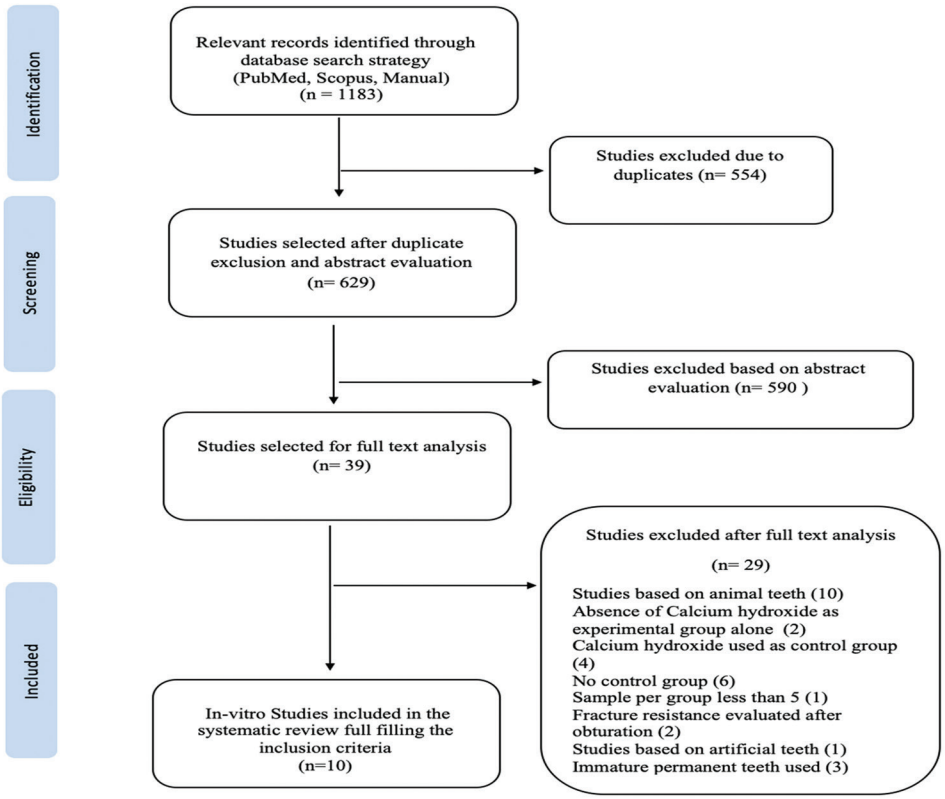

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses literature search flow diagram

Table 1: Data extraction under the headings as author and year, type of teeth used, standardization of teeth, presence of any restorations, cracks, fractures, type of mechanical test used, duration of exposure, and pertinent outcome of the study

Author and year	Type of human teeth used	Tested property as per the study	Specifications of the mechanical test performed	Duration of exposure	Outcome of the study
Doyon *et al*., 2005[19]	Single-rooted human maxillary and mandibular incisors, canines, and premolars	Fracture resistance	Universal testing machine at a cross head speed of	30 days (1 month), 180 days (6 months)	It was seen that 180 days of calcium hydroxide exposure significantly reduced fracture resistance
Sahebi *et al*., 2010[9]	Single-rooted human mandibular premolars	Fracture resistance	Universal testing machine	30 days (1 month)	Teeth exposed to calcium hydroxide for 30 days required less force and were prone to fracture
Zarei *et al*., 2013[11]	Single-rooted human mandibular premolars	Fracture resistance	Zwick testing machine	1 week, 1 month, 3 months, 6 months and 12 months	Fracture resistance of teeth was reduced on exposure to long exposure to calcium hydroxide
Yassen *et al*., 2013[20]	Single-rooted human mandibular premolars	Fracture resistance and microhardness	Universal testing machine Knoop microhardness tester	1 week, 1 month and 3 months	Application time of 3 months significantly reduced fracture resistance of dentin, thereby affecting the strength of the tooth
Prabhakar *et al*., 2013[21]	Single-rooted mature permanent human teeth	Microhardness	Vickers hardness indentation machine	24 h (1 day), 3 days, 7 days (1 week)	It was observed that both MTAP and CH reduced microhardness and aloe vera showed the least effect
Yassen *et al*., 2015[22]	Human third molars	Microhardness	Vicker's Microhardness test	4 weeks	In comparison to TAP, DAP and CH had less effect on microhardness of dentin
Yilmaz *et al*., 2016[23]	Human maxillary incisors	Microhardness	Knoop microhardness tester	Baseline, 1 week, 2 weeks and 4 weeks	Application of DAP and TAP for 4 weeks decreased microhardness of dentin
Sireesha *et al*., 2017[24]	Single-rooted human teeth	Fracture resistance	Universal testing machine	1 week and 1 month	Calcium hydroxide reduced fracture resistance if teeth on prolonged exposure
Naseri *et al*., 2019[25]	Single-rooted human teeth	Microhardness	Vicker's microhardness test	1 week and 4 weeks	Use of CH as intracanal medication for 4 weeks decreased microhardness of dentin
Parashar *et al*., 2020[26]	Single-rooted human bicuspid	Microhardness	Knoop Microhardness tester	2 weeks	MTAP and CH reduced microhardness of root dentin

MTAP: Modified triple antibiotic paste, CH: Calcium hydroxide, DAP: Double antibiotic paste, TAP: Triple antibiotic paste

Table 2: Number of studies and their reason for exclusion

Reason for exclusion	Number of studies excluded
Studies were based on animal teeth	10
Studies showed the absence of calcium hydroxide as an experimental group alone	2
Studies used calcium hydroxide as a control group	4
Lack of control group	6
Study had less than five samples per group	1
Studies evaluated fracture resistance after obturation	2
Studies based on artificial teeth	1
Studies were conducted on Immature permanent teeth	3

DISCUSSION

The aim of this review was to identify and systematically analyze studies that assessed the effect of calcium hydroxide as an intracanal medicament in endodontics on the fracture resistance and microhardness of dentin in human teeth. The intracanal medication with calcium hydroxide was evaluated at different time intervals that is 1 day (24 h), 3 days, 7 days (1 week), 2 weeks, 1 month (30 days or 4 weeks), 3 months, 6 months (180 days), and 12 months (180 days). In this review, only those studies were undertaken that were conducted on mature permanent human teeth as the previous study speculated that incompletely formed or immature roots and resorption defects could make the root prone to fracture due to thin dentin walls.[2,27]

Based on the past literature so far, it was reported that calcium hydroxide as intracanal dressing causes changes in the surface of root canals and softens the tooth tissue.[4,7,9,11,12,18] A previous systematic review revealed that modulus of elasticity was the least affected property on exposure to calcium hydroxide; therefore, it was not taken into consideration in this review.[2] This review, in total, reports four studies that evaluated fracture resistance and five that evaluated microhardness and one study that considered both parameters. As per this review, it was seen that in majority studies increased exposure of calcium hydroxide to dentin decreased fracture resistance and microhardness, thereby affecting the strength of the tooth on the whole.

Table 3: Risk of bias assessment for the included studies in this review

Author and year	Teeth randomization	Standardization of tooth type	Teeth free of caries/restoration/ cracks	Standardization of duration of exposure	Standardization of type of testing machine used	Single operator protocol execution	Statistical analysis	Risk of bias
Doyon *et al*., 2005[19]	+	Unclear	Unclear	+	+	−	+	Moderate
Sahebi *et al*., 2010[9]	+	−	+	+	+	−	+	Low
Zarei *et al*., 2013[11]	+	+	+	+	+	−	+	Low
Yassen *et al*., 2013[20]	+	+	+	+	+	−	+	Low
Prabhakar *et al*., 2013[21]	−	+	−	+	+	−	+	Moderate
Yassen *et al*., 2015[22]	+	Unclear	−	+	+	−	+	Moderate
Yilmaz *et al*., 2016[23]	+	−	+	+	+	−	+	Moderate
Sireesha *et al*., 2017[24]	+	+	+	+	+	−	+	Low
Naseri *et al*., 2019[25]	+	+	+	+	+	−	+	Low
Parashar *et al*., 2020[26]	Unclear	−	+	+	−	+	+	Moderate

This decrease is often elucidated by the alkaline nature of calcium hydroxide that might result in neutralization, dissolution, and degradation of proteins in dentin that are involved in linking collagen fibers to hydroxyapatite crystals. Moreover, Kawamoto *et al*. hypothesized that the high pH of calcium hydroxide can be one of the paramount factors that cause denaturation and destruction of inorganic content of root dentin and the collagen network making the tooth susceptible to fracture.[28] One of the rational explanations behind the relatively long-term exposure required to bring about a change in mechanical properties is that the collagen fibrils are amalgamated with hydroxyapatite crystals and these are not readily available to calcium hydroxide.[28]

However, further studies are required to understand the mechanism behind the changes in mechanical properties in a manner that closely replicates clinical scenarios.

Limitations

However, one of the important facts to consider in interpretation of the results from the included *in vitro* studies is that these do not truly represent clinical situations. This is due to the fact that the amount, type, and manner of force application as performed in *in-vitro* studies do not replicate the physiological forces that the teeth undergo in a real-life situation. In an *in vitro* set up, the forces are applied to dentin bars, cylinders, or dentin discs thereby results from these studies may or may not be accurate in recreating a true clinical scenario. Another instance is that teeth function differently within the oral cavity in harmony with specialized periodontium and *in vitro* studies fail to reproduce such an environment.

Another limitation of the included studies lies in the substantial heterogenicity of the study designs reflected upon by the varied sample size, tooth type, and anatomy and direction, and load of applied force. It is also important to note that in these *in vitro* setups, microhardness was tested by immersing the dentin discs in testing solutions which is not the case clinically.

CONCLUSION

The majority of studies included in this review indicated that long-term calcium hydroxide (more than 1 month) negatively affected the fracture resistance and microhardness of dentin in human teeth. Therefore, calcium hydroxide as an intracanal medicament should be used cautiously in order to ensure the long-term strength of the tooth.

Acknowledgment

The authors would like to thank Dr. Vivek Aggarwal (Professor, Department of Conservative Dentistry and Endodontics, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India) for his guidance and advice, which helped in doing the systematic review.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Hawkins JJ, Torabinejad M, Li Y, Retamozo B. Effect of three calcium hydroxide formulations on fracture resistance of dentin over time. Dent Traumatol 2015;31:380-4.
2. Yassen GH, Platt JA. The effect of nonsetting calcium hydroxide on root fracture and mechanical properties of radicular dentine: A systematic review. Int Endod J 2013;46:112-8.
3. Mohammadi Z, Shalavi S, Yazdizadeh M. Antimicrobial activity of calcium hydroxide in endodontics: A review. Chonnam Med J 2012;48:133-40.
4. Andreasen JO, Farik B, Munksgaard EC. Long-term calcium hydroxide as a root canal dressing may increase risk of root fracture. Dent Traumatol 2002;18:134-7.
5. Brizuela C, Ormeño A, Cabrera C, Cabezas R, Silva CI, Ramírez V, *et al.* Direct pulp capping with calcium hydroxide, mineral trioxide aggregate, and biodentine in permanent young teeth with caries: A randomized clinical trial. J Endod 2017;43:1776-80.
6. Kawashima N, Wadachi R, Suda H, Yeng T, Parashos P. Root canal medicaments. Int Dent J 2009;59:5-11.
7. Yoldaş O, Doğan C, Seydaoğlu G. The effect of two different calcium hydroxide combinations on root dentine microhardness. Int Endod J 2004;37:828-31.
8. Said F, Moskovitz M. Effect of calcium hydroxide as a root canal dressing material on dentin fracture strength in primary teeth- *in vitro* study. J Clin Pediatr Dent 2018;42:146-9.
9. Sahebi S, Moazami F, Abbott P. The effects of short-term calcium hydroxide application on the strength of dentine. Dent Traumatol 2010;26:43-6.
10. Batur YB, Erdemir U, Sancakli HS. The long-term effect of calcium hydroxide application on dentin fracture strength of endodontically treated teeth. Dent Traumatol 2013;29:461-4.
11. Zarei M, Afkhami F, Malek Poor Z. Fracture resistance of human root dentin exposed to calcium hydroxide intervisit medication at various time periods: An *in vitro* study. Dent Traumatol 2013;29:156-60.
12. Rosenberg B, Murray PE, Namerow K. The effect of calcium hydroxide root filling on dentin fracture strength. Dent Traumatol 2007;23:26-9.
13. Kahler SL, Shetty S, Andreasen FM, Kahler B. The effect of long-term dressing with calcium hydroxide on the fracture susceptibility of teeth. J Endod 2018;44:464-9.
14. Yassen GH, Platt JA, Hara AT. Bovine teeth as substitute for human teeth in dental research: A review of literature. J Oral Sci 2011;53:273-82.
15. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al.* The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. PLoS Med 2021;18:e1003583.
16. VanVoorhis CR, Morgan BL. Understanding power and rules of thumb for determining sample size. Tutor Quant Methods Psychol 2007;3:43-50.
17. Sarkis-Onofre R, Skupien JA, Cenci MS, Moraes RR, Pereira-Cenci T. The role of resin cement on bond strength of glass-fiber posts luted into root canals: A systematic review and meta-analysis of *in vitro* studies. Oper Dent 2014;39:E31-44.
18. Silva EJ, Zanon M, Hecksher F, Belladonna FG, de Vasconcelos RA, Fidalgo TK. Influence of autoclave sterilization procedures on the cyclic fatigue resistance of heat-treated nickel-titanium instruments: A systematic review. Restor Dent Endod 2020;45:e25.
19. Doyon GE, Dumsha T, von Fraunhofer JA. Fracture resistance of human root dentin exposed to intracanal calcium hydroxide. J Endod 2005;31:895-7.
20. Yassen GH, Vail MM, Chu TG, Platt JA. The effect of medicaments used in endodontic regeneration on root fracture and microhardness of radicular dentine. Int Endod J 2013;46:688-95.
21. Prabhakar A, Taur S, Hadakar S, Sugandhan S. Comparison of antibacterial efficacy of calcium hydroxide paste, 2% chlorhexidine gel and turmeric extract as an intracanal medicament and their effect on microhardness of root dentin: An *in vitro* study. Int J Clin Pediatr Dent 2013;6:171-7.
22. Yassen GH, Eckert GJ, Platt JA. Effect of intracanal medicaments used in endodontic regeneration procedures on microhardness and chemical structure of dentin. Restor Dent Endod 2015;40:104-12.
23. Yilmaz S, Dumani A, Yoldas O. The effect of antibiotic pastes on microhardness of dentin. Dent Traumatol 2016;32:27-31.
24. Sireesha A, Jayasree R, Vidhya S, Mahalaxmi S, Sujatha V, Kumar TS. Comparative evaluation of micron- and nano-sized intracanal medicaments on penetration and fracture resistance of root dentin – An *in vitro* study. Int J Biol Macromol 2017;104:1866-73.
25. Naseri M, Eftekhar L, Gholami F, Atai M, Dianat O. The effect of calcium hydroxide and nano-calcium hydroxide on microhardness and superficial chemical structure of root canal dentin: An *ex vivo* study. J Endod 2019;45:1148-54.
26. Parashar V, Khan SA, Singh P, Sharma S, Kumar A, Kumar A. Effect of intracanal medicaments (Modified Triple Antibiotic Paste, Calcium Hydroxide, and Aloe Vera) on microhardness of root dentine: An *in vitro* study. J Contemp Dent Pract 2020;21:632-5.
27. Cvek M. Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha. A retrospective clinical study. Endod Dent Traumatol 1992;8:45-55.
28. Kawamoto R, Kurokawa H, Takubo C, Shimamura Y, Yoshida T, Miyazaki M. Change in elastic modulus of bovine dentine with exposure to a calcium hydroxide paste. J Dent 2008;36:959-64.