# "A COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH OBTURATED WITH DIFFERENT OBTURATING TECHNIQUES : AN IN VITRO STUDY"

## DISSERTATION

Submitted to

BABU BANARASI DAS UNIVERSITY, LUCKNOW, UTTAR PRADESH

In the partial fulfilment of the requirement for the degree

of

MASTER OF DENTAL SURGERY

In the subject of

CONSERVATIVE DENTISTRY & ENDODONTICS


Submitted by

DR. SHIVANI AGARWAL

Under the guidance of

DR. TANU TEWARI

Reader

DEPARTMENT OF CONSERVATIVE DENTISTRY & ENDODONTICS

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW


Batch: 2021-24 Enrolment No.: 12103222931

# "A COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH OBTURATED WITH DIFFERENT OBTURATING TECHNIQUES: AN IN VITRO STUDY"

**DISSERTATION**

**Submitted to**

**BABU BANARASI DAS UNIVERSITY,**
**LUCKNOW, UTTAR PRADESH**

**In the partial fulfillment of the requirement for the degree**

**of**

**MASTER OF DENTAL SURGERY**

**In the subject of**

**CONSERVATIVE DENTISTRY & ENDODONTICS**

**Submitted by**


**DR. SHIVANI AGARWAL**

**Under the guidance of**

**DR. TANU TEWARI**
**Reader**

**DEPARTMENT OF CONSERVATIVE DENTISTRY & ENDODONTICS**

**BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW**
**(Faculty of Babu Banarasi Das University)**


**Batch: 2021-24** **Enrolment No.: 12103222931**

## DEPARTMENT OF CONSERVATIVE DENTISTRY & ENDODONTICS
## BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW.

## DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled "**A COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH OBTURATED WITH DIFFERENT OBTURATING TECHNIQUES: IN VITRO STUDY"** is a bonafide and genuine research work carried out by me under the guidance of **DR. TANU TEWARI**, Reader and, **DR. PRAGYAN PALIWAL**, Senior Lecturer as Co-Guide in Department of Conservative Dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

Shivani Agarwal

**Date:** 19/02/2024

**Signature of the Candidate**

**Place: BBDCODS**

**Dr. Shivani Agarwal**

# CERTIFICATE BY THE GUIDE/CO-GUIDE

This is to certify that the dissertation entitled **"A COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH OBTURATED WITH DIFFERENT OBTURATING TECHNIQUES: IN VITRO STUDY"** is a bonafide work done by **Dr. Shivani Agarwal**, under our direct supervision and guidance in partial fulfillment of the requirement for the degree of **Master of Dental Surgery (M.D.S.)** in the specialty of Conservative Dentistry and Endodontics.

Tanu.

**GUIDE**
**Dr. Tanu Tewari**
Reader
Department of Conservative Dentistry and Endodontics, Babu Banarasi Das College of Dental Sciences, Lucknow.

Pragya.

**CO-GUIDE**
**Dr. Pragyan Paliwal**
Senior Lecturer
Department of Conservative Dentistry and Endodontics, Babu Banarasi Das College of Dental Sciences, Lucknow.

**DEPARTMENT OF CONSERVATIVE DENTISTRY AND ENDODONTICS**

**BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW.**

# ENDORSEMENT BY THE HOD

This is to certify that this dissertation entitled **"A COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH OBTURATED WITH DIFFERENT OBTURATING TECHNIQUES: IN VITRO STUDY"** is a bonafide work done by **Dr. Shivani Agarwal** under the direct supervision and guidance of **Dr. Praveen Singh Samant** Professor and Head, of Department of Conservative Dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

**Dr. Praveen Singh Samant**
**Professor & Head**
Department of Conservative
Dentistry and Endodontics,
Babu Banarasi Das College
of Dental Sciences,
Lucknow.

**DEPARTMENT OF CONSERVATIVE DENTISTRY &ENDODONTICS**

**BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW.**

## ENDORSEMENT BY THE HEAD OF THE INSTITUTE

This is to certify that this dissertation entitled **"A COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH OBTURATED WITH DIFFERENT OBTURATING TECHNIQUES: IN VITRO STUDY"** is a bonafide work done by **Dr. Shivani Agarwal** under the direct supervision & guidance of **Dr. Tanu Tewari** Reader, Department of Conservative Dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

**Dr. Puneet Ahuja**
**Principal**
Babu Banarasi Das
College of Dental
Sciences,
Babu Banarasi Das
University, Lucknow.

PRINCIPAL
Babu Banarasi Das College of Dental Sciences
Babu Banarasi Das University
Ayodhya Road, Lucknow-226028

**DEPARTMENT OF CONSERVATIVE DENTISTRY & ENDODONTICS**

**BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW.**

## COPYRIGHT



Shivani Agarwal

Date: 19/02/2024

Signature of the Candidate

Place: BBDCODS

**Dr. Shivani Agarwal**

## ACKNOWLEDGMENT

This work would have been impossible without the support of the existing power; **GOD Almighty** for showering me with the required strength, blessings, and being the strongest shield for me to rely upon.

Words cannot describe my emotions for my beloved Parents – **Dr. Ashwini K. Agrawal, and Mrs. Sadhana Agrawal** & my loving brother **Dr. Shantanu Agarwal** & sister **Dr. Shobhna A. Nayak** my sister-in-law **Shivangi Agarwal**, brother-in-law **Dr. Manish Nayak,** my father & mother in law **Mr. Alok S Agarwal, Mrs. Prakash K Agarwal** brother & sister in law **Dr. Anant Agarwal, Dr. Swarnika P. Agarwal** who have been my pillars of strength throughout my life & I owe them everything for all the sacrifices, undying support & relentless prayers throughout my educational tenure. They always stood by me in times of joy & distress & have given me the strength to face the world. I am infinitely obliged to express my feelings of pride for my most cherished treasure – my husband, **Dr. Ankur Agarwal** & my daughter, **Yashika Agarwal** for their love & support. I present this thesis as an unassertive tribute to all their love, affection, dreams, & blessings with which they have nurtured me. I would like to thank my colleagues **Dr. Shalu Shukla, Dr. Anuja Kaushik, Dr. Satyam Kashyap, Dr. Aayush Poddar** & **Dr. Priyanka Mahajan** for their valuable suggestions & support whenever I needed them. I wish my sincere thanks to my seniors, **Dr. Chris Cherian Georgi, Dr. Ananya Jain, Dr. Richu Raju, Dr. Rimjhim Singh & Dr. Laxmi Pandey** who have been a great source of inspiration & encouragement to me. Special thanks to my juniors, **Dr. Yashi, Dr. Ria, Dr. Gunja Dr. Jhankriti, Dr. Pranjal, and Dr. Prachi** who have been a constant support throughout.

It is a profound sense of gratitude that I express my thankfulness to my mentor and guide, **Dr. Tanu Tewari, Reader,** Department of Conservative Dentistry and Endodontics, Babu Banarasi Das College of Dental Sciences, Lucknow, who has been a constant source of inspiration and encouragement to me. Throughout this work she patiently beared with me, understood me and accordingly guided me. She selflessly dedicated her time and efforts to nurture this work and give it wings, and I am a witness to this right from the start. The present work bears at every stage the interest of her wise, logical suggestions and meticulous attention to detail, which has helped me in bringing this dissertation to its goal. With a deep sense of gratitude, I thank and acknowledge my Co-Guide **Dr. Pragyan Paliwal, Senior Lecturer,** Babu Banarasi Das College of Dental Sciences, Lucknow. She was one of the most approachable teachers, giving thoughtful suggestions and corrections through her smiling face. She has selflessly set aside her time and energy to bring this work to its completion. I thankfully acknowledge her efforts in imparting quality and fineness to the study. I am deeply indebted to respected **Professor and Head of the Department, Dr. Praveen Singh Samant,** Babu Banarasi Das College of Dental Sciences, Lucknow, for his constant support, caring attitude, fatherly advice & interest that has helped me to carry out this work.

I would like to extend my sincere thanks to **Dr. Vishesh Gupta, Professor** Babu Banarasi Das College of Dental Sciences, Lucknow for all the much-needed constructive criticism, along with the ingenious suggestions to overcome them. I would like to express my gratitude to **Dr. Akanksha Bhatt, Ph.D., MDS, Reader,** Babu Banarasi Das College of Dental Sciences, Lucknow for extending all cooperationand everlasting guidance when the need arose, and for being there when I needed her help. I would like to extend my sincere thanks to **Dr. Sandeep Dubey, Reader** Babu Banarasi Das College of Dental Sciences, Lucknow for all the much-needed constructive criticism, along with the ingenious suggestions to overcome them. I am truly grateful to **Dr. Jaya Singh, Dr. Palak Singh, Dr. Ananya Sharma, Dr. Tarun Saxena, Dr. Rita Gupta, Dr. Tanima Deep Srivastava &, Dr. Srinjal Suman Senior Lecturer,** Babu Banarasi Das College of Dental Sciences, Lucknow for their help & support in the completion of my dissertation. With a deep sense of gratitude, I acknowledge my revered teacher **Dr. Amit Nigam, Senior lecturer,** at Babu Banarasi Das College of Dental Sciences, Lucknow for his thoughtful suggestions & efforts in imparting quality, fineness & quality to the study. I would like to acknowledge the support of the non-teaching staff of our department **Mr. Parshuram and Mr. Rohit.**

I beg forgiveness from those, whose names I have inadvertently missed but they should find solace that their knowledge has been extended to others by way of this thesis.

**DR. SHIVANI AGARWAL**

# INDEX

## TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF GRAPHS

# LIST OF FIGURES

## LIST OF ANNEXURES

# ABSTRACT

# ABSTRACT

**Aim**: The study aims to compare the fracture resistance of endodontically treated root canals obturated with four distinct obturating techniques. The goal is to determine how endodontically treated teeth are fracture resistant from cold lateral condensation, fluid gutta-percha, cross-linked thermoplastic gutta-percha, and down-pack backfill obturation technique.

**Methodology**: 30 freshly extracted single-rooted mandibular human premolars teeth were divided based on the type of obturation done into control groups where, Group I (n = 6): where teeth were instrumented but not obturated; Group II (n = 6): instrumented and obturated by Continuous-wave condensation, Group III (n = 6): Obturated using cold lateral compaction technique, Group IV (n = 6): Obturated using fluid gutta percha and Group V (n = 6): obturated using cross-linked thermoplastic gutta-percha.

**Result**: the evaluation of fracture resistance was done using a universal testingmachine and, Data were analyzed by one-way ANOVA and student t-test. The fractureresistance of five different groups (Group 1, Group 2, Group 3, Group 4, and Group 5) was summarised in Table 2 and depicted. The mean fracture resistance of Group 5 wasfound the highest followed by Group 4, Group 3, Group 2, and Group 1, the least (Group 1 < Group 2 < Group 3 < Group 4 < Group 5).

**Conclusion**: Group 5 Gutta core had the highest fracture resistance among all the groups. This may be attributed to the highest gutta-percha content within the filled canal space when using the core-carrier technique for obturation of the root canals.

**Keywords**: cold lateral condensation, Thermafil-Down pack backfill, Guttaflow 2, Gutta Core, fracture resistance.

# INTRODUCTION

# INTRODUCTION

A tooth undergoing endodontic treatment is more susceptible to fractures and is weaker than vital teeth.[1] Around 11%–13% of teeth extracted after endodontic treatment show vertical root fractures, making it the second most frequently recognized cause of tooth loss after root canal therapy.[2,3]

The strength of an endodontically treated tooth is influenced by various factors, including the loss of tooth structure due to caries or trauma, the preparation of access cavities, dentin dehydration, aggressive instrumentation and irrigation during root canal procedures, excessive pressure during root obturation, and the creation of intra-radicular post spaces.[4,5] The combined impact of these factors plays a role in loading the tooth and distributing stresses, increasing the potential for catastrophic failure. Although the most frequently employed root canal filling material is a combination of gutta-percha and sealer, the low elastic modulus of gutta-percha provides minimal or no ability to reinforce roots after treatment.[6,7]

Various obturating materials are accessible and the initiation of this study was to evaluate fracture resistance among them. The lack of a chemical union between the polyisoprene component of gutta-percha and methacrylate-based resin sealers hampers the bonding concept of the root-filling material.[8]

Continuous-wave condensation, introduced to enhance apical control and achieve improved homogeneity and surface adaptation, entails the down-packing of a master cone of gutta-percha as a core material. Subsequently, the remaining portion was backfilled with thermoplasticized gutta-percha using injection devices.[9]

Guttaflow 2, developed by Coltene/Whaledent in Langenau, Germany, was a root canal filling material that comprises a blend of gutta-percha powder, poly-dimethylsiloxane, and silver particles.[10]

Guttacore developed by Dentsply Tulsa Dental Specialties in Johnson City, Tennessee, USA, stands out as a carrier-based obturation system. It features an internal core made of cross-linked gutta-percha surrounded by a layer of α-phase gutta-percha.[11]

The traditional obturation technique, commonly emphasized in undergraduate courses at many dental schools, was cold lateral condensation.[12, 13 14] This technique entails inserting a single cone of gutta-percha with sealer into the prepared root canal and subsequently adding secondary gutta-percha cones. These additional cones are compacted together using a spreader, and they remain in place due to the frictional grip and the presence of a sealer.[15]

Despite being a time-consuming procedure, lateral condensation is preferred for its cost-effectiveness and the controlled placement of gutta-percha within the canal. They comprised numerous gutta-percha cones pressed together, with the sealer filling most of the spaces in between.[16]

The ongoing quest for an ideal obturating material continues, with the goal of not only achieving a satisfactory seal but also strengthening the compromised tooth structure to prevent the occurrence of Vertical Root Fracture. This innovative study aims to compare the fracture resistance of two recently developed obturating materials, namely Guttacore and Guttaflow 2, against conventional techniques such as lateral compaction and continuous-wave condensation in the obturation process.

# AIM
# AND
# OBJECTIVES

## AIM OF THE STUDY:

This study aims to comparatively evaluate the fracture resistance of root canals obturated with four different obturating systems in endodontically treated teeth. The tooth samples used in this study were obturated with cold lateral condensation, cross-linked thermoplastic gutta-percha, Down pack backfill obturation technique, and fluid gutta-percha, and one control group for the fracture resistance of endodontically treated teeth.

## OBJECTIVES

1. To assess the fracture resistance of an endodontically treated tooth that was not obturated with a Universal testing machine.
2. To assess the fracture resistance of endodontically treated tooth obturated with lateral condensation technique with a Universal testing machine.
3. To assess the fracture resistance of endodontically treated tooth obturated with continuous wave technique with a Universal testing machine
4. To assess the fracture resistance of endodontically treated tooth obturated with gutta flow 2 with a Universal testing machine
5. To assess the fracture resistance of endodontically treated tooth obturated with gutta core with a Universal testing machine.
6. To compare and evaluate the fracture resistance of the control group with lateral condensation technique with a Universal testing machine.
7. To compare and evaluate the fracture resistance of lateral condensation technique to continuous wave technique with a Universal testing machine.
8. To compare and evaluate the fracture resistance continuous wave technique with gutta flow 2 with a Universal testing machine
9. To compare and evaluate the fracture resistance gutta flow 2 to gutta core obturation with a Universal testing machine.
10. To compare and evaluate the fracture resistance of endodontically treated teeth amongst each other a Universal testing machine

# REVIEW OF LITERATURE

1. **Trope M, Maltz DO, Tronstad L. (1985)** conducted a study that concluded that the different root filing materials tested in this study (Endofill, Sealer 26, AH Plus, and Epiphany combined with gutta-percha cones, and Epiphany/Resilon system) were not able to increase the fracture resistance of root canals submitted to chemo-mechanical preparation. [17]

2. **Willsiams C, Loushine RJ, Weller RN, Pashley DH, Tay FR.(1992)** carried out a study to compare the cohesive strength and stiffness of Resilon and gutta-percha under dry conditions and after one month of water, storage to determine if they were stiff enough to reinforce roots. They concluded that the stiffness of Resilon and gutta-percha was too low to reinforce roots after root canal therapy .[6]

3. **Onnink PA, Davis RD, and Wayman BE (1994)** compared the incidence of incomplete root fractures among five groups of mandibular incisors. The groups were no canal preparation, canal preparation, canal preparation and obturation with laterally condensed gutta-percha, canal preparation and obturation with thermoplasticized gutta-percha on a central carrier (Thermafil), and canal preparation and obturation with thermoplasticized injectable gutta-percha (Ultrafil) and they concluded that the incidence of stained fracture in the three obturation groups was not significantly different from the incidence in the group which had only canal preparation.[18]

4. **Saw LH, Messer HH (1995)** assessed the influence of different obturation techniques (lateral condensation, Obtura, and Thermafil) on root strains. The obturation method had a major impact on the root strains; the highest strains were produced by the obtura. Comparing the Thermafil group to the Obtura or lateral condensation groups, a substantial difference in strain was observed. The unexpected discovery was the dentin's thermal expansion. A large proportion of strain in the Obtura and Thermafil groups was found to be due to thermal strain. The mean load required to cause vertical root fracture was five to six times higher than the load used in obturation.[19]

5. **Fuss Z, Lustig J, Tamse A (1999)** Evaluated the prevalence of vertical root fractures in extracted endodontically treated teeth and correlated the findings to previous studies and surveys; they concluded that the relatively high prevalence of vertical root fractures in this survey compared with previous clinical and radiographic surveys was probably related to the difficulties in making a clinical diagnosis of vertical fractures before extraction. [2]
6. **Lertchirakarn V, Timyam A, Messer HH. (2002)** compared vertical forces at fracture of endodontically treated mandibular incisors obturated with different types of root canal sealer-lateral condensation with gutta-percha and AH Plus, Tubliseal, or Ketac-Endo, respectively, and concluded that force at fracture of roots obturated with Ketac-Endo was significantly higher than those obturated with AH Plus and Tubliseal.[20]

7. **Teixeira FB, Teixeira EC, Thompson JY, Trope M (2004)** evaluated the fracture resistance of endodontically treated teeth filled with either gutta-percha or a new resin-based obturation material. They concluded that filling the canals with the new resin-based obturation material increased the in vitro resistance to fracture of endodontically treated single-canal extracted teeth when compared with standard gutta-percha techniques.[8]

8. **G De-Deus, E D Gurgel-Filho, K M Magalhaes, T Coutinho-Filho (2006)** Determined the percentage of gutta-percha-filled area in the apical third of root canals when filled with either Thermafil, System B or lateral condensation. It was concluded that the coated carrier gutta-percha system thermafil produced a significantly higher gutta-percha-filled area than lateral condensation and System B techniques. [21]

9. **Hammad M, Qualtrough A, Silikas N. (2007)** compared vertical forces at fracture of teeth obturated with different materials- gutta percha and a zine oxide sealer, EndoRez points and EndoRez sealer, Resilon and RealSeal sealer and Guttaflow. It was found that forces at fracture were statistically significantly higher in the Resilon and EndoRez groups. It was concluded that obturation of roots with resin-based obturation materials (Resilon and

EndoRez) increased the resistance of root canal-filled teeth to vertical root fracture.[22]

10. **Ribeiro FC, Souza-Gabriel AE, Marchesan MA (2008)** To evaluate the influence of different endodontic materials on root fracture susceptibility. The core materials (gutta-percha or Resilon) combined with the tested endodontic sealers were not able to increase the root fracture resistance in canals submitted to chemo-mechanical preparation.[7]

11. **Wadhwani KK, Gurung S. (2010)** compared the fracture toughness of the instrumented roots after obturating it with three different sealers and comparing it with the control group. All the materials used for the study reinforced the prepared root canals.[23]

12. **Asokan S, C. Sooriaprakas, V. Raghu, R. Bairavi (2010)** analyzed volumetrically the efficacy of lateral compaction, Thermafil, Obtura II, and System B obturation techniques using spiral computed tomography. They observed that the percentage of obturated volume obtained with System B and Thermafil was greater as compared to other techniques used. Voids were seen in all 3 filling materials. Vitapex showed the maximum percentage of obturated volume among the 3 groups.[24]

13. **Farea M (2010)** evaluated *in vitro* the apical sealing ability of cold lateral and system B root filling techniques using dye penetration. The results of this study showed that cold lateral condensation leaked significantly more than thesystem B technique.[25]

14. **Phukan AH, Mathur S, Sandhu M, Sachdev V. (2011)** compared the *in vitro* effects of four different root canal sealers on the fracture resistance of endodontically treated teeth. resin-based sealer was more effective as compared to other sealers and the control group. However, no significant differences were observed between ZOE and the control group. The effect of

different root canal sealers on the fracture resistance of endodontically treated teeth-*in vitro* study.[26]

15. **Anantula K, Ganta AK. (2011**) -The results obtained showed GuttaFlow 2 to be inferior to GuttaCore but superior to all other groups. GuttaFlow 2 is a silicone-based material that adapts closely to the dentinal walls, thus providing a homogenous obturation. The high viscosity of this material allows for adequate condensation of the obturating material.[27]

16. **Ghoneim AG, Lutfy RA, Sabet NE, Fayyad DM. (2011)** conducted a study to evaluate and compare the fracture resistance of roots obturated with various contemporary canal-filling systems- iRoot SP sealer with ActiV GP cone, iRoot SP sealer with gutta-percha (GP), ActiV GP sealer with ActiV GP cone,and ActiV GP sealer with GP and observed that the fracture resistance was highest in iRoot SP/ActiV GP cone and lowest in ActiV GP sealer/GP. They concluded that bioceramic-based sealer (i.e. Root SP) is a promising sealer in terms of increasing in vitro resistance to the fracture of endodontically treated roots particularly when accompanied by ActiV GP cones.[28]

17. **Makam S, Shashikala K (2011**) Assessed the ability of two obturatingsystems to reinforce the root canal-treated teeth in which obturations were doneusing Thermafill with AH plus sealer, and single cone gutta-percha with Guttaflow sealer respectively. They concluded through this study that the Guttaflow system showed better reinforcement of the roots as compared with the Thermafill system. [29]

18. **Manal Farea, Abdulqawee Rani, Adam Husein (2011)** This study aimed to determine the percentage of gutta-percha-filled area (PGFA) in the apical third of root canals after filling with either System B or cold lateral condensation techniques. It concluded that System B produced significantly higher PGFAs than the lateral condensation technique. The results favored the use of System B for better and homogenous obturation of the root canal with a minimal amount of sealer.[30]

19. **Sağsen B, Ustün Y, Pala K, Demırbuğa S. (2012)** compared the fracture resistance of roots filled with gutta-percha (GP) and different root canalsealers. In conclusion, all the root canal sealers used in the present study increased the fracture resistance of instrumented root canals.[31]

20. **Topçuoğlu HS, Arslan H, Keleş A, Köseoğlu M, (2012)** compared in vitro root fracture resistance following root canal filling with AH 26 using lateral condensation, BeeFill, and Thermafil techniques and the results suggest that instrumentation of root canals significantly weakens the tooth structure to fracture and the root canal obturation techniques that are used are not able to form reinforcement.[32]

21. **Shashidhar J, Shashidhar C (2014)** – conducted a study in which the fracture resistance of lateral compaction was lower than guttaflow2. This could be because gutta-percha in combination with sealer has good adaptability to root canal wall and master cone and can be comparable to guttaflow2.[33]

22. **T Sandikci, RF Kaptan (2014)** compared the fracture resistance of teeth filled using different root canal filling systems, Gutta-percha with AH Plus, Thermafil with AH Plus, Resilon/ with Epiphany self-etch, Gutta-percha with Epiphany SE, EndoREZ sealer with EndoREZ cone and Concluded that lateral condensation performed with AH Plus sealer and Gutta-percha and the Thermafil technique was found to be more successful.[34]

23. **Carlos RB, Makam S, Yaragonda VK, (2014)** Compared the vertical root fracture resistance of endodontically treated teeth among negative control, guttapercha with TubliSeal EWT sealer, ThermaFil with AH Plus sealer, RealSeal with RealSeal sealer and GuttaFlow obturating system. They concluded obturation of roots with resin-based obturation material RealSeal increased Vertical root fracture resistance compared to the gutta-percha obturation systems.[35]

24. **Wiaam Al-Ashou (2014)** - Compared and evaluated the fracture resistance of root dentin following the application of AH Plus sealer, MTA Fillapex sealer, and BioRoot RCS sealer and concluded that the use of cold lateral condensation technique may weaken the roots which became more susceptible to vertical root fracture. The statistical mean difference between group lateral condensation and gutta core was highly statistically significant. [36]

25. **Khan S, Inamdar MN, Munaga S, Ali SA, Rawtiya M, Ahmad E (2015)** compared in vitro fracture resistance after filling with either Gutta-percha or Resilon by lateral condensation techniques in root canals. This study evaluated a new thermoplastic synthetic polymer based on polyester, which contains bioactive and radiopaque filler, Resilon performs every way as Gutta-percha except that it allows the bonding agent to attach to the resin core and the dentin wall thus forming a monoblock. Within the limitation of the present in-vitro study, Resilon/Epiphany sealer performs better than Gutta-percha/AH 26 sealer with lateral condensation technique.[37]

26. **Langalia AK, Dave B, Patel N, Thakkar V, Sheth S, (2015)** compared fracture resistance of endodontically treated teeth obturated with different resin-based adhesive sealers with a conventional obturation technique. concluded that roots obturated with newer resin systems (Resilon and EndoREZ) enhanced the root strength almost up to the level of the intact root.[38]

27. **Ersoy I, Evcil MS, (2015)** compared the fracture resistance of teeth filled with AH Plus and MTA Fillapex root canal sealers by using different root canal obturation techniques. It was concluded that shaping and widening of the root canals reduced the fracture resistance of teeth while Thermafil increased the resistance of roots against fracture.[39]

28. **Hedge V, Arora S (2015)** Compared the fracture resistance of roots obturated with three hydrophilic systems - novel C Point system, Resilon/ Epiphany system, and Endo Sequence BC sealer; and one hydrophobic gold standard gutta-percha/AH Plus system using the universal testing machine. They

concluded that hydrophilic systems showed higher fracture resistance than hydrophobic systems; among the hydrophilic systems, the C Point system and Endo Sequence BC sealer had the highest fracture resistance. [40]

29. **Tavanafar S, Karimpour A, Karimpour H, Mohammed Saleh A, Hamed Saeed M, (2015)** compared the effects of three different instrumentation techniques on vertical root fracture resistance of endodontically treated teeth. All three instrumentation techniques caused weakening of the structure of the roots and rendered them susceptible to fracture under lesser load than unprepared roots. The fracture resistance of roots prepared with the single-file reciprocating technique was like that of those prepared with NiTi hand and rotary instrumentation techniques.[41]

30. **Guneser MB, Akman M, Kolcu İB, Eldeniz AU (2016**) evaluated the vertical-fracture resistance of roots obturated with a newly developed tricalcium silicate cement using cold lateral compaction technique or matched-taper single-cone gutta-percha technique. The vertical fracture resistance of roots obturated with BioRoot RCS and iRoot SP sealers using either LC or SC technique was found to be like that of intact teeth. BioRoot RCS, a newly developed tricalcium silicate cement, might have the potential to reinforce the instrumented teeth against vertical root fracture.[42]

31. **Velugu R, Karunakar P, Reddy R (2016)** evaluated the fracture resistance of endodontically treated teeth obturated using lateral compaction technique with AH plus/Gutta-percha, Resilon/RealSeal self-etch (SE), and Endofill/Gutta-percha using universal testing machine. Their study demonstrated higher fracture resistance values for Resilon/RealSeal SE than AH plus/Gutta-percha, followed by Endofill/Gutta-percha.[43]

32. **Punjabi M, Dewan R, Kochhar R (2017)** evaluated and compared the fracture resistance of root canals obturated with four different obturating systems in endodontically treated teeth. Techniques used for obturation were namely cold lateral compaction technique, cold free-flow compaction technique, warm vertical compaction technique, and injection-molded

thermoplasticized technique. It was concluded that GuttaFlow2 had the potential to strengthen the endodontically treated roots to a level that is like that of intact teeth.[44]

33. **Upadhyay ST, Purayil TP, Guntupalli K (2017)** Evaluated and compared the effect of an epoxy-based sealer and a pozzolan-based mineral trioxide aggregate sealer on the fracture resistance ofendodonticallytreated teeth and concluded that the new root canal sealer Endoseal MTA was able to reinforce the tooth against fracture as good as AH Plus.[45]

34. **Mittal A, Dadu S, Garg P, Yendrembam B, (2017)** evaluated and compared the fracture resistance of endodontically treated teeth obturated with gutta-percha using two sealers, AH Plus, and mineral trioxide aggregate Fillapex and concluded AH Plus and mineral trioxide Fillapex gave comparable results as root canal sealer .[46]

35. **Dibaji F, Afkhami F, Bidkhori B, Kharazifard MJ. (2017)** assessed the fracture resistance of roots following the application of different sealers including Epiphany, iRoot sealer, and AH-plus, and concluded application of AH-Plus, bioceramic, and Resilon sealers did not change the fracture resistance of roots compared to that of unprepared root canals.[47]

36. **Jindal D, Sharma M, Raisingani D, Swarnkar A, Pant M, Mathur R, (2017)** conducted in a study in which the statistical mean difference between group gutta core and continuous wave technique was highly significant. This could be because no heat was used during placement of the material therefore no occurrence of shrinkage while in the downpack backfill technique shrinkage of gutta percha and expansion of root dentin occurred which might decrease the fracture resistance.[48]

37. **Chadha R, Taneja S, Kumar M, and Sharma M (2018)** evaluated the in vitro effect of various obturating materials on fracture resistance of root canal-treated teeth. Teeth were divided into four groups based on the type of obturating materials used. On evaluation teeth obturated with AH Plus and

gutta-percha showed higher fracture resistance than those obturated with Resilon-Epiphan, the group obturated with gutta-percha and zinc oxide eugenol sealer showed the lowest fracture resistance.[49]

38. **Demiriz L, Bodrumlu EH (2018).** examined fracture resistance after filling simulated incomplete vertical fractured permanent teeth using two different bioceramic-based sealers. In conclusion Well Root ST and MTA Fillapex sealer significantly increased the fracture resistance of untreated incomplete vertical fractured roots.[51]

39. **Tanwar P (2019) -** evaluated and compared the fracture resistance of teeth that are prepared by Self Adjusting File (SAF) and filled with three different obturation techniques, i.e. warm vertical compaction technique, cold lateral compaction technique, and thermafil obturation technique. It was concluded that the Control group had the highest fracture resistance, followed by the Thermafil system then warm vertical condensation followed by cold lateral compaction. Cold lateral compaction had the lowest fracture resistance and the control group had the highest fracture resistance.[52]

40. **Gamal S, Shafei J, Asfouri H (2019)** assessed the fracture resistance and sealing ability of endodontically treated teeth obturated with the Guttacore root canal obturator as compared with Thermafil root canal obturator, and examined the Guttacore material to verify its cross-linked structure and concluded that the Guttacore material provides strengthening for the root dentin together with adequate sealing ability properties comparable to lateral condensation technique.[53]

41. **Goyal K (2020)** Compared the vertical fracture resistance of teeth obturated with four different obturating techniques, Lateral compaction continuous-wave condensation, GuttaFlow 2, and GuttaCore. Universal testing Machine was used for the evaluation of fracture resistance and the conclusion was that the GuttaCore system showed superior fracture resistance when compared to GuttaFlow 2, continuous-wave condensation, and lateral compaction obturation method.[54]

42. **Guido Migliau, Gaspare Palaia, Daniele Pergolini (2021)** Compared the quality of the root canal obturation obtained with two different techniques, thermoplastic GuttaCore and fluid gutta-percha (GuttaFlow2). They concluded that both systems showed excellent filling qualities and to make the most of their advantages and minimize their limitations, a combination of the two techniques might be considered.[54]

43. **Bhandi S (2021)** conducted a study in which it was observed that heated gutta-percha ie backfill Thermoplastic techniques were more favorable methods of root canal obturation compared to the more widely taught cold lateral condensation. [55]

44. **Chandra P, Singh V, Singh S, (2021)** assessed different root canal filling systems in terms of fracture resistances of endodontically treated teeth and it was found that lateral condensation performed with AH Plus sealer and gutta-percha and the Thermafil technique were the highest among all other methods.[56]

45. **Chaudhari, W. A., Bhadrarao, V. V., Jani, K., (2022)** evaluated the fracture resistance of root canals filled with Resilon and Epiphany, gutta-percha, and AH plus, gutta-percha with Endomethasone sealer using Instron Machine. They concluded that all materials significantly increased the fracture toughnessof the instrumented roots after obturation.[57]

46. **Yadav P, Nagpal AK (2022**) evaluated the fracture resistance of root canals obturated with three different obturating systems in endodontically treated teeth to find the effect of cold lateral condensation, Thermafil obturation, and Downpack backfill obturation technique with the positive and negative control group, on the fracture resistance of endodontically treated teeth and concluded that the negative control group which was neither instrumented nor obturated had the highest fracture resistance among all the groups.[58]

47. **Elnawawy M A, Pullishery F, Alattas M (2023)** The objective of the research was to appraise and contrast the fracture resistance of teeth using lateral condensation technique with, AH+ and gutta-percha, Resilon-Epiphany System sealed with AH 26 and a group of teeth without any obturation and concluded that AH plus sealer was found to strengthen the tooth structure more effectively than the Resilon-Epiphany system but there was an insignificant difference with the AH 26 sealer.[59]

# MATERIALS AND METHOD

# MATERIALS AND METHOD

## TABLE A: MATERIALS AND ARMAMENTARIUM USED FOR SAMPLE PREPARATION

| S. NO. | MATERIAL AND ARMAMENTARIUM | MANUFACTURER |
|---|---|---|
| 1 | Straight handpiece | Marathon, Korea |
| 2 | Micromotor | Marathon, Korea |
| 3 | Scaling machine | Coltene, Switzerland |
| 4 | Diamond disc & Mandrel | Shofu, Japan |
| 5 | 0.1% Thymol | NH Organics, INDIA |

## TABLE B: MATERIAL & ARMAMENTARIUM USED FOR SAMPLE SAMPLE-TOOTH BIOMECHANICAL PREPARATION

| S.NO | MATERIALS & ARMAMENTARIUM | MANUFACTURER |
|---|---|---|
| 1 | K-files (NO.10,15) | Dentsply, U.S. A |
| 2 | 17% Ethylenediamine tetraacetic acid | Safe Endo Dental India Pvt Ltd, India |
| 3 | 5.25%sodium hypochlorite (NaOCl) | Prevest Denpro, Limited, India |
| 4 | Normal Saline (0.9%w/v NaCl) | (KRPL, India) |
| 5 | Endo block | (Dentsply, U.S.A.). |
| 7 | Normal Saline (0.9%w/v NaCl) | (KRPL, India) |
| 8 | Disposable syringe of 5ml | Dispo Van, India |
| 9 | Endo motor | NSK, Japan |
| 10 | 30-gauge side vented needle | Oro, India |

**TABLE C: MATERIAL AND ARMAMENTARIUM USED FOR SAMPLE OBTURATION AND RESTORATION**

| S.NO | MATERIALS & ARMAMENTARIUM | MANUFACTURER |
|---|---|---|
| **1** | AH Plus sealer | Densply, USA |
| **2** | Gutta Percha points (#F3) | Meta Aurum Pro, India |
| **3** | Gutta flow 2 sealer | Coltene, Switzerland |
| **4** | Paper point | Dentsply, U.S.A. |
| **5** | AH Plus sealer | Dentsply, U.S.A. |
| **6** | ProTaper gold rotary files 21mm size (SX, S1, S2, F1, F2, F3) | Dentsply, U.S.A. |
| **7** | Gutta Percha points (#F3) | Densply, USA |
| **8** | Composite resin | Walldent, India |
| **9** | Fast Pack Pro- Down Pack Device for 3D Obturation | Oricam, India |
| 11 | Gutta core oven | Dentsply, U.S. A |
| 12 | Hand Spreader | GDC, India |

**TABLE D: MATERIALS USED FOR BLOCK PREPARATION**

| S.NO | MATERIALS & ARMAMENTARIUM | MANUFACTURER |
|---|---|---|
| 1 | Modelling Wax | Pyrax, India |
| 2 | Cold cure resin | Pyrax, India |
| 3 | Marking scale | Jaxson, India |

**Place of the study:**

This study was conducted at the Department of Conservative Dentistry and Endodontics, Babu Banarasi Das College of Dental Sciences, Lucknow, and, Central Institute for Petrochemical Engineering and Technology, Lucknow.

**Sample size:**

**Based on groups' mean difference using one-way analysis of variance (ANOVA)**

The present *in vitro* study evaluates and compares the fracture resistance of endodontically treated teeth obturated with different obturating techniques. The sample size of the present study was priori based on the mean difference (i.e. effect size: f) in fracture resistance among five groups (control, continuous-wave condensation technique, lateral compaction technique, GuttaFlow, and GuttaCore).

Expecting effect size was at least 0.70 (N) in fracture resistance among five groups with considering a 5.0% margin of error (*α=0.05 i.e. type I error*), 80.0% power (*1-β=0.80 i.e. type II error*) and 1:1 ratio, then minimum 30 samples need to be sampled (n) for the study or 6 samples per group, evaluated by G*Power 3.1.9.7 software as

**TABLE E:**

| **Input parameters** | **Output parameters** |
|---|---|
| Effect size (f)=0.70 | Non-centrality parameter (λ)=14.7000000 |
| α error probability=0.05 | Critical F=2.7587105 |
| Power (1-β error probability) =0.80 | Numerator df=4 |
| Number of groups=5 | Denominator df=25 |
| Allocation of samples (n)=1:1 | Total sample size=30 |
| | Actual power=0.8089341 |

**df:** degree of freedom, **Critical F:** ANOVA F value

Thus, a minimum of 30 samples was sufficient for the study, or 6 samples per group.

Thirty single-rooted mandibular premolars were instrumented using ProTaper gold rotary files up to size F3. Samples were obturated using four different methods of obturation (Lateral compaction, continuous-wave condensation (CWC), GuttaFlow 2, and GuttaCore). A universal testing machine was used for the evaluation of fracture resistance. Data were analyzed by one-way ANOVA and student t-test.

**The following inclusion and exclusion criteria were set to select the teeth:**

INCLUSION CRITERIA-

1. Freshly extracted intact single-rooted mandibular premolars extracted for orthodontic reasons were collected and verified radiographically to ascertain the presence of a single straight canal.
2. Tooth with a single canal (one orifice and one foramen) which was determined radiographically.

EXCLUSION CRITERIA –

1. Teeth with any crack, caries, or calcification.
2. Teeth with any developmental anomaly.
3. Restored teeth.

Sampling Method-

A total of 30 human permanent single-rooted teeth were collected. The collected teeth were cleaned using an ultrasonic scaler and were stored in saline until further use.

**METHODOLOGY**

30 Single-rooted human premolar teeth

**TABLE F:**

| **Treatments/Technique** | **Group name** | **Total sample (n=30)** |
|---|---|---|
| Control | Group A | 6 |
| Continuous-wave condensation | Group B | 6 |
| Lateral compaction | Group C | 6 |
| GuttaFlow 2 | Group D | 6 |
| GuttaCore | Group E | 6 |

**Specimen preparation:**

Thirty freshly extracted intact single-rooted mandibular premolars were collected and verified radiographically to ascertain the presence of a single straight canal. The teeth were disinfected in a solution of 0.1% thymol and stored in saline until the samples were used. Each tooth was horizontally sectioned to obtain a standardized length of 12 mm. Apical patency was established with a size 10 K-file, working length was determined 1 mm short of the working length.

**Preparation of root canals**

Chemo mechanical preparation was done up to size #F3 using ProTaper Gold Rotary files (Dentsply Tulsa Dental, Switzerland) as per the manufacturer's instructions.

During instrumentation, the root canals were irrigated with 5 ml of 5% sodium hypochlorite followed by 3 ml of 17% ethylenediaminetetraacetic acid for removal of the smear layer, and a final rinse with 5 -10 ml of normal saline using 30 G side vented needle.

Canals were then dried with sterile paper points of corresponding size (Dentsply Maillefer, Ballaigues, Switzerland).

Teeth were randomly divided into five groups, based on obturating techniques used: -

• Group A (n = 6) – Control

A root canal was instrumented but not obturated to serve as a control.

• Group B (n = 6) – Continuous-wave condensation.

A ProTaper F3 (Dentsply Maillefer, Ballaigues, Switzerland) gutta-percha master cone along with AH plus sealer was selected. A touch “n” heat plugger at 200°C was inserted into the canal to a depth 3–4 mm short of the working length to create an apical plug. The sealer was reapplied and the remaining root canal space was backfilled with softened gutta-percha using System B Heat Source (Oricam, Orange, CA, USA) until the canal filling (According to the manufacturer’s guideline).

• Group C (n = 6) – Lateral compaction technique.

The obturation was performed using a master gutta-percha cone of size F3 and accessory gutta-percha points with AH plus root canal sealer.

• Group D (n = 6) – GuttaFlow 2.

The obturation was performed using GuttaFlow 2 (Coltene/Whaledent, Langenau, Germany) along with a size F3 gutta-percha master cone (According to the manufacturer’s guidelines).

• Group E (n = 6) – GuttaCore.

The canal was coated with AH Plus sealer and GuttaCore Obturator F3 (Dentsply Tulsa Dental Specialities, Johnson City, Tennessee, USA) was inserted after being thermoplasticized in a Therma Prep oven (According to the manufacturer’s guideline).

Teeth were radiographed to confirm the adequacy of the root canal fillings 1mm short of the apex.

The coronal access was sealed with composite resin restoration after removing 1.5 mm of obturating material. All teeth were then kept in a humidifier at 37°C for 7 days, to allow proper setting of the sealer.[10]

FIG 1 SAMPLE COLLECTED FIG 2:SAMPLES STORED IN SALINE

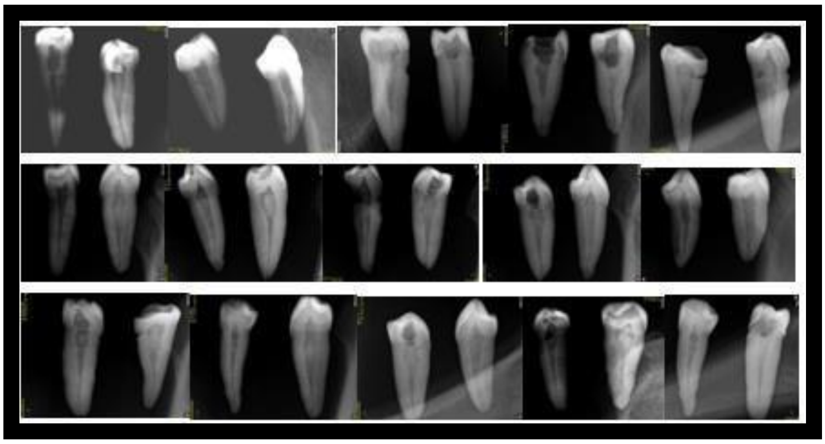


FIG 3: X-RAY FOR SINGLE CANAL CONFIRMATION


FIG 4: IMAGES OF MATERIALS USED

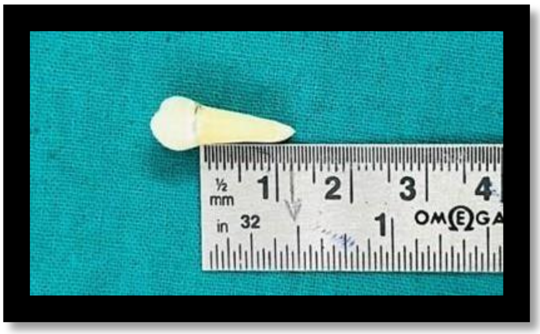


FIG 5: MEASUREMENT OF TOOTH AT 12 MM

FIG 6:DECORONATION OF SAMPLE TOOTH


FIG 7: MICROMOTOR WITH DIAMOND DISC

FIG 8: PROTAPER GOLD ROTARY FILE

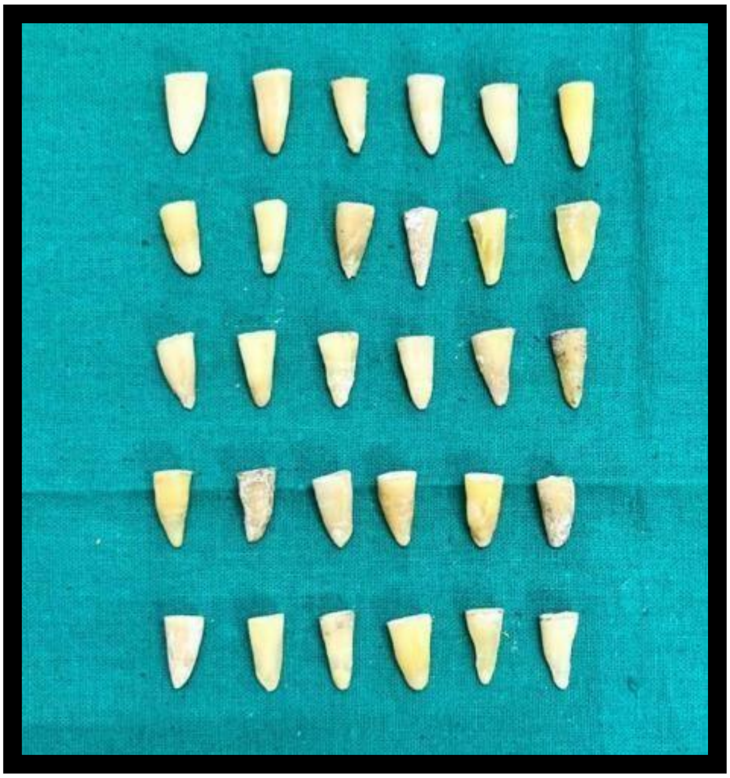


FIG. 9: CORONALLY SECTIONED SAMPLES

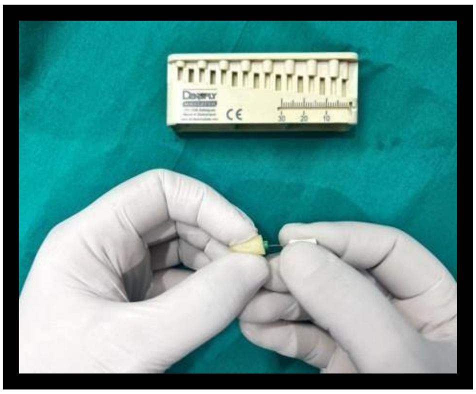


FIG 10: MEASUREMENT OF CANAL

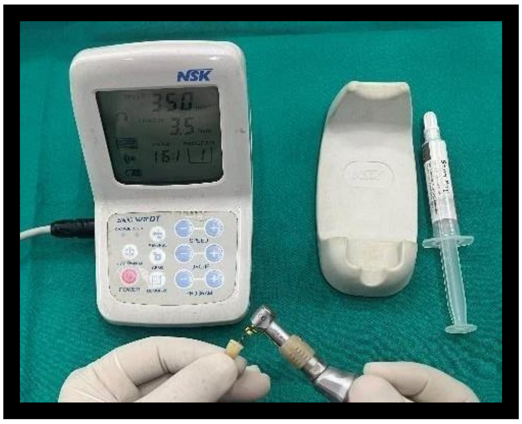



FIG 11: BIOMECHANICAL PREPARATION OF TOOTH CANAL

FIG 12: LENGTH CONFIRMATION BY RADIOGRAPH

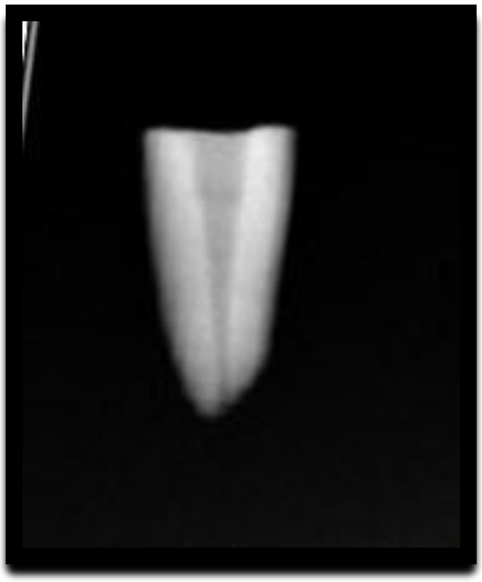


FIG 13: BIOMECHANICALLY PREPARED TOOTH

**GROUP 1**

## GROUP 2

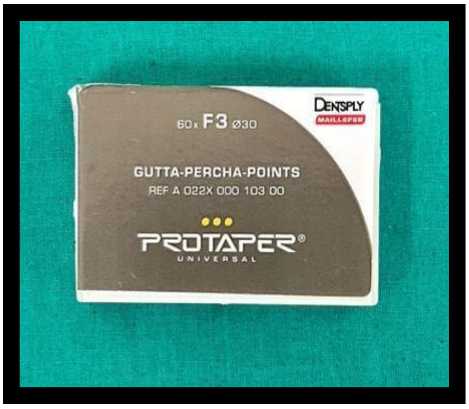




FIG 14: A H PLUS SEALER

FIG 15: PROTAPER F3 GUTTA-PERCHA

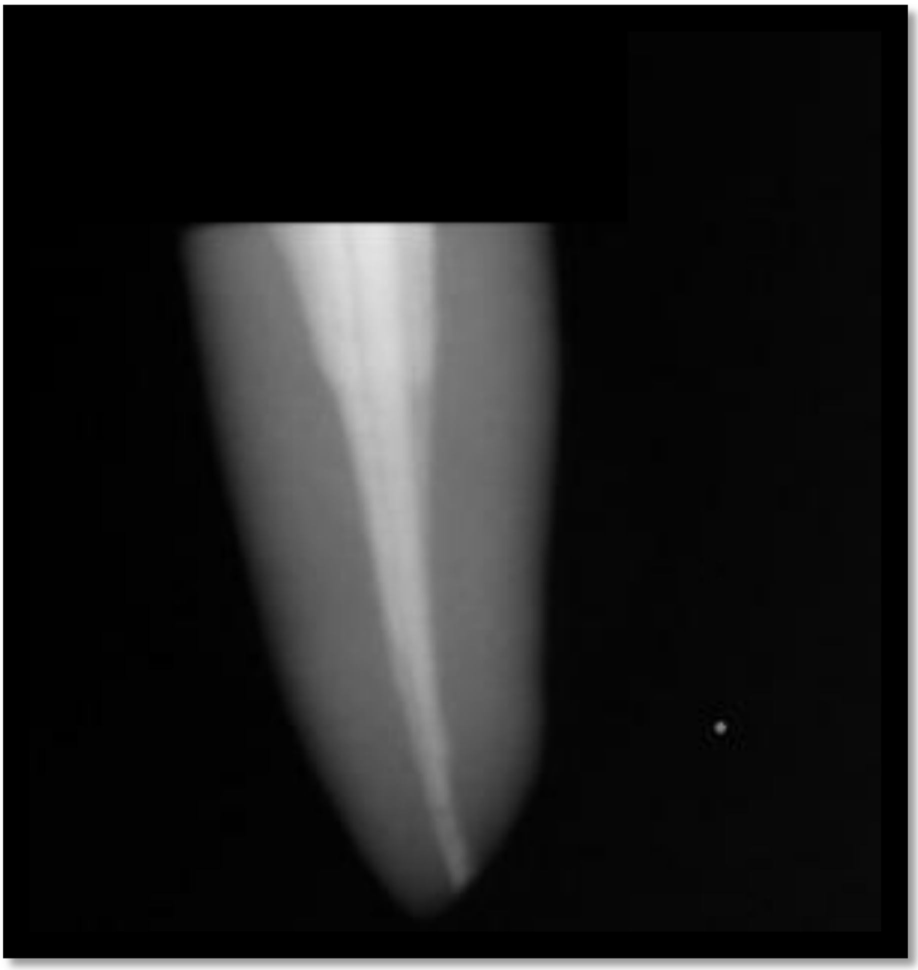


FIG 16: OBTURATION DONE WITH LATERAL CONDENSATION TECHNIQUE

## GROUP 3

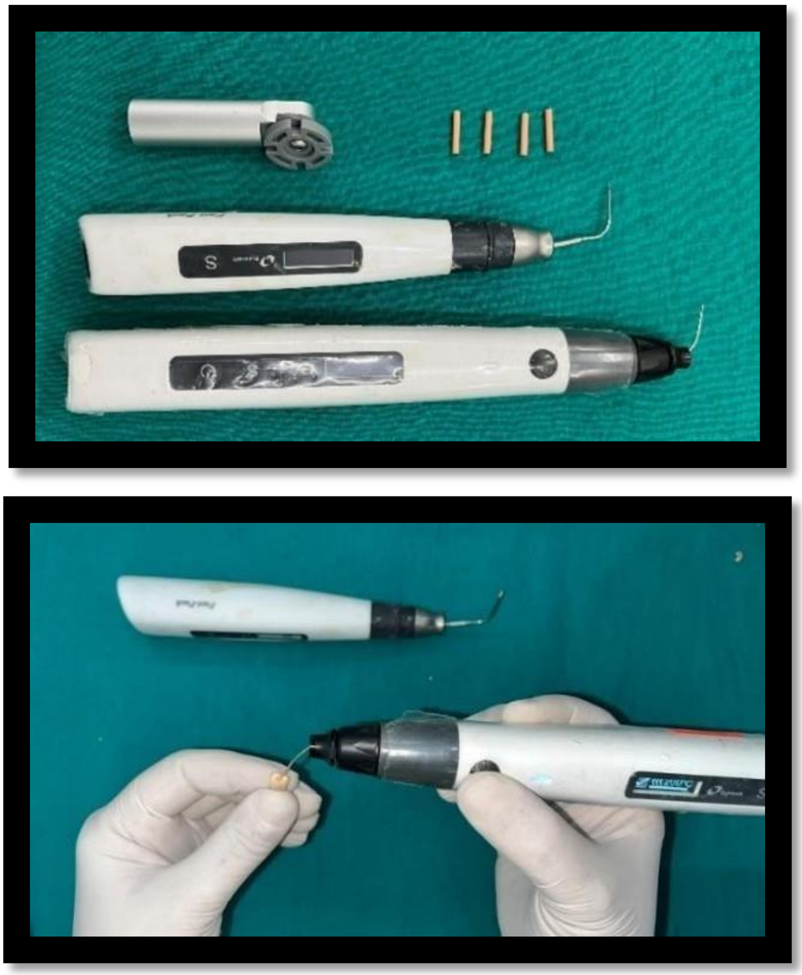


FIG 17: FAST PACK PRO- DOWN PACK DEVICE FOR 3D OBTURATOR

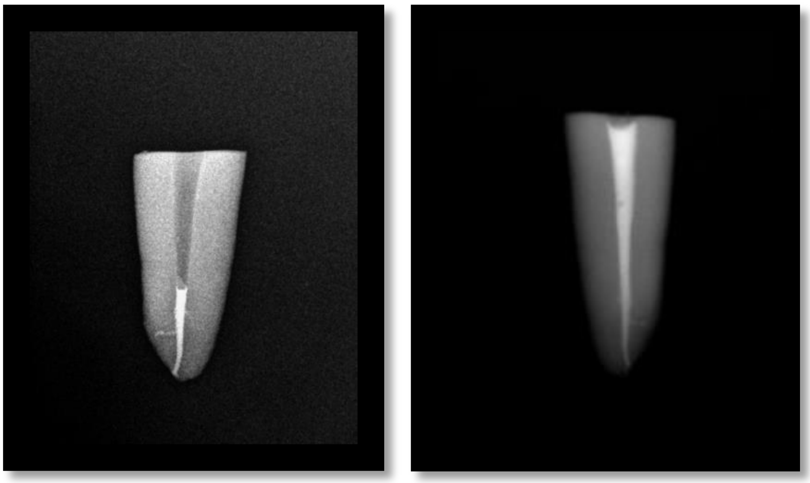


FIG 18: OBTURATION WITH CONTINUOUS WAVE TECHNIQUE

## GROUP 4


FIG 19. GUTTA FLOW 2

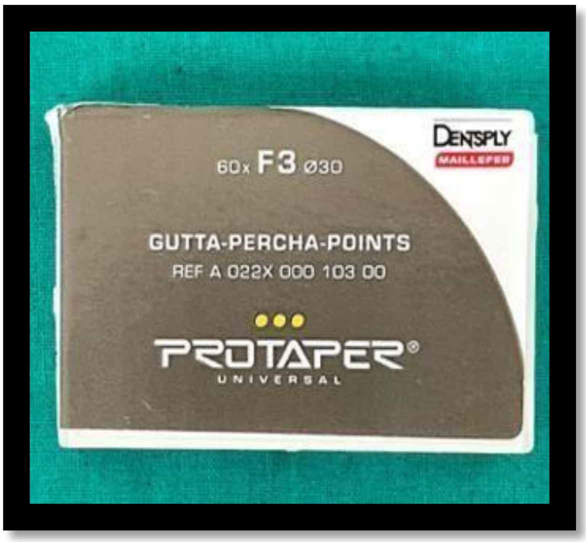



FIG 20: PROTAPER F3 GUTTA-PERCHA

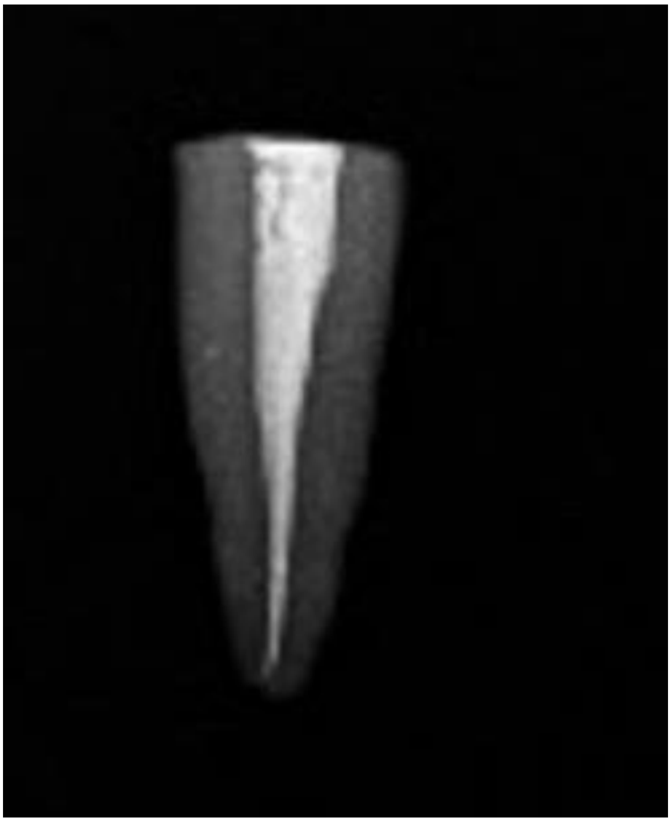


FIG 21: OBTURATION WITH GUTTA FLOW 2

## GROUP 5


FIG 22: GUTTA CORE OVEN AND GUTTA CORE


FIG 23: AH PLUS SEALER

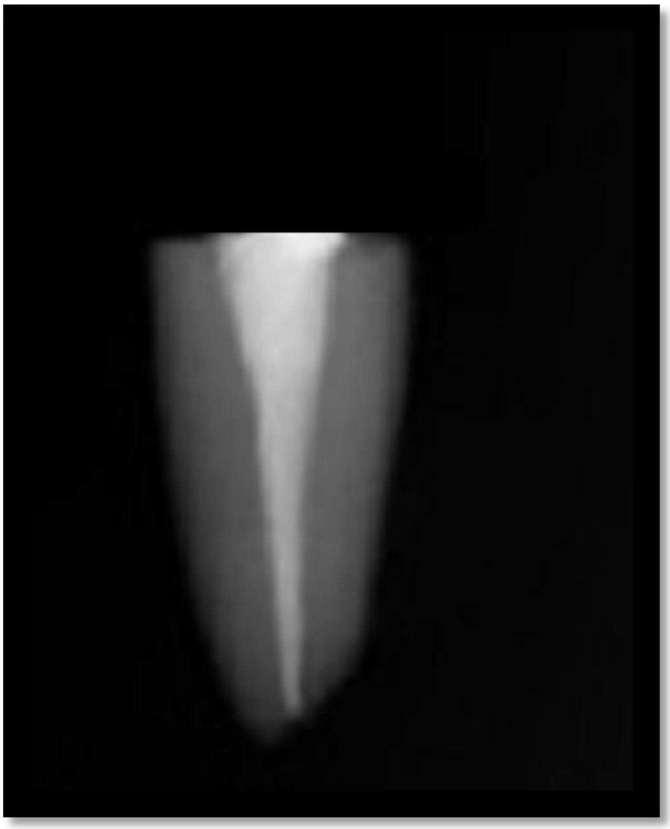


FIG 24: OBTURATION WITH GUTTA CORE

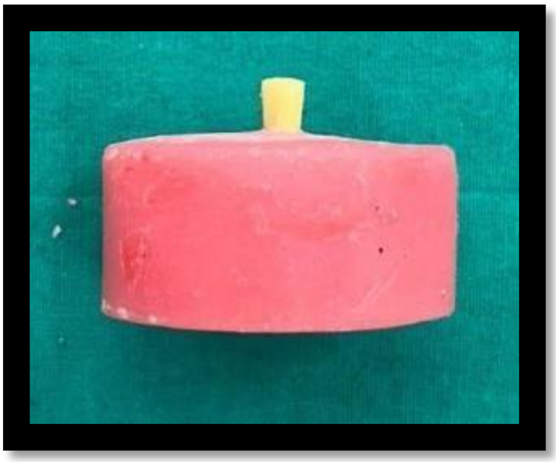


FIG 25: ACRYLIC MOUNTED TOOTH

FIG 26: COMPOSITE RESTORED TOOTH

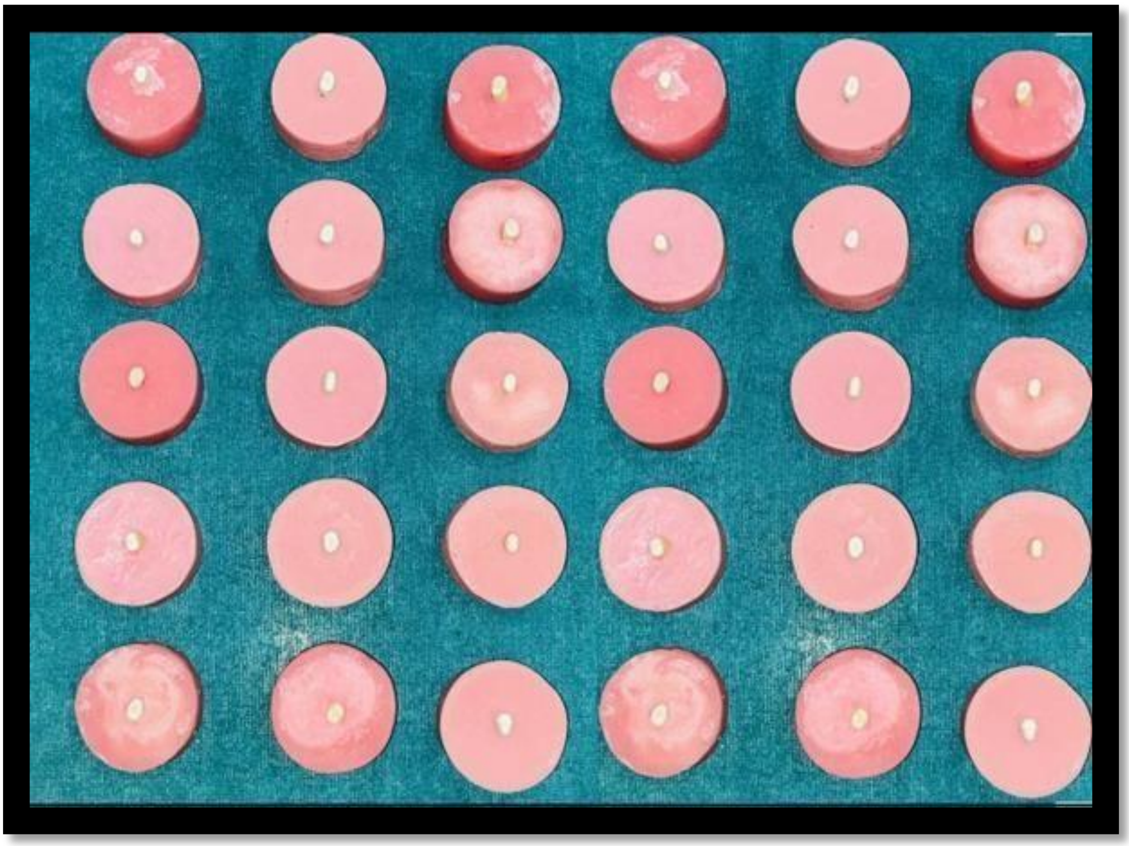


FIG 27: ACRYLIC-MOUNTED TEETH FOR FRACTURE RESISTANCE TEST


FIG 28: INSTRON UNIVERSAL TESTING MACHINE

FIG 29: SPECIMEN MOUNTED ON INSTRON TESTING MACHINE

FIG 30:FRACTURED SPECIMEN

# OBSERVATION AND RESULT

## STATISTICAL ANALYSES

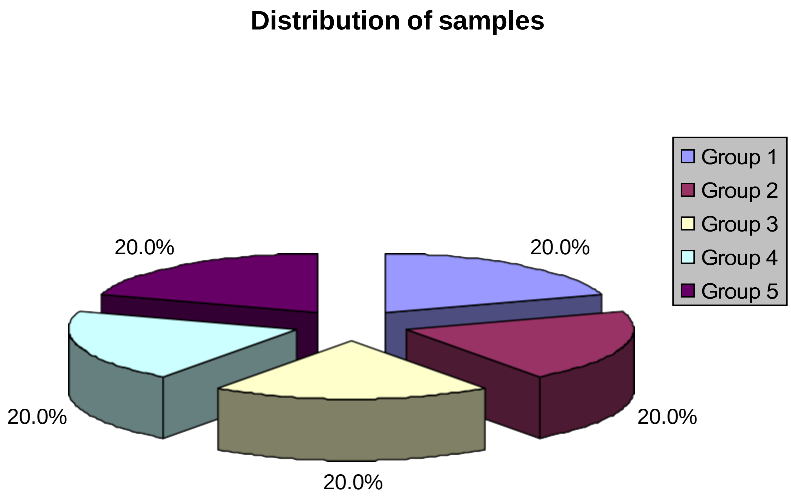
Data were summarised as Mean ± SE (standard error of the mean). Groups were compared by one-factor analysis of variance (ANOVA) and the significance of mean difference between the (inter) groups was done by Tukey's HSD (honestly significant difference) post hoc test after ascertaining normality by Shapiro-Wilk's test and homogeneity of variance between groups by Levene's test. A two-tailed ($\alpha$=2) $P < 0.0$ is considered statistically significant. Analysis was performed on SPSS software (Windows version 22.0).

### RESULTS AND OBSERVATIONS

The present *in-vitro* study evaluates and compares the fracture resistance of endodontically treated teeth obturated with different obturating techniques. A total of 30 human permanent single-rooted teeth extracted for orthodontic/periodontal purposes were collected from the Department of Oral and Maxillofacial Surgery, BBDCODS, Lucknow. Teeth were randomly divided into five groups and treated with control (*Group 1, n=6*), continuous-wave condensation (CWC) technique (*Group 2, n=6*), lateral compaction (LC) technique (*Group 3, n=6*), GuttaFlow 2 (*Group 4, n=6*) and GuttaCore (*Group 5, n=6*) (Table 1 and Fig. 1). The outcome measure of the study was fracture resistance assessed after the treatment and measured in Newton (N). The objective of the study was to compare the fracture resistance among five groups/techniques.

**TABLE G: GROUP ALLOCATION AND DISTRIBUTION OF SAMPLES IN FIVE DIFFERENT GROUPS**

| Treatments/Technique | Group Name | Total sample (n=30) (%) |
|---|---|---|
| Control | Group 1 | 6 (20.0) |
| Continuous-wave condensation | Group 2 | 6 (20.0) |
| Lateral compaction | Group 3 | 6 (20.0) |
| GuttaFlow 2 | Group 4 | 6 (20.0) |
| GuttaCore | Group 5 | 6 (20.0) |




**Graph no. 1. Distribution of samples in five different groups.**

## Outcome measure

### *Fracture resistance*

The fracture resistance of five different groups (Group 1, Group 2, Group 3, Group 4, and Group 5) were summarised in Table 2 and also depicted in Fig. 2. The fracture resistance of Group 1, Group 2, Group 3, Group 4, and Group 5 ranged from 70.21 to 86.41, 140.60 to 169.46, 160.28 to 190.36, 190.20 to 230.40 and 325.12 to 410.10 N respectively with mean (± SE) 79.87 ± 2.31, 154.93 ± 4.18, 177.34 ± 4.04, 205.36 ± 5.78 and 357.03 ± 12.72 N respectively and median 80, 155, 179, 203 and 353 N respectively.

The mean fracture resistance of Group 5 was the highest followed by Group 4, Group 3, Group 2, and Group 1, the least (Group 1 < Group 2 < Group 3 < Group 4 < Group 5).

Comparing the mean fracture resistance of five different groups, ANOVA showed significantly different fracture resistance among the groups (F=221.60, $P < 0.001$) (Table 3).

Further, comparing the difference in mean fracture resistance between the groups (i.e. group), the Tukey test showed significantly ($P < 0.001$) different and higher fracture resistance of Group 5 as compared to all other groups (Group 1, Group 2, Group 3 and

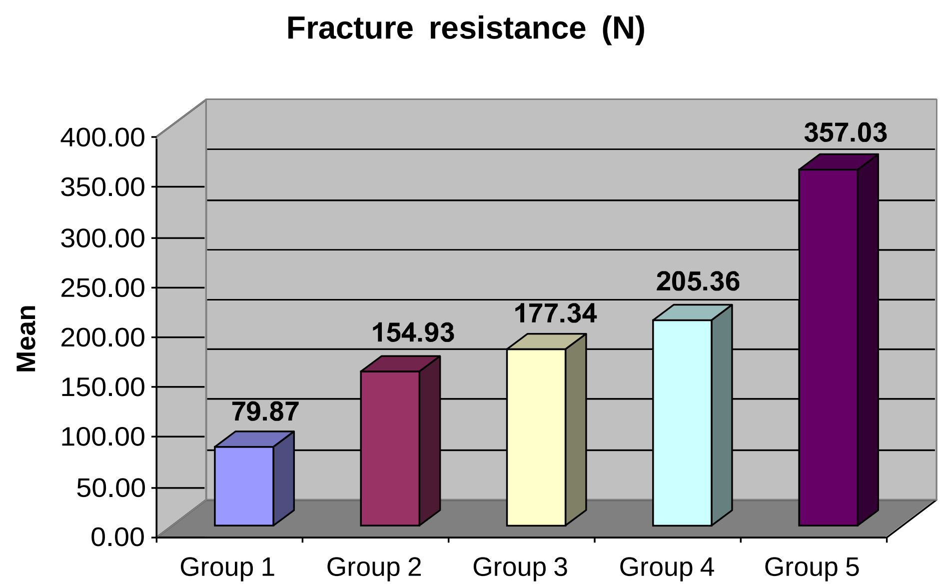
Group 4) (Table 4 and Fig. 3-6). Further, the mean fracture resistance of Group 2, Group 3, and Group 4 was also found significantly (*P* < 0.001) different and higher as compared to Group 1. Furthermore, the mean fracture resistance of both Group 4 was also found significantly (*P* < 0.001) different and higher as compared to Group 2. However, the mean fracture resistance did not differ (*P* > 0.05) between Group 2 and Group 3, and Group 3 and Group 4 i.e. found to be statistically the same.

In conclusion, the mean fracture resistance of Group 5 was the maximum and it was 77.6, 56.6, 50.3, and 42.5% higher significantly (*P* < 0.001) as compared to Group 1, Group 2, Group 3, and Group 4 respectively.

**Table H: Summary of fracture resistance (N) of five different groups**

| Group | n | Range (min to max) | Mean ± SD | Median |
|---|---|---|---|---|
| Group 1 | 6 | 70.21 to 86.41 | 79.87 ± 2.31 | 80 |
| Group 2 | 6 | 140.60 to 169.46 | 154.93 ± 4.18 | 155 |
| Group 3 | 6 | 160.28 to 190.36 | 177.34 ± 4.04 | 179 |
| Group 4 | 6 | 190.20 to 230.40 | 205.36 ± 5.78 | 203 |
| Group 5 | 6 | 352.12 to 410.10 | 357.03 ± 12.72 | 353 |

Fracture resistance of five different groups was summarised in range (min to max), Mean ± SE, and median.




**Graph no. 2. Mean fracture resistance of five different groups.**

**Table I: Comparison of mean fracture resistance (N) of five different groups by ANOVA**

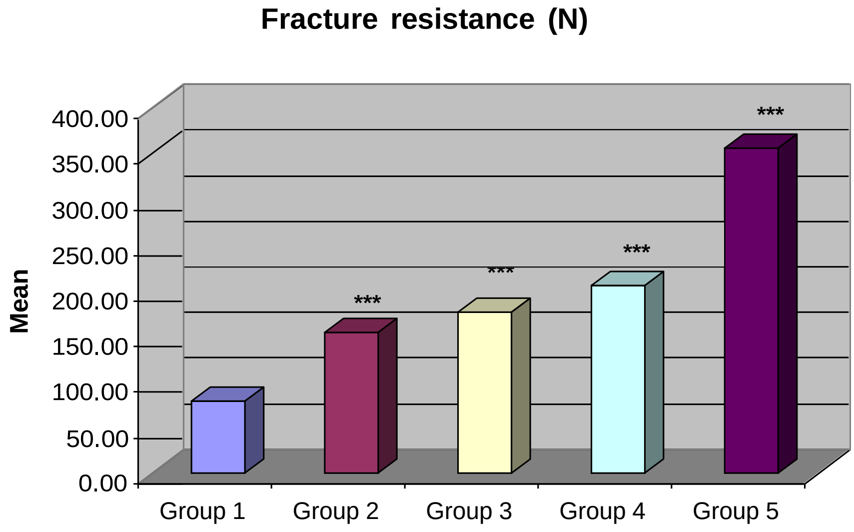
| **Source of variation (SV)** | **Sum of square (SS)** | **Degree of freedom (DF)** | **Mean square (MS)** | **F value** | ***P* value** |
|---|---|---|---|---|---|
| Groups | 249199.0 | 4 | 62300.0 | 221.60 | < 0.001 |
| Residual | 7030.0 | 25 | 281.2 | | |
| Total | 256229.0 | 29 | 62581.2 | | |

**F value:** ANOVA F value

**TABLE J: COMPARISON (*P* VALUE) OF DIFFERENCE IN MEAN FRACTURE RESISTANCE (N) BETWEEN GROUPS BY TUKEY TEST**

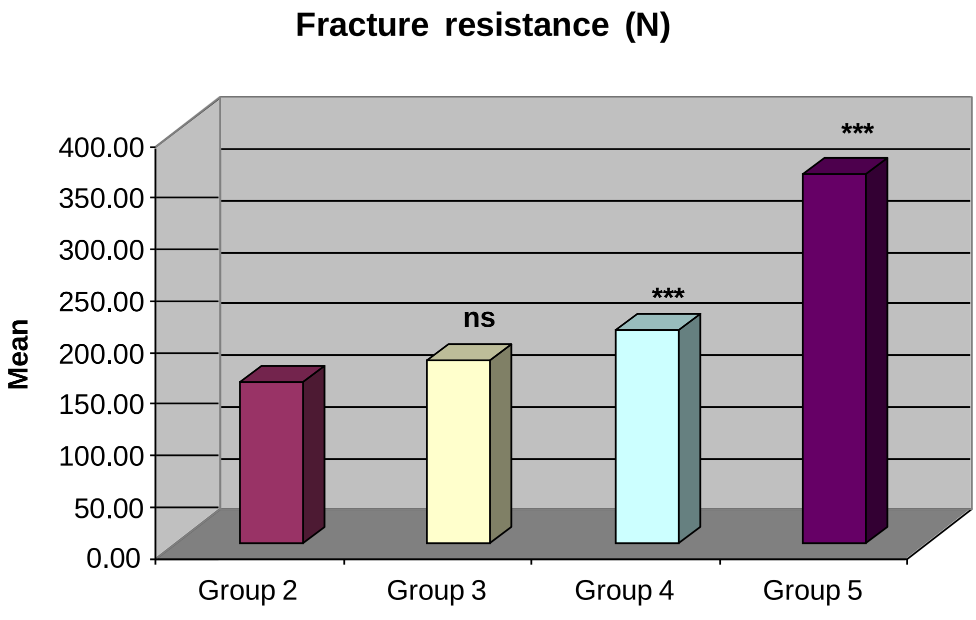
| Comparison | Mean diff. | q value | *P* value | 95% CI of diff. |
|---|---|---|---|---|
| Group 1 vs. Group 2 | 75.06 | 10.96 | P < 0.001 | 46.61 to 103.50 |
| Group 1 vs. Group 3 | 97.47 | 14.24 | P < 0.001 | 69.02 to 125.90 |
| Group 1 vs. Group 4 | 125.49 | 18.33 | P < 0.001 | 97.04 to 153.9 |
| Group 1 vs. Group 5 | 277.16 | 40.49 | P < 0.001 | 248.70 to 305.60 |
| Group 2 vs. Group 3 | 22.41 | 3.27 | P > 0.05 | 6.04 to 50.86 |
| Group 2 vs. Group 4 | 50.43 | 7.37 | P < 0.001 | 21.98 to 78.87 |
| Group 2 vs. Group 5 | 202.10 | 29.52 | P < 0.001 | 173.70 to 230.50 |
| Group 3 vs. Group 4 | 28.02 | 4.09 | P > 0.05 | 0.43 to 56.46 |
| Group 3 vs. Group 5 | 179.69 | 26.25 | P < 0.001 | 151.20 to 208.10 |
| Group 4 vs. Group 5 | 151.67 | 22.16 | P < 0.001 | 123.20 to 180.10 |

**Diff:** difference, **CI:** confidence interval, **q value:** Tukey test value



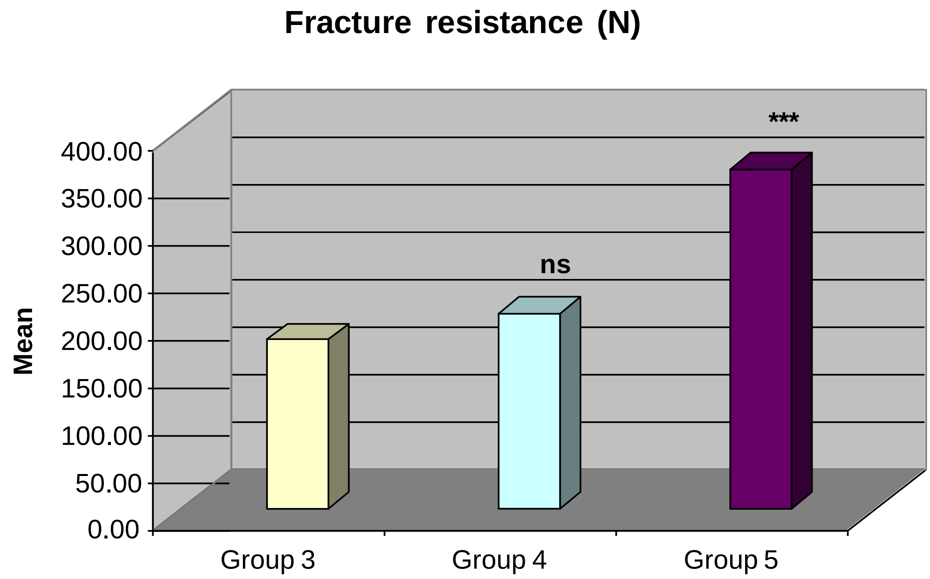

$^{***}P < 0.001$- as compared to Group 1

**Graph 3. Comparisons of difference in mean fracture resistance between five different groups.**



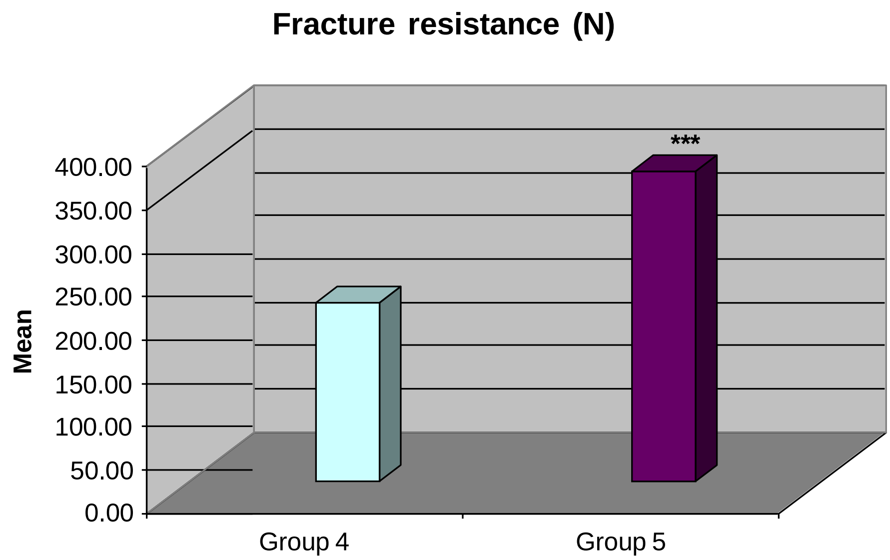

$^{ns}P > 0.05$ or $^{***}P < 0.001$- as compared to Group 2

**Graph 4. Comparisons of difference in mean fracture resistance between four different groups.**




$^{ns}P > 0.05$ or $P < 0.001$- as compared to Group 3

**Graph 5. Comparisons of difference in mean fracture resistance between three different groups.**




$P < 0.001$- as compared to Group 4

**Graph 6. Comparisons of difference in mean fracture resistance between two different groups.**

## OBSERVATIONS

### Fracture resistance (N)

### TABLE K:

| SNO | Control (Group 1) | Continuous-wave condensation (Group 2) | Lateral compaction (Group 3) | GuttaFlow 2 (Group 4) | GuttaCore (Group 5) |
|---|---|---|---|---|---|
| 1 | 86.41 | 150.4 | 178.4 | 210.1 | 346.14 |
| 2 | 70.21 | 158.6 | 180.2 | 205.2 | 330.26 |
| 3 | 78.46 | 149.21 | 160.28 | 201.14 | 325.12 |
| 4 | 84.47 | 161.32 | 190.36 | 190.2 | 410.1 |
| 5 | 80.21 | 140.6 | 174.2 | 195.1 | 360.4 |
| 6 | 79.46 | 169.46 | 180.6 | 230.4 | 370.16 |

**The formula used for the analysis**

**Arithmetic Mean**

The most widely used measure of central tendency was the arithmetic mean, usually referred to simply as the mean, calculated as

$$X = \frac{\sum_{i=1}^{n} X_i}{n}$$

**Standard deviation and standard error**

The standard deviation (SD) is the positive square root of the variance and was calculated as

$$SD = \sqrt{\frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n-1}}$$

and SE (standard error of the mean) was calculated as

$$SE = \frac{SD}{\sqrt{n}}$$

where, n= no. of observations

# Minimum and Maximum

Minimum and maximum are the minimum and maximum values respectively in the measure data and the range may be dented as

Range = Min to Max or Min-Max

and also evaluated by subtracting the minimum value from the maximum value as

Range = Maximum Value-Minimum value

**Median**

The median was generally defined as the middle measurement in an ordered set of data. That was, there are just as many observations larger than the median as there are smaller. The median (M) of a sample of data may be found by first arranging the measurements in order of magnitude (preferably ascending). For even and odd number of measurements, the median was evaluated as

M= $[(n+1)/2]^{th}$ observation- odd number

M= $[n(n+1)/2]^{th}$ observation – even number

## Analysis of Variance

Analyses of variance (ANOVA) were used when we compared more than two groups simultaneously. The purpose of one-way ANOVA was to find out whether data from several groups have a common mean. That was, to determine whether the groups were different in the measured characteristics. One-way ANOVA was a simple special case of the linear model. For more than two independent groups, simple parametric ANOVA was used when variables under consideration followed Continuous exercise Group 4wastribution and group variances were homogeneous otherwise non parametric alternative Kruskal-Wallis (H) ANOVA by ranks was used. The one-way ANOVA form of the model was

$$Y_{ij} = \alpha_{.j} + \varepsilon_{ij}$$

where;

- $Y_{ij}$ was a matrix of observations in which each column represents a different group.
- $\alpha_{.j}$ was a matrix whose columns are the group means (the "dot j" notation means that α applies to all rows of the $j^{th}$ column i.e. the value $\alpha_{ij}$ was the same for all i).
- $\varepsilon_{ij}$ was a matrix of random disturbances.

The model posits that the columns of Y are a constant plus a random disturbance. We want to know if the constants are all the same.

## Tukey Multiple Comparison Test

After performing ANOVA, the Tukey HSD (honestly significant difference) post hoc test was generally used to calculate differences between group means as

were,

$$q = \frac{X_1 - X_2}{SE}$$

$$SE = \sqrt{\frac{S^2}{2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

$S^2$ was the error mean square from the analyses of variance and $n_1$ and $n_2$ are the number of data in groups 1 and 2 respectively.

**Statistical significance**

**Level of significance** "*P*" was the probability that signifies the level of significance. The mentioned p in the text indicates the following:

$P > 0.05$ -Not significant (ns)

$P < 0.05$- Just significant (*)

$P < 0.01$- Moderate significant (**)

$P < 0.001$- Highly significant (***)

# DISCUSSION

# DISCUSSION

The present *in-vitro* study was conducted in the Department of Conservative Dentistry and Endodontics, Babu Banarasi Das College of Dental Sciences, and Central Institute of Plastic Engineering Technology, Lucknow.

30 test samples were divided into 5 groups and were obturated using different techniques. The fracture resistance (measured in Newtons) of these five groups were assessed and compared with each other. The results obtained from this study showed, that Gutta Core (group 5) had the highest fracture resistance, succeeded by Gutta Flow-2 (group 4), Lateral Condensation (group 3), was found to have better fracture resistance than continuous wave technique (group 2), and, finally, the least fracture resistance was exhibited by the control group (group 1).

Although, between Group II and Group III, the result was found to be statistically the same or insignificant.

The limited literature on the fracture resistance of root canal obturating materials in preventing vertical root fracture necessitated the need to conduct the present study hence this study was undertaken to evaluate and compare the fracture resistance of endodontically treated teeth obturated with different obturating techniques.

Freshly extracted mandibular premolars selected for this study. Since they are situated in a dental arch transition zone, where they are the best candidates to assess fracture resistance under load since they are more vulnerable to compressive and shear stresses.[60] To prevent desiccation, these teeth were then stored in normal saline.

The superior results were obtained by the Gutta core carrier-based obturator; Its outer skin is made of flowable gutta-percha, while its inner carrier is made of either metal, polymer, or an all-gutta-percha formulation. This system comprises a size verifier, a carrier-based obturator, a heating oven, and an AH Plus root canal sealer, which is a sealer made of epoxy resin that, according to reports, somewhat expands after setting [61] and has the exceptional capacity to penetrate the dentinal tubule.[62]

Gutta core was used in a similar study done by Anantula K *et al* who concluded that fracture resistance results showed GuttaCore to be superior to all other groups used in this study including the Guttaflow2 [27]. In addition to permitting the flow of sealer into the isthmuses, lateral canals, and canal aberrations, this thermoplasticized GuttaCore also permitted the creation of a tenaciously adhering coating on the root canal walls. The advantage of this system of being simple to use along with achieving an excellent 3D seal, showing significantly fewer voids.[62]

Further, another study conducted by Guido Migliau *et al*, the comparative evaluation of the quality of the root canal obturation obtained with two different techniques, thermoplastic gutta-percha introduced through a thermafil GuttaCore and free flow gutta-percha GuttaFlow2 was carried out. GuttaCore showed a better filling in the apical third of the canal with 5 % of voids, and concluded that due to the rigidity of the carrier, in the most apical areas of the canals, GuttaCore can penetrate more easily, improving fracture resistance.[63]

Goyal K *et al* undertook a study in which samples were obturated using four different methods of obturation GuttaFlow 2, continuous wave condensation, Lateral compaction, and GuttaCore and concluded that the thermafil Gutta Core was found to have the highest fracture resistance as compared to other materials. [53] he stated that the thermafil core-carrier Guttacore approach utilized for root canal obturation yields the highest gutta-percha content in the filled canal space, which could explain the better results obtained with GuttaCore.

These results are in harmony with a study conducted by Gencoglu *et* al who also concluded that when adopting the core-carrier technique for root canal obturation, as suggested in the present study. The maximum gutta-percha content within the filled canal space may be the reason for the improved outcomes obtained with GuttaCore. [64]

De-Deus G *et al* conducted a laboratory analysis of a gutta-percha filled area obtained using thermafil, system B and lateral condensation where the greatest fracture resistance was observed with when GuttaCore was used in combination with an epoxy resin-based sealer AH plus as the Core-carrier. Highest gutta-percha content was found within the filled canal space when using the core-carrier technique for obturation along with Gutta core [65].

Few other studies concluded that Gutta Core gave better fracture resistance when compared with other obturating techniques.[51] It has been stated the reason for this is the thermafil cone plastic carrier modifies the stresses applied to the root, stabilized the root canal shape, and strengthened fracture resistance. In addition, the heat-softened gutta-percha carrier's ease of insertion has been demonstrated to be a contributing factor in its superiority over other materials.

However, according to Shrija Paradkar *et al*, the study revealed that while GuttaFlow2 was not as effective as Guttacore, it was still better than the other groups employed. Specifically, teeth that were obturated using the GuttaFlow2 method had a higher fracture resistance when compared to those that used the Continuous-wave condensation and lateral condensation approaches.[53]

This result was similar to another study done by Punjabi *et al* where he found that GuttaFlow2 was superior to the continuous wave technique and lateral condensation technique used for obturation. Nonetheless, its fracture resistance values were discovered to be higher than both the other groups[44]. The reason that may be attributed to this is that guttaFlow2 obturating material has a homogenous structure with gutta-percha particles and a good sealing ability.

GuttaFlow 2 is a silicone-based product that forms a homogeneous obturation by closely adhering to the dentinal walls. This can be a result of the guttaFlow2 obturating material with a robust sealing capacity and uniform structure made of gutta-percha particles. It seems to have excellent adherence to gutta-percha cones and fill the dentinal tubules.[66] Gutta flow2 is the first sealer and gutta-percha combination that can be employed without a solid master cone as an obturating paste and sealer that is flowable at room temperature.[23] This is the reason why Gutta flow2 was chosen in our study as a comparable technique against Gutta core.

Few other studies conducted by Weis M.V; Zhong, X were not in agreement with our study, they stated that, GuttaCore and Guttaflow2, demonstrated superior filling characteristics, maximizing their benefits, and minimizing their drawbacks. They said that an intersection of the two systems may also be considered.; contradicting our inferior results of Guttaflow2 obturating material.[67]

The most used technique for obturation is lateral compaction.[29] The lateral condensation obturating method has demonstrated superior result to the continuous wave technique which may be credited to the rapid cooling of the material during the filling of thermafil gutta-percha resulting in poor compaction.[68]

The present study resulted in, the fracture resistance of teeth obturated with the Lateral condensation technique which were comparable with the Continuous-wave condensation technique. The findings are in agreement with the study done by Punjabi *et al* who found the vertical fracture resistance following the lateral compaction technique to be inferior to GuttaFlow 2, and GuttaCore.[44]

In a similar study conducted by Saw and Messer *et al,*and another study done by Huseyin S *et al* the fracture resistance of Lateral condensation and Gutta flow2 were not found to be statistically significant because these techniques did not increase the fracture resistance of the teeth.[19]

In the present study among the obturated groups, the fracture resistance was found to be lowest with the Continuous-wave condensation technique when compared to lateral compaction the reason for which could be stated that due to the material cooling quickly, resulting in poorer compaction resulted. According to Padda BK *et al* [68] Unnecessary stresses are created in the root dentin by the force produced by the continuous wave condensation technique and the heat transmitted by the heated plugger during obturation, which negatively affects fracture resistance.[19]

The fracture resistance of the group having lateral condensation and continuous wave technique as obturating techniques were not statistically significant because the use of a spreader and plugger during obturation caused additional forces to be created in the root canal system, thus leading to a decrease in the resistance to fracture in the root canal.[61]

The statistical mean difference between group gutta core and continuous wave technique was highly significant. This could be because the down pack backfill technique causes the gutta-percha to shrink and the root dentin to expand, which may reduce the fracture resistance, whereas the thermafil technique causes the gutta-percha to flow into lateral canals and fill the space between the root canal wall, thus increasing the fracture resistance of the root canal walls. As rightly stated by Jindal D *et al* in their study that the highest overall percentage of obturated volume was obtained with thermafil.[48]

In the present study, the mean difference of fracture resistance in group I (positive control group) was lower than all other groups. Since a weakening effect on the root is unavoidable during the instrumentation phase when the dentin is removed. ShemeshH *et al* also showed in their study that improper root canal preparation results in defectsin the dentin, such as fractures, crack lines, and incomplete cracks, but leaves the roots unprepared, weakening the tooth and decreasing its resistance to fracture, during mastication.[69]

There has been no statistical significant difference between the control group and the cold lateral condensation technique. Sandikci T *et al* further demonstrated, in contrast to our study, that the root canal shaping process reduces the teeth's resistance to fracture, whereas obturation carried out using lateral condensation done with AH plus sealer, gutta-percha, and the thermafil technique was found to be more successful.[34]

The materials testing machine, also called a universal tester, and the materials test frame is used to test the tensile and compressive strengths of the material; This is the reason, this machine was selected for our study. The teeth used in this study were put through a fracture resistance test following obturation in the machine.[34]

Utilizing a Universal Testing Machine, the fracture resistance of the obturated roots were assessed. The force was applied vertically and parallel to the long axis of the roots, primarily causing a splitting stress above the access opening and the results were evaluated.[64]

# CONCLUSION

# CONCLUSION

The study was limited by the fact that the force applied to the tooth during obturation was not uniform across the various obturation techniques. Moreover, the method used for testing fracture load was static load in the study, whereas, in the intra-oralcondition, a dynamic load is applicable it may be concluded that the control group showed significantly lower resistance to vertical root fracture when compared to the other obturated groups in this study.

Among the obturated groups, the highest resistance to vertical tooth fracture was observed with GuttaCore followed by GuttaFlow 2, lateral compaction, and continuous-wave condensation.

Hence, GuttaCore presented highly promising results that can be considered as the obturating material of choice for the future. Still, long-term clinical trials should be conducted to determine the superiority of the material as the root canal obturating material. The superior results obtained with GuttaCore may be attributed to the highest gutta-percha content within the filled canal space when using the core-carrier technique for obturation of the root canals as demonstrated in studies. [67]

Null hypothesis:

The tooth filled with a Gutta Core obturator demonstrates the highest fracture resistance.

According to our study:
The null hypothesis was validated.

# REFERENCES

# REFERENCES


1. Bender IB, Freedland JB. Adult root fracture. J Am Dent Assoc. 1983 Sep;107(3):413–9.
2. Fuss Z, Lustig J, Tamse A. Prevalence of vertical root fractures in extracted endodontically treated teeth. Int Endod J. 1999 Aug;32(4):283–6.
3. Caplan DJ, Weintraub JA. Factors related to loss of root canal-filled teeth. J Public Health Dent. 1997;57(1):31–9.
4. Tang W, Wu Y, Smales RJ. Identifying and reducing risks for potential fractures in endodontically treated teeth. J Endod. 2010 Apr; 36 (4):609–17. 5.
5. Sedgley CM, Messer HH. Are endodontically-treated teeth more brittle? J Endod. 1992 Jul;18(7):332–5.
6. Willsiams C, Loushine RJ, Weller RN, Pashley DH, Tay FR. A comparison of cohesive strength and stiffness of Resilon and gutta-percha. J Endod. 2006 Jun;32(6):553–5.
7. Ribeiro FC, Souza-Gabriel AE, Marchesan MA, Alfredo E, Silva-Sousa YTC, Sousa-Neto MD. Influence of different endodontic filling materials on root fracture susceptibility. J Dent. 2008 Jan;36(1):69–73.
8. Teixeira FB, Teixeira EC, Thompson JY, Trope M. Fracture resistance of roots endodontically treated with a new resilion filling material. J Am Dent Assoc 2004;135(5):646-52.
9. Buchanan LS. The continuous wave of obturation technique: “Centered” condensation of warm gutta percha in 12 seconds. Dent Today 1996;15:60-2, 64-7.
10. Shakya VK, Gupta P, TikkuAP, PathakAK, ChandraA, Yadav RK, et al. An in vitro evaluation of antimicrobial efficacy and flow characteristics for AH plus, MTA fillapex, CRCS, and gutta flow 2 root canal sealer. J Clin Diagn Res 2016;10:ZC104-8.
11. Gutmann JL. The future of root canal obturation. Dent Today 2011;30:128, 130-1.

12. Cailleteau, J.G.; Mullaney, T.P. Prevalence of Teaching Apical Patency and Various Instrumentation and Obturation Techniques in United States Dental Schools. J. Endod. 1997, 23, 394–396.
13. Levitan, M.E.; Himel, V.T.; Luckey, J.B. The Effect of Insertion Rates on Fill Length and Adaptation of a Thermoplasticized Gutta-Percha Technique. J. Endod. 2003, 29, 505–508.
14. Cueva-Goig, R.; Forner-Navarro, L.; Llena-Puy, M.C. Microscopic Assessment of the Sealing Ability of Three Endodontic Filling Techniques. J. Clin. Exp. Dent. 2016, 8, e27–e31.
15. Leduc, J.; Fishelberg, G. Endodontic Obturation: A Review. Gen. Dent. 2003, 51, 232–233.
16. Budd, C.S.; Weller, R.N.; Kulild, J.C. A Comparison of Thermoplasticized Injectable Gutta-Percha Obturation Techniques. J. Endod. 1991, 17, 260–264
17. Trope M, Maltz DO, Tronstad L. Resistance to fracture of restored endodontically treated teeth. Endod Dent Traumatol. 1985 Jun;1(3):108-11. doi: 10.1111/j.1600-9657.1985.tb00571.x. PMID: 3893998.
18. Onnink, P A et al. "An in vitro comparison of incomplete root fractures associated with three obturation techniques." *Journal of Endodontics* 20 1 (1994): 32-7.
19. Saw LH, Messer HH, "Root strains associated with different obturation techniques", J Endod, vol. 21, pp. 314-320, 1995.
20. Lertchirakarn V, Timyam A, Messer HH. Effects of root canal sealers on vertical root fracture resistance of endodontically treated teeth. J Endod. 2002 Mar;28(3):217-9. doi: 10.1097/00004770-200203000-00018. PMID: 12017185.
21. De-Deus G, Gurgel-Filho ED, Magalhães KM, Coutinho-Filho T. A laboratory analysis of gutta-percha-filled area obtained using thermafil, system B and lateral condensation. Int Endo
22. Hammad M, Qualtrough A, Silikas N. Effect of new obturating materials on vertical root fracture resistance of endodontically treated teeth. J Endod. 2007 Jun;33(6):732-6. doi: 10.1016/j.joen.2007.02.004. Epub 2007 Apr 16. PMID: 17509416.

23. Wadhwani, K. K and Sarita Rana Gurung. "Evaluation of root canal sealers on the fracture resistance of root canal treated teeth - An in vitro study." *Endodontology* (2010): n.
24. Asokan S, Sooriaprakas C, Raghu V, Bairavi R. Volumetric analysis of root canal fillings in primary teeth using spiral computed tomography: an in vitro study. Journal of Dentistry for Children (Chicago, Ill.). 2012 May-Aug;79(2):46-48. PMID: 22828756.
25. Farea M, Masudi S, Wan Bakar WZ. Apical microleakage evaluation of system B compared with cold lateral technique: In vitro study. Aust Endod J. 2010 Aug;36(2):48-53. doi: 10.1111/j.1747-4477.2009.00187.x. PMID: 20666748.
26. Phukan, Anuve Hrishi, et al. "The effect of different root canal sealers on the fracture resistance of endodontically treated teeth-in vitro study." *Dental Research Journal* 14 (2017): 382 - 388.
27. Anantula K, Ganta AK. Evaluation and comparison of sealing ability of three different obturation techniques – Lateral condensation, obtura II, and guttaFlow: An in vitro study. J Conserv Dent 2011;14:57-61.
28. Ghoneim AG, Lutfy RA, Sabet NE, Fayyad DM. Resistance to fracture of roots obturated with novel canal-filling systems. J Endod. 2011 Nov;37(11):1590-2. doi: 10.1016/j.joen.2011.08.008. Epub 2011 Sep 28. PMID: 22000470.
29. A Comparative Evaluation of the Fracture Resistance of Endodontically Treated Teeth Using Two Obturating Systems - An In Vitro Study Suman Makam, 1 Shashikala K2IJCD • OCTOBER, 2011 • 2(5) © 2011 Int. Journal of Contemporary Dentistry

30. The effect of different sealer placement techniques on sealing ability: An in vitro study. Journal of Conservative Dentistry 15(3):257-60
31. Sağsen B, Ustün Y, Pala K, Demırbuğa S. Resistance to fracture of roots filled with different sealers. Dent Mater J. 2012;31(4):528-32. PMID: 22864204.
32. PMCID: PMC3476110, PMID: 22143717 Fracture resistance of roots filled with three different obturation techniques Hüseyin S. Topçuoğlu,[1] Hakan Arslan,[1] 2012
33. *Shashidhar J: An in vitro comparison of fracture resistance in endodontically treated teeth. J Indian Soc Pedod Prev Dent 2014;32:53- 7.*

34. Davis, Kaptan RF, "Comparative evaluation of the fracture resistances of endodontically treated teeth filled using five different root canal filling systems", Niger J Clin Pract, GROUP VVol. 17, pp. 667-672, 2014.
35. A Comparative in vitro Evaluation of Vertical Root Fracture Resistance of Endodontically Treated Teeth using Different Obturating Materials. World J Dent 2014;5(2):113-117.
36. Fracture Resistance of Roots After Canal Preparation by Two Methods and Obturated by Different Techniques" Al-Rafidain Dent J, vol. 14, pp. 212-219, 2014.
37. Endodontically Treated Teeth Filled with Gutta-Percha and Resilon Obturating Material: An In Vitro Study. J Int Oral Health. 2015;7(Suppl 2):21-5. PMID: 26668476; PMCID: PMC4672844.
38. Comparative Evaluation of Fracture Resistance of endodontically Treated Teeth Obturated with Resin Based Adhesive Sealers with Conventional Obturation Technique: An In vitro Study. J Int Oral Health. 2015 Feb;7(2):6-12. PMID: 25859099; PMCID: PMC4377154.
39. Evaluation of the effect of different root canal obturation techniques using two root canal sealers on the fracture resistance of endodontically treated roots", Microsc Res Tech, vol. 78, pp. 404-407, 2015

40. Hegde V, Arora S. Fracture resistance of roots obturated with novel hydrophilic obturation systems. J Conserv Dent. 2015 May-Jun;18(3):261-4. doi: 10.4103/0972-0707.154047. PMID: 26069417; PMCID: PMC4450537.
41. Effect of Different Instrumentation Techniques on Vertical Root Fracture Resistance of Endodontically Treated Teeth", J Dent (Shiraz), vol. 16, pp. 50-55, 2015.
42. Fracture resistance of roots obturated with a novel calcium silicate-based endodontic sealer (BioRoot RCS) J Adhes Sci Technol. 2016;30:2420–8
43. Comparative evaluation of fracture resistance of teeth obturated using three different systems – AH plus/Gutta-percha, Resilon/Realseal self-etch, and Endofill/Gutta-percha: An in vitro study. J Oral Res Rev 2016;8:1-5.

44. Comparative evaluation of fracture resistance of root canals obturated with four different obturating systems. JCD, 01 Nov 2017, 20(6):445-450
45. Comparative evaluation of fracture resistance of endodontically treated teeth obturated with Pozzolan-based MTA sealer and epoxy resin-based sealer: An in vitro study." *World Journal of Dentistry* 8 (2017): 37-40.
46. Comparative evaluation of fracture resistance of endodontically treated teeth with epoxy resin-based sealers AH plus and Mineral Trioxide Aggregate Fillapex: An *in vitro* study Indian J Dent Sci. 2017;9:8–11
47. Fracture resistance of roots after application of different sealers Iran Endod J. 2017;12:50–4
48. Volumetric analysis of root filling with cold lateral compaction, Obtura II, Thermafil, and Calamus using spiral computerized tomography: An In vitro Study, Indian J Dent Res, vol. 28, pp. 175-180, 2017
49. An in vitro comparative evaluation of the depth of tubular penetration of three resin-based canal sealers jcd 2012/15/1/18/92600
50. Fracture resistance of simulated incomplete vertical fractured teeth treated with different bioceramic-based root canal sealers Int J Appl Dent Sci. 2018;4:25–30
51. An in-vitro evaluation and comparison of the fracture resistance of teeth prepared by self-adjusting file, and obturated with three different obturation techniques", Int J Adv Res, vol. 7, pp. 691-714,2019.
52. Investigating the Fracture Resistance and Sealing Ability of Teeth Obturated with a Novel Carrier-Based Obturation System: Guttacore as Compared with Thermafil Obturator A Comparative In-Vitro Study". Acta Scientific Dental Sciences 3.2 (2019): 68-72
53. A comparative evaluation of fracture resistance of endodontically treated teeth obturated with four different methods of obturation: An in vitro study Endodontology 2020, IP: 140.138.178.101
54. Comparison of Two Root Canal Filling Techniques: Obturation with Guttacore Carrier Based System and Obturation with Guttaflow2 Fluid Gutta-Percha 10.3390/dj10040071

55. Complete Obturation - Cold Lateral Condensation vs. Thermoplastic Techniques: A Systematic Review of Micro-CT Studies Shilpa Bhandi 1, Mohammed Mashyakhy 1, Materials 2021, 14, 4013.
56. Assessment of Fracture Resistances of Endodontically Treated Teeth Filled with Different Root Canal Filling Systems. J Pharm Bioallied Sci. 2021 Jun;13(Suppl 1): S109-S111. doi 10.4103/jpbs.JPBS_573_20. Epub 2021 Jun 5. PMID: 34447055; PMCID: PMC8375822.
57. Comparative evaluation of root fracture resistance using different root canal sealers. International Journal of Health Sciences, 6(S6), 5284 5295.https://doi.org/10.53730/ijhs.v6nS6.10650
58. Comparative evaluation of fracture resistance of root canal treated teeth obturated with different obturating systems: an in vitro study, DOI: 10.47750/pnr.2022.13.S01.179
59. Comparison of the Fracture Resistance of Root-Canal-Treated Premolars Obturated With Dissimilar Materials: An In Vitro Study. Cureus 15(11): e49426. DOI 10.7759/cureus.49426
60. Versiani MA, Carvalho JR Jr., Padilha MI, Lacey S, Pascon EA, Sousa-Neto MD. A comparative study of physicochemical properties of AH plus and epiphany root canal sealants. Int Endod J 2006;39:464-71.
61. Chadha R, Taneja S, Kumar M, Sharma M. An in vitro comparative evaluation of fracture resistance of endodontically treated teeth obturated with different materials. Contemp Clin Dent 2010;1:70-2.
62. Li GH, Niu LN, Selem LC, Eid AA, Bergeron BE, Chen JH, et al. Quality of obturation achieved by an endodontic core-carrier system with crosslinked gutta-percha carrier in single-rooted canals. J Dent 2014;42:1124-34.
63. Comparison of Two Root Canal Filling Techniques: Obturation with Guttacore Carrier Based System and Obturation with Guttaflow2 Fluid Gutta-Percha. Dent J (Basel). 2022 Apr goyal doi: 10.3390/dj10040071. PMID: 35448065; PMCID: PMC9032128.
64. Gençoğlu N. Comparison of 6 different gutta-percha techniques(part II): Thermafil, JS quick-fill, soft core, microseal, system B, and lateral condensation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:91-5

65. De-Deus, G.; Lack of Correlation between Sealer Penetration into Dentinal Tubules and Sealability in Nonbonded Root Fillings. Int. Endod. J. 2012, 45, 642–651.
66. Vujasković M, Teodorović N. Analysis of sealing ability of root canal sealers using scanning electronic microscopy technique. Srp Arh Celok Lek 2010;138:694-8
67. Zhong, X.; Shen, Y.; Ma, J.; Chen, W.; Haapasalo, M. Quality of Root Filling after Obturation with Gutta-percha and 3 Different Sealers of Minimally Instrumented Root Canals of the Maxillary First Molar. J. Endod. 2019, 45, 1030–1035.
68. Bansal A, Padda BK. An in vitro comparison of the apical seal produced by techniques in oval canals. Dent J Adv Stud 2015;3:39-46.
69. Shemesh H, Bier CA, Wu MK, Tanomaru-Filho M, Wesselink PR, “The effects of canal preparation and filling on the incidence of dentinal defects”, Int Endod J, vol. 42, pp. 208-213, 2009

# ANNEXURES

# BABU BANARASI DAS UNIVERSITY
## BBD COLLEGE OF DENTAL SCIENCES, LUCKNOW

BBD UNIVERSITY

BBDCODS/IEC/09/2022 Dated: 16th September, 2022

**Communication of the Decision of the Xth Institutional Ethics Sub-Committee Meeting**

**IEC Code: 05**

**Title of the Project:** A Comparative Evaluation Of Fracture Resistance Of Endodontically Treated Teeth Obturated With Different Obturating Techniques: In Vitro Study.

**Principal Investigator:** Dr Shivani Agarwal **Department:** Conservative Dentistry and Endodontics

**Name and Address of the Institution:** BBD College of Dental Sciences Lucknow.

**Type of Submission:** New, MDS Project Protocol

Dear Dr Shivani Agarwal,

The Institutional Ethics Sub-Committee meeting comprising following members was held on 15th September, 2022.

| | | |
|---|---|---|
| 1. | Dr. Lakshmi Bala<br>Member Secretary | Prof. and Head, Department of Biochemistry |
| 2. | Dr. Praveen Singh Samant<br>Member | Prof. & Head, Department of Conservative Dentistry & Endodontics |
| 3. | Dr. Jiji George<br>Member | Prof. & Head, Department of Oral Pathology & Microbilogy |
| 4. | Dr. Amrit Tandan<br>Member | Professor, Department of Prosthodontics and Crown & Bridge |
| 5. | Dr. Rana Pratap Maurya<br>Member | Reader, Department of Orthodontics & Dentofacial Orthopaedics |

The submitted documents of the current MDS Project Protocol is exempted for review in the meeting.

**Decision: The MDS Protocol is exempted for review by the Institutional Ethics Sub-Committee.**

Forwarded by:

16/9

**Prof. Dr. Puneet Ahuja**
Principal
BBD College of Dental Sciences
BBD University, Lucknow

PRINCIPAL
Babu Banarasi Das College of Dental Sciences
(Babu Banarasi Das University)
BBD City, Faizabad Road, Lucknow-226028

Lakshmi Bala
16/09/22

**Dr. Lakshmi Bala**
Member-Secretary
Institutional Ethics Sub-Committee (IEC)
BBD College of Dental Sciences
BBD University, Lucknow

Member-Secretary
Institutional Ethic Committee
BBD College of Dental Sciences
BBD University
Faizabad Road, Lucknow-226028

# BABU BANARASI DAS UNIVERSITY

## BBD COLLEGE OF DENTAL SCIENCES, LUCKNOW

BBD UNIVERSITY

## INSTITUTIONAL RESEARCH COMMITTEE APPROVAL

The project titled **"A Comparative Evaluation Of Fracture Resistance Of Endodontically Treated Teeth Obturated With Different Obturating Techniques: In Vitro Study"** submitted by **Dr Shivani Agarwal** Postgraduate student in the **Department of Conservative Dentistry and Endodontics** for the Thesis Dissertation as part of MDS Curriculum for the academic year 2021-2024 with the accompanying proforma was reviewed by the Institutional Research Committee in its meeting held on **14th September, 2022** at BBDCODS.

The Committee has granted approval on the scientific content of the project. The proposal may now be reviewed by the Institutional Ethics Committee for granting ethical approval.

**Prof. Dr. Puneet Ahuja**
Chairperson

**Dr. Mona Sharma**
Co-Chairperson

केंद्रीय पेट्रोरसायन अभियांत्रिकी एवं प्रौद्योगिकी संस्थान (सिपेटः आई.पी.टी.)
(पूर्व में केंद्रीय प्लास्टिक इंजीनियरिंग एवं तकनीकी संस्थान)
रसायन एवं पेट्रोरसायन विभाग,
रसायन एवं उर्वरक मंत्रालय, भारत सरकार
बी-२७, अमौसी इण्डस्ट्रियल एरिया, लखनऊ-२२६ ००८
फोन : ७६०७१९४०१४, ८७५६९९२८८२
E-mail : testing-lucknow@cipet.gov.in, lucknow@cipet.gov.in
www.cipet.gov.in

सिपेट CIPET

Central Institute of Petrochemicals Engineering & Technology (CIPET: IPT)
(Formerly Central Institute of Plastics Engineering & Technology)
Department of Chemicals & Petrochemicals
Ministry of Chemicals & Fertilizers, Govt. of India
B-27, Amausi Industrial Area, Lucknow-226 008
Phone : 7607194014, 8756992882
E-mail : testing-lucknow@cipet.gov.in, lucknow@cipet.gov.in
www.cipet.gov.in

Series : G

PLASTIC TESTING CENTRE
TEST CERTIFICATE

S.No. 2904
Date: 24.01.2024

**Issued to:** **Dr. Shivani Agarwal**
**PG Student (MDS)**
**Conservative Dentistry & Endodontics Department,**
**BBD University, BBD City,**
**Faizabad Road, Lucknow (U.P.)- 226028**

**Your Ref.No. & Date : BBDCODS/Gen._Int./2024/07** **dated : 03.01.2024**

**TEST REPORT AS PER RELEVENT IS/ASTM STANDARD FOLLOWED**

**TEST REPORT NO: 3323(I-V)**

**PART – A :- PARTICULARS OF SAMPLE SUBMITTED**

| | | | |
|---|---|---|---|
| a) | Name of the sample | : | **Dental Sample** as stated by the party |
| b) | Grade / Variety / type / size / class | : | -- |
| c) | Declared value, if any & | : | -- |
| d) | Code No. | : | -- |
| e) | Batch No. & Date of Manufacture | : | -- |
| f) | Quantity | : | 30 Nos (6 Nos of each 5 Groups) |
| g) | Mode of Packing | : | Packed in plastic container |
| h) | Sealed or not | : | Not sealed |
| i) | Date of receipt of sample | : | 08.01.2024 |
| j) | Date of starting of the testing | : | 10.01.2024 |
| k) | Date of completion of testing | : | 24.01.2024 |
| l) | Any other information | : | Payment received on 08.01.2024 |

**PART - B :- SUPPLEMENTARY INFORMATIONS**

| | | | |
|---|---|---|---|
| a) | Reference to sampling procedure | : | Not Applicable. |
| b) | Supporting document for the measurement taken & result derived | : | Not Applicable. |
| c) | Deviation from the test method as prescribed in relevant work instructions, if any | : | Not Applicable. |

DrillBit

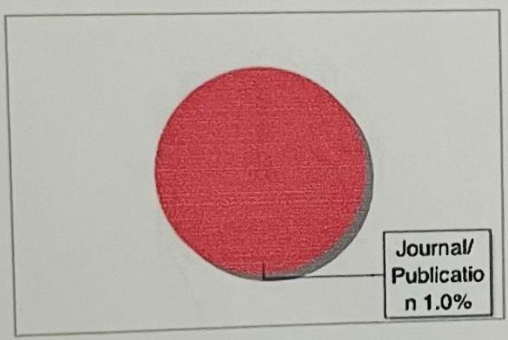
The Report is Generated by DrillBit Plagiarism Detection Software

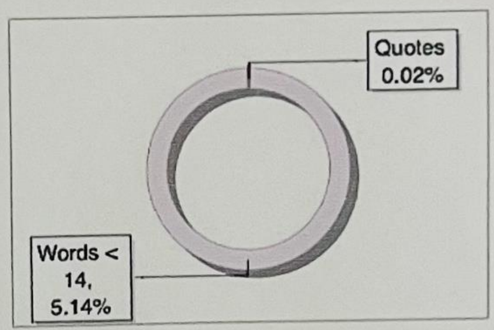
***Submission Information***

| | |
|---|---|
| Author Name | SHIVANI AGARWAL |
| Title | "A COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH OBTURATED WITH DIFFERENT OBTURATING TECHNIQUES: AN IN VITRO STUDY" |
| Paper/Submission ID | 1419683 |
| Submitted by | amarpal.singh056@bbdu.ac.in |
| Submission Date | 2024-02-10 14:27:37 |
| Total Pages | 46 |
| Document type | Dissertation |

***Result Information***

Similarity **1 %**




***Exclude Information***

| | |
|---|---|
| Quotes | Excluded |
| References/Bibliography | Excluded |
| Sources: Less than 14 Words % | Excluded |
| Excluded Source | 0 % |
| Excluded Phrases | Not Excluded |

***Database Selection***

| | |
|---|---|
| Language | English |
| Student Papers | Yes |
| Journals & publishers | Yes |
| Internet or Web | Yes |
| Institution Repository | Yes |

A Unique QR Code use to View Download Share Pdf File