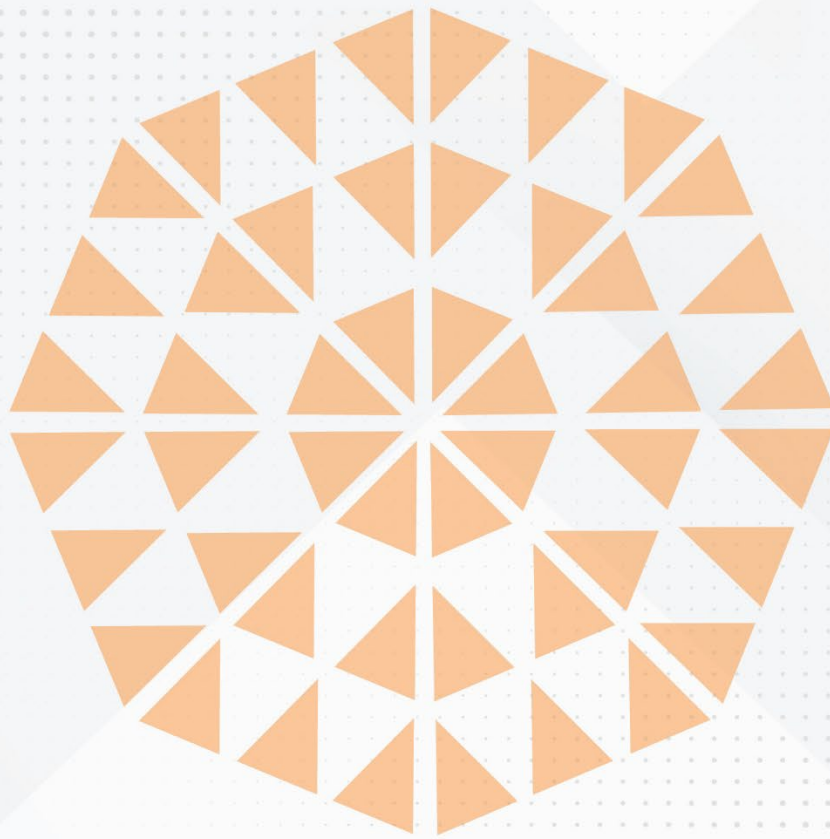


DENTAL BITES

Volume 13 issue 1 | January - March 2026

RESTORATIVE AND RECONSTRUCTIVE DENTISTRY



a quarterly publication of



KMCT.org
GROUP OF INSTITUTIONS

KMCT
DENTAL COLLEGE



INNOVATION AND
ENTREPRENEURSHIP
DEVELOPMENT CENTRE



KMCT Medical College Campus,
Mukkom, Kozhikode - 673602

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www.kmctdentalcollege.org dental@kmct.edu.in

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Editorial

Dear Readers,

At KMCT Dental College, we believe that education should not only shape competent professionals but also responsible citizens who care for the environment. The adoption of a Green Protocol on our campus reflects this shared commitment toward sustainability and ecological responsibility.

A green campus is not built overnight. It evolves through consistent efforts in reducing environmental impact and promoting eco-friendly practices. Our institution has taken meaningful steps in this direction by encouraging the use of conventional energy responsibly, reducing unnecessary electricity consumption, and promoting awareness about energy conservation among students and staff. Small changes in daily habits can make a significant difference.

Waste management continues to be one of the major pillars of our green initiative. Proper segregation of waste, scientific disposal methods, and minimizing waste generation remain our priorities. Along with this, we are steadily moving toward a paper-less and plastic-free campus, encouraging digital communication and responsible material usage wherever possible.

Our campus biodiversity initiatives are equally encouraging. The plantation of fruit trees, development of a butterfly park, and continuous landscaping efforts are helping create a healthier and more vibrant ecosystem within our institution. These steps not only improve environmental quality but also provide students with a living example of sustainable practices.

Another important initiative is the regulation of vehicle parking away from academic zones, which helps reduce pollution within the core campus and promotes a cleaner learning environment for everyone.

To further strengthen these efforts, our Green Audit scheduled in the third week of February will serve as an important milestone. It will help us assess our present practices, identify areas for improvement, and guide us toward achieving higher standards of environmental responsibility.

Let us work together as a campus community to make sustainability not just a policy, but a culture. A greener campus today ensures a healthier tomorrow for all.

With warm regards,
Dr. Manoj Kumar K.P
Principal



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Original article

COMPARATIVE EVALUATION OF PUSH-OUT BOND STRENGTH OF MINERAL TRIOXIDE AGGREGATE CEMENT, MTA PUTTY AND BIODENTINE- RETROGRADE FILLING MATERIALS IN TEETH WITH ROOT APICES RESECTED AT 90°- AN IN-VITRO STUDY.

*Dr. Archana A, **Dr. Elsy P Simon, ***Dr Khadeeja M, ***Dr Nejiya P K,
*** Dr Kavya Belaram

Abstract:

Background: An ideal retrograde material should be able to adhere to the dentin walls of the root-end preparation. The material – dentin interface must be kept intact in static situations and also during function. Material properties and the surface of root-end preparation strongly affect the bond strength of retrograde filling material.

Aim: The aim of the study is to compare the push-out bond strength of mineral trioxide aggregate cement (MTA Angelus), MTA putty (Maarcidental) and biodentine (septodont)-retrograde filling materials in teeth with root apices resected at 90 degrees.

Materials and Methods: An in vitro study was conducted on 54 extracted human teeth, decoronated to standard root length of 16 mm. Instrumentation of the canals was done with NiTi rotary files upto 6% 30 size files. Canals irrigated with 3% sodium hypochlorite, 17% EDTA and distilled water. Canals then dried and obturated with gutta-percha and Zinc oxide eugenol sealer. After 1 week of storage apical 3mm root resection will be performed with a diamond disc under continual distilled water irrigation at a 90° angle to the tooth's long axis with an ultrasonic surgical tip a 3 mm deep root-end cavity will be made and specimens will be divided randomly into groups. • Group I: The retro-cavities were filled with MTA Angelus • Group II: The retro-cavities were filled MTA Putty. • Group III: The retro-cavities were filled with Biodentine

Results: Biodentine showed the highest mean push-out bond strength among the three retrograde filling materials tested. MTA Angelus demonstrated intermediate bond strength, higher than MTA Putty but lower than Biodentine. MTA Putty had the lowest mean push-out bond strength of the three groups:

Conclusion:

Within the limits of this study, it can be concluded that Biodentine may be considered the most



favorable retrograde filling material when superior bond strength is desired. MTA Angelus demonstrated intermediate bond strength, higher than MTA Putty but lower than Biodentine.

Key words: Retrograde filling, Biodentine, MTA, MTA PUTTY, Push out bond strength

Corresponding author: Dr Archana A (archanarajan987@gmail.com)

* Post graduate student, ** Professor and Head, ***Assistant Professor, Department of Conservative Dentistry and Endodontics, KMCT Dental College, Kozhikode, Kerala.

Introduction

Apical surgery is advised when traditional root canal treatment fails. This technique necessitates resection of the root end, which removes the infected area of the root following which a root end preparation is done and sealed with a suitable root end filling material. An ideal retrograde material should be able to adhere to the dentin walls of the root-end preparation.¹

The push-out bond strength test conventionally assesses the material's resistance to displacement by applying a perpendicular force to the material interface. This test is employed to gauge the interfacial shear strength between various cement-like materials (such as root-end filling, perforation repair material, obturation material, and root canal sealer) and the adjacent tooth structure.²

This test provides information about the adhesive properties of the material being tested by helping the dental practitioner understand how well the material can bind to the tooth structure.¹ The primary focus of

the push-out test is to evaluate the resistance of the tested material to dislodgement. Greater push-out strength implies stronger adhesion between the tested material and the tooth surface. High push-out strength is desirable in clinical applications as it suggests better stability and longevity of dental restoration.

White mineral trioxide aggregate (MTA) is considered the gold standard for the single-visit apexification technique. However, this material presents certain shortcomings including a long set-up time and handling difficulties.³ Recently, a new type of MTA known as MTA PUTTY has been proposed. Another commercially available bioactive material is Biodentine (Septodont, Saint-Maur-des-Fossés, France), which also offers color stability and is easier to apply in several clinical procedures including the management of immature necrotic teeth.

The material – dentin interface must be kept intact in static situations and also during function. During apexification procedures, the apical plug must be able to remain



bonded to the root canal walls without displacement while maintaining the dentin/material interfacial integrity either by frictional retention or adhesion. Material properties and the surface of root-end preparation strongly affect the bond strength of retrograde filling material.

Therefore, the aim of the present research is to evaluation the “push-out bond strength” of three different calcium silicate-based cements commonly used as retrograde cements, namely

MTA Cement (MTA Angelus), MTA Putty (Maarc dental), and Biodentine (Septodont) retrograde restorations.

Materials and methods

Sample selection

and Sample Preparation

Total 54 number of extracted mandibular premolars collected and decoronated to standard root length of 16 mm (from root apex to coronal reference point). Instrumentation of the canals was done with NiTi rotary files upto 6% 30 size files (fig 1). During instrumentation irrigation of root canals will be done with 3% sodium hypochlorite and distilled water. Final irrigation with 17% EDTA followed with distilled water. Canals then will be dried with paper points before being obturating with gutta-percha and Zinc oxide eugenol sealer (fig2). After 24 hrs dry storage at room temperature, the apical 3mm of the

root was resected at 90° angle to the tooth's long axis using a carborundum disc(fig.3). will be divided randomly into three groups. With an ultrasonic surgical tip(#ED10) a 5 mm depth, cylinder shaped root-end cavity was made (fig 3a,3b).

Specimens were the divided randomly into three experimental groups, each group contain 18 samples.

Grouping

- Group I: The retro-cavities were filled with MTA Angelus
- Group II: The retro-cavities were filled MTA Putty.
- Group III: The retro-cavities were filled with Biodentin Retrograde filling done according to the group. (fig.4)



Fig.1 Instrumentation of the canals was done with NiTi rotary files upto 6% 30 size files.

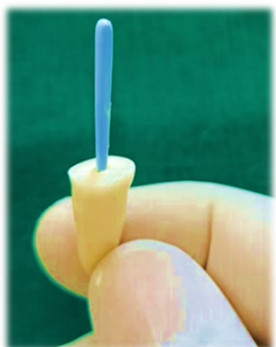


Fig.2 Canals obturation

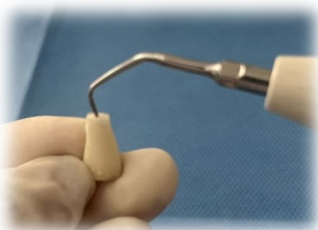


Fig3a With an ultrasonic surgical tip (#ED10) a 5 mm depth, cylinder shaped root-end cavity was made.

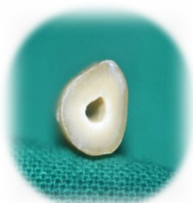


Fig3b.Retrograde cavity

Fig.4 Retrograde filling



5mm apical root discs were made by cutting perpendicular to the long axis of the root.

The cut ends were covered with wax while mounting in acrylic blocks(fig.5).



Fig.5 Tooth section mounted on acrylic resin

Pushout bond strength testing

The specimens were attached to a Universal Testing Machine with the needle directed in an apicocoronal direction positioned in the center of the cement. A compressive push-out load was applied until debonding occurs(fig.6).

Bonded surface area analysed using a digital microscope and measured using the equation;(fig.7)

$$\text{Bond Strength (MPa)} = \frac{\text{Debonding force(N)}}{\text{Bonded surface area (mm}^2\text{)}}$$

Bonded surface area= $2\pi rh$

r=radius of bonded area

h=Thickness if specimen (fig.6).



Fig.6 Pushout bond strength testing in universal testing machine

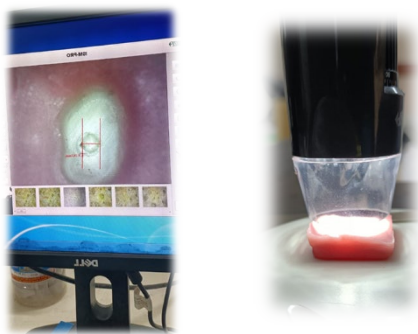


Fig.7: Radius measured by digital microscope

Statistical Analysis

Data was analysed using statistical package via multipurpose programming language Python 3.11 version. A p-value of <0.005

was considered statistically significant.

Results

Analysis 1 presents the mean, standard deviation (SD), standard error (SE), minimum and maximum values of push-out bond strength (in MPa) for each experimental group: MTA Angelus, MTA Putty, and Biodentine. It allows for a clear comparison of the central tendency and variability of bond strength among the tested materials, illustrating which material demonstrated the highest and lowest resistance to dislodgement.

Analysis 2 summarizes the results of the post-hoc Tukey HSD test, which was performed following one-way ANOVA. It displays the mean difference in push-out bond strength between each pair of materials, along with the corresponding standard deviation and P-value. This table identifies which differences between groups are statistically significant, helping

Analysis 1: Descriptive Statistics of Push-Out Bond Strength (MPa)

Material	Mean $\pm$ SD	Minimum	Maximum
Biodentine	15.42 $\pm$ 1.52	13.50	16.90
MTA Angelus	12.18 $\pm$ 1.23	10.80	13.75
MTA Putty	8.95 $\pm$ 0.98	7.60	10.20

Analysis 2: Comparison of Push-Out Bond Strength Between Individual Groups Using Post-Hoc Tukey HSD Test.

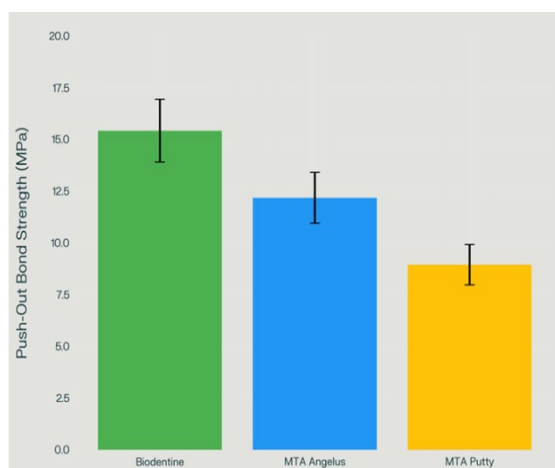
Comparison	Difference $\pm$ SD	P-value
Biodentine vs. MTA Angelus	3.24 $\pm$ 1.52	<0.001
Biodentine vs. MTA Putty	6.47 $\pm$ 0.98	<0.001
MTA Angelus vs. MTA Putty	3.23 $\pm$ 1.23	<0.001

Analysis 3: One-way ANOVA summary table showing the comparison of push-out bond strength.

Source of Variation	Degrees of Freedom	F-value	P-value
Between Groups	2	96.81	<0.001
Within Groups	33		

to clarify the hierarchy of material performance.

Analysis 3 provides the essential results of the one-way ANOVA used to compare the mean push-out bond strengths across all groups. It includes the degrees of freedom, F-value, and P-value, indicating whether there is a statistically significant difference among the materials tested. This concise summary supports the validity of further pairwise comparisons.



Graph 1: Mean push out bond strength.

Bar graph shows the mean push-out bond strength (MPa) of Biodentine, MTA Angelus and MTA Putty as retrograde filling materials. Error bars represent standard deviation for each group. Biodentine exhibited the highest mean bond strength, followed by MTA Angelus and MTA Putty.

Discussion

The success of surgical endodontic treatment is largely influenced by the

sealing ability and retention of retrograde filling materials.

All calcium silicate-based material has good sealing ability which is attributed to the formation of calcium hydroxyapatite the interface between dentin and the material.³

However, the findings in this study are consistent with previous literature, which suggests that Biodentine exhibits superior handling characteristics, enhanced marginal adaptation, and faster setting time, all of which contribute to improved bond strength to dentin.³

Gunesar M et al (2013) showed that the good adhesion of Biodentine to root canal walls is because of the finer particle size ranging at 10 microns that enhances the infiltration of the cement into the dentinal tubules.⁴

Martin RI et al (2007) reported drawbacks in MTA such as prolonged setting time, difficult handling characteristics that can affect the bonding in comparison to Biodentine.⁵

MTA putty, a pre mixed ready to use material, showed the least bond strength among the three materials; though the composition is said to be similar to MTA cement. This may be related to physical alterations of the product affecting the wettability of the cement. Further studies are required to identify the reason for poor



bond strength.⁶

Limitations

In vitro design, which does not fully replicate the clinical environment, including the presence of moisture, periapical tissue pressure, and healing response.

More research is needed to understand the physical properties of MTA putty, a recently introduced material.

This study evaluated the bond strength only at 24 hours; However, assessment of long-term bond strength is also necessary.

Additionally, long-term stability and sealing ability under functional load need to be assessed.

Conclusion

Within the limits of this study, we may conclude that Biodentine may be considered the most favorable retrograde filling material when superior bond strength is desired.

MTA Angelus demonstrated intermediate bond strength, higher than MTA Putty but lower than Biodentine. MTA Putty had the lowest mean push-out bond strength of the three groups.

Further studies are required to understand the physical properties of MTA putty.

References

1. Nepal M, Shubham S, Tripathi R, Khadka J, Kunwar D, Gautam V, et al. Spectrophotometric analysis evaluating apical microleakage in retrograde filling using GIC, MTA and biodentine: an in-vitro study. BMC Oral Health. 2020 Dec;20(1):37. doi:10.1186/s12903-020-1025-9
2. Shancy Merlin AR, Ravindran V, Jeevanandan G, Eswaramoorthy R, Arthanari A. Comparative Evaluation of Push-Out Bond Strength of Conventional Mineral Trioxide Aggregate, Biodentine, a Modified Mineral Trioxide Aggregate, and Two Novel Antibacterial-Enhanced Mineral Trioxide Aggregates. Cureus. 2024 Mar 17. doi:10.7759/cureus.56320
3. Chaudhari P, Chandak M, Jaiswal A, Ikhar A. Comparative evaluation of push-out bond strength of three retrograde filling materials in teeth with root apices resected at 90°: Mineral trioxide aggregate Angelus, Zirconomer, and Bioactive bone cement. J Conserv Dent. 2022;25(6):605. doi:10.4103/jcd.jcd_268_22
4. Gardos G, Cole JO. Maintenance antipsychotic therapy: is the cure worse



than the disease? Am J Psychiatry. 1976
Jan;133(1):32–6.
doi:10.1176/ajp.133.1.32 PubMed
PMID: 2021.

5. Gardos G, Cole JO. Maintenance
antipsychotic therapy: is the cure worse
than the disease? Am J Psychiatry. 1976
Jan;133(1):32–6.
doi:10.1176/ajp.133.1.32 PubMed
PMID: 2021.

6. Nosrat A, Kolahdouzan A, Revana
Siddappa RH, Cheng C, Li FC, Moradi
M, et al. Biomechanical Characterization
of Immature Roots Following
Regenerative Endodontic Treatment and
MTA Apexification: A Clinical Study.
Journal of Endodontics. 2025
Oct;51(10):1429–37.
doi:10.1016/j.joen.2025.06.018



Original Article

COMPARATIVE EVALUATION OF EFFECT OF TWO DIFFERENT BLEACHING AGENTS ON MICROHARDNESS OF NANOFILLED COMPOSITE RESINS – AN IN VITRO STUDY

*Dr Fathimathu Farisa Abdul Aziz, **Dr. Elsy P Simon, *** Dr Chandini Raveendran,
****Dr Ravi SV**** Dr Sarin Korothe, *****Dr Kavya Belaram

Abstract:

Dental bleaching is a widely accepted conservative procedure for tooth whitening. However, bleaching agents act through oxidative mechanisms that may adversely affect restorative materials, particularly composite resins. Nanofilled composite resins, despite their superior mechanical and esthetic properties, may undergo alterations in surface characteristics following exposure to bleaching agents.

Aim:

To compare and evaluate the effect of 35% hydrogen peroxide and 16% carbamide peroxide on the microhardness of nanofilled composite resin.

Materials and Methods:

Sixty nanofilled composite resin specimens (n = 60) were fabricated and randomly divided into three groups (n = 20 each). Group I (control) specimens were stored in distilled water. Group II specimens were treated with 35% hydrogen peroxide for 45 minutes over a period of two weeks. Group III specimens were treated with 16% carbamide peroxide for 6 hours daily for two weeks. Microhardness was evaluated using a Vickers microhardness tester under standardized conditions. Statistical analysis was performed using one-way ANOVA, and a p-value < 0.05 was considered statistically significant.



Results:

A statistically significant reduction in microhardness was observed in both bleaching groups compared to the control group ($p = 0.001$). The greatest reduction in microhardness was noted in specimens treated with 35% hydrogen peroxide. The 16% carbamide peroxide group exhibited a comparatively moderate decrease in microhardness values.

Conclusion:

Bleaching agents significantly influence the microhardness of nanofilled composite resins. The extent of reduction is dependent on the concentration and type of bleaching agent, with higher concentration hydrogen peroxide producing greater surface softening. Repolishing of composite restorations following bleaching procedures is recommended to restore surface integrity.

Keywords: *Nanofilled composite resin, hydrogen peroxide, carbamide peroxide, bleaching, microhardness, Vickers hardness test.*

Corresponding author: Dr Fathimathu Farisa Abdul Aziz (farisamna019@gmail.com)

*Postgraduate, **Professor & HOD, ***Professor ****Associate Professor, ***** Assistant Professor, Department of Conservative Dentistry and Endodontics, KMCT Dental College

Introduction

Dental bleaching has become one of the most widely accepted and conservative aesthetic procedures for enhancing tooth brightness. The bleaching process primarily relies on **hydrogen peroxide** as the active agent, which may be applied directly or released through the

breakdown of **carbamide peroxide**.

Carbamide peroxide acts as a reservoir compound, decomposing into hydrogen peroxide and urea, thereby enabling sustained whitening action.¹

Carbamide peroxide formulations, particularly at 10% concentration, are



commonly used for supervised home bleaching, whereas higher concentrations of hydrogen peroxide (up to 35%) are generally recommended for in-office and non-vital bleaching procedures. Recently, there has been an increasing trend toward prescribing carbamide peroxide gels exceeding 10% concentration for home use, raising concerns regarding their potential effects on dental tissues and restorative materials.¹

Although bleaching agents are considered safe when properly administered, higher concentrations may increase the risk of adverse effects, including tooth sensitivity, soft tissue irritation, and alterations in the structural integrity and microhardness of enamel, dentin, and restorative materials. However, the literature presents inconsistent findings regarding the extent and severity of these morphological and biomechanical changes.¹

Surface roughness is a critical property of restorative materials, as increased roughness can promote plaque accumulation, discoloration, and reduced longevity of restorations. Previous studies evaluating the effects of bleaching agents on composite resins have reported contradictory results. Some investigations demonstrated slight but statistically significant increases in surface roughness

with carbamide peroxide concentrations ranging from 10% to 16%, whereas others found no significant alterations even with hydrogen peroxide concentrations as high as 30–35%. These discrepancies may be attributed to differences in composite resin formulations, bleaching protocols, or measurement methodologies.¹

Patients having composite restorations may demand whiter teeth to enhance their aesthetic appearance. Bleaching agents were introduced by Haywood and Heyman and are now gaining popularity in improving the aesthetic form of patients because of their efficacy as well as safety. Bleaching comprises 30-38 % hydrogen peroxide in the form of gel for in-office bleaching technique and 10 to 22 % carbamide peroxide in gel form for at-home bleaching technique. This peroxide is decomposed to release free radicals, which undergo oxidation/reduction reactions. These free radicals split the double bond of pigmented molecules to smaller sizes that either are diffused out of the tooth or appear lighter due to less absorption of light.²

Organic matrix in composite resin is more susceptible to be chemically altered as compared to other aesthetic restorations including ceramic or metal. The impact of bleaching agents on certain properties of composites like surface hardness, surface

roughness, staining susceptibility, microleakage, etc. have been examined by a lot of scholars.²

One of the most crucial physical properties of dental materials is their surface hardness, which describes the strength of the material and its ability to resist abrasion from opposing structures. Bleaching results in chemical softening of organic portion of restoration, which raises objections on the clinical durability of composite. Hence, it proves the aim of this research study, which states that, the microhardness of a nanofilled composite is reduced after the use of bleaching agents (16% carbamide peroxide and 35% hydrogen peroxide).²

The aim of this study is to compare & evaluate the influence of bleaching with 35% hydrogen peroxide & 16% carbamide peroxide on microhardness of nanofilled composite resin.

Materials and Methods

Sample preparation

60 Composite resin blocks of 10mm diameter & 2mm thickness were prepared from a square mold with glass slide kept underneath.

Light curing of material was done continuously from top & bottom according to manufacturer's instructions

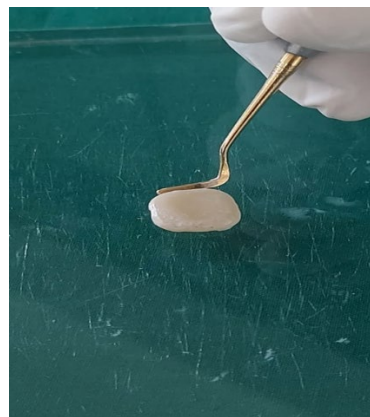


Figure 1: Preparation of composite resin blocks



Figure 2: Bleaching agents used- 35% hydrogen peroxide & 16% carbamide peroxide

The specimens were then polished using silicon carbide burs of increasing granulation. Then the discs were stored in relative humidity at 37°C for 24 hrs.

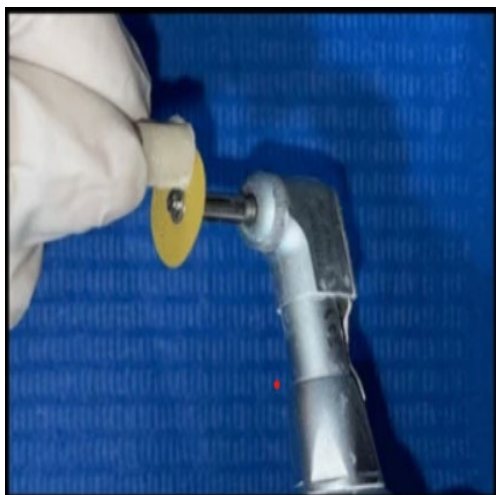


Figure 3: Polishing of the prepared composite discs

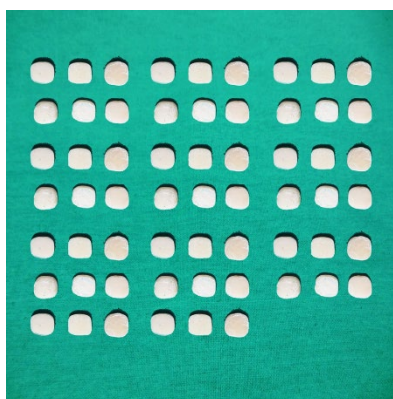


Figure 4: Prepared 60 composite resin blocks

An initial microhardness test was performed after completion of polymerization.

Then the composite resin blocks were divided into 3 groups with equal number of samples

Grouping

The prepared 60 nanofilled composite resin blocks were then randomly assigned into 3 groups:

Group I: Stored in distilled water
(n=20)

Group II: Immersed in 35% hydrogen peroxide for 45 min -- 2 weeks
(n=20)

Group III: Immersed in 16% carbamide peroxide for 6 hrs – 2 weeks
(n=20)

After 15 days when the bleaching process was completed a quantitative evaluation of final microhardness values was taken.

Microhardness Testing

At the end of the treatment period, all specimens were subjected to Vickers surface microhardness testing using a microhardness tester. The composite resin blocks were stabilized & placed in Vickers microhardness testing machine. A load of 100 grams was applied for 15 seconds at three standardized locations on each specimen, and the average Vickers Hardness Number (VHN) as recorded for each sample by viewing the indentations under digital microscopy.

The average value was converted into Vickers hardness number (VHN) & expressed in kg/mm².



Figure 5: Stabilization of composite resin blocks in Vickers Microhardness Tester and recording of Vickers hardness number under digital microscopy

final Vickers Hardness number value of individual specimen. The baseline and final obtained VHN for every specimen were statistically analyzed. All statistical procedures were performed using Statistical Package for Social Sciences (SPSS) 20.0.

One way ANOVA test was used.

Probability value $p < 0.05$ was considered statistically significant.

Results

The results showed that bleaching agents significantly influenced the microhardness values of nanofilled resin composites ($p = 0.001$). Lower microhardness values were noted after bleaching treatment with 35% hydrogen peroxide. Compared to the significant reduction in microhardness observed with 35% hydrogen peroxide, 16% carbamide peroxide resulted in a more moderate decrease.

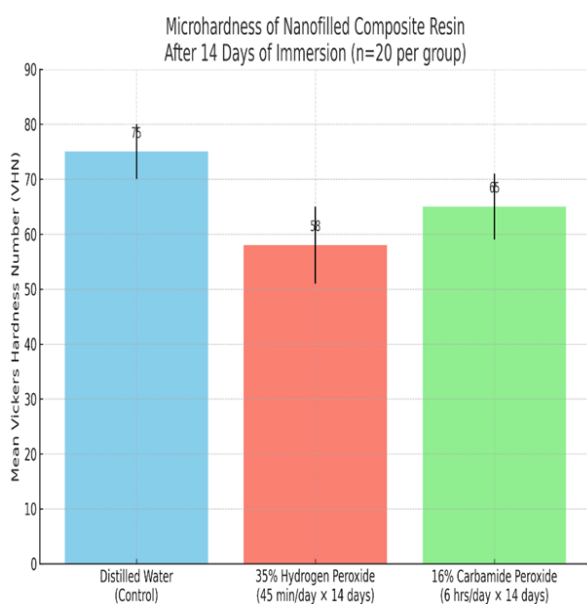
Pre-Bleaching HV								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		F value	P value
					Lower Bound	Upper Bound		
Distilled Water	20	89.65	1.920	.42952	88.7580	90.5560	6.17	0.004*
35_H2O2	20	90.93	2.053	.45907	89.9732	91.8948		
16 Carbamide Peroxide	20	88.95	1.382	.30914	88.3050	89.5990		
Total	60	89.84	1.96	.25316	89.3411	90.3542		

Table 1: Vickers hardness values recorded pre bleaching.



Post-Bleaching HV								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		F value	P value
					Lower Bound	Upper Bound		
Distilled Water	20	88.4680	1.93590	.43288	87.5620	89.3740	152.31	0.001*
35_H2O2	20	75.9210	2.78044	.62172	74.6197	77.2223		
16 Carbamide Peroxide	20	81.0890	2.04586	.45747	80.1315	82.0465		
Total	60	81.8260	5.65713	.73033	80.3646	83.2874		

Table 2: Vickers hardness values recorded post bleaching



Graph 1: Bar graph showing Mean Vickers microhardness (VHN) of nanofilled composite resin after 14 days of treatment. The 35% hydrogen peroxide group showed the greatest reduction compared to control and 16% carbamide peroxide.

Discussion

Effect of Bleaching Agents on Composite Resin

The results of the present study demonstrated that both hydrogen peroxide and carbamide peroxide produced a statistically significant reduction in the microhardness of nanofilled composite resin ($p < 0.05$). The reduction was more pronounced in the hydrogen peroxide group.

Hydrogen peroxide exhibits strong oxidative potential, which facilitates the generation of free radicals. These free radicals are capable of attacking the unreacted double bonds present within the polymer matrix, resulting in oxidative cleavage of polymer chains. This degradation of the resin matrix contributes to a reduction in surface microhardness. Furthermore, the by-products of peroxide decomposition may accelerate hydrolytic degradation at the resin–filler interface. As described by **Chakraborty et al.**, free radical activity can lead to filler–matrix debonding, formation of microscopic cracks, and increased surface roughness, ultimately compromising the mechanical integrity of composite resins.³

Similarly, **Andrade et al.** reported that bleaching agents promote breakdown of



polymer chains, adversely affecting the physical properties of composite restorations and leading to softening of both superficial and deeper layers. The disruption of the filler–resin bond may result in increased water absorption and filler particle loss, thereby reducing surface microhardness. The oxidative capacity of peroxides has also been implicated in cleaving composite polymer chains, further contributing to surface degradation.⁴

In contrast, the present study observed that 16% carbamide peroxide caused a comparatively moderate decrease in microhardness. This finding may be attributed to its slower decomposition rate and lower concentration of active hydrogen peroxide, as explained by **Tahmeena et al.**, who suggested that reduced oxidative intensity results in less pronounced structural degradation.⁵

However, literature findings are not entirely consistent. **Bandiera et al.** demonstrated in an in situ study that bleaching with 15% carbamide peroxide did not significantly affect the microhardness of nanofilled composite resin, possibly due to dilution of the bleaching agent by saliva. Conversely, **Malkondu et al.** reported a significant decrease in microhardness following 6 hours per day application of 10% carbamide peroxide, suggesting that

prolonged exposure may allow sufficient diffusion of peroxide into the high molecular weight organic matrix of nanofilled composites, thereby inducing degradation.⁶

Additionally, **Satheesh et al.** suggested that repolishing composite restorations after bleaching procedures can enhance surface microhardness by removing the superficially degraded layer.⁷

Overall, the findings indicate that the effect of bleaching agents on composite resin microhardness is influenced by peroxide concentration, exposure duration, and environmental conditions.

Conclusion

Within the limitations of this in vitro study, bleaching procedures were found to significantly influence the surface properties of nanofilled composite restorations. Both hydrogen peroxide and carbamide peroxide resulted in a reduction in microhardness, with the extent of alteration being dependent on the composition of the restorative material as well as the concentration and duration of exposure to the bleaching agents.

The findings underscore the clinical relevance of repolishing composite



restorations following bleaching therapy to restore surface smoothness and improve surface microhardness, thereby maintaining the longevity and functional integrity of the restoration.

Limitations

This in vitro study did not incorporate artificial aging procedures to simulate the dynamic oral environment. Clinical factors such as saliva and occlusion, which were not replicated that may influence the surface properties of restorative materials.

References

1. Markovic L, Jordan RA, Glasser MC, Arnold WH, Nebel J, Tillmann W, et al. Effects of bleaching agents on surface roughness of filling materials. *Dent Mater J*. 2014;33(1):59–63. doi:10.4012/dmj.2012-217
2. Effects of Two Different Bleaching Agents on the Microhardness of Composite. *Pak J Med Dent*. 2021 Oct 31. doi:10.36283/PJMD10-4/003
3. Chakraborty A, Purayil T, Ginjaipalli K, Pentapati KC, Shenoy N. Effect of in-office bleaching agent on the surface roughness and microhardness of nanofilled and nanohybrid composite resins [version 2; peer review: 2 approved]. 2023.
4. De Andrade ICGB, Basting RT, Rodrigues JA, Do Amaral FLB, Turssi CP, França FMG. Microhardness and color monitoring of nanofilled resin composite after bleaching and staining. *Eur J Dent*. 2014 Apr;08(02):160–5. doi:10.4103/1305-7456.130586
5. Effects of Two Different Bleaching Agents on the Microhardness of Composite. *Pak J Med Dent*. 2021 Oct 31. doi:10.36283/PJMD10-4/003
6. Fernandes RA, Strazzi-Sahyon HB, Suzuki TYU, Briso ALF, Dos Santos PH. Effect of dental bleaching on the microhardness and surface roughness of sealed composite resins. *Restor Dent Endod*. 2020;45(1):e12. doi:10.5395/rde.2020.45.e12
7. Satheesh S, Vg SJ, Fathima R. Impact of In-office and Home Bleaching Agents on Surface Roughness and Microhardness of Single-shade and Nanofilled Composite Resins: An In Vitro Study. *World J Dent*. 2025 Feb 8;15(11):989–93. doi:10.5005/jp-journals-10015-2536



Case Report

MANAGEMENT OF UNTREATED HORIZONTAL ROOT FRACTURE: A CASE REPORT

*Dr. Adithya Varma, **Dr. Elsy P Simon, ***Dr. Ravi S,
****Dr. Chandini Raveendran

Abstract

Traumatic dental injuries often occur to the teeth and their supporting tissues and they are the main reasons for an emergency visit to a dental clinic. Horizontal root fractures usually are characterized by a fracture line that is perpendicular to the long axis of the root. Root fractures are diagnosed through clinical and radiographic examination. Treatment depends on the position of the fracture, the extent of root involvement, correct diagnosis, clinical management, and radiographic follow-up. This article presents endodontic management of horizontal root fracture using a fibre post. A 57-year-old female patient presented with a horizontal fracture of the maxillary right central incisor at the cervical level. Root canal treatment followed by fiber post gave satisfactory results.

Key words: Conservative management, fiber post, horizontal root fracture, trauma.

Corresponding author: Dr Adithya Varma

*Postgraduate student, **Professor & HOD, ***Professor ****Associate Professor,
Department of Conservative Dentistry and Endodontics, KMCT Dental College.

Introduction

Root fracture can be defined as a “fracture that involves cementum, dentin and pulp”.¹ This type of dental injury is relatively uncommon. Among all the traumatic dental injuries, root fractures account only for 0.5%-7%. Most commonly, horizontal root

fractures are seen in the middle third of the root compared to the coronal and apical third.² Due to the position of the maxillary central incisor in the dental arch, the chance of occurrence of traumatic dental injuries is more in these teeth (approximately 68%). This is followed by maxillary lateral



incisors (27%) and mandibular incisors (5%).^{3,4}

The chance of occurrence is more in male patients which may be due to trauma associated with automobile accidents, sports injuries, fights, etc. A root fracture is frequently seen in teeth that are permanent and fully erupted having complete formation of the apex. This may be due to the presence of support through bone and periodontium.¹

For accurate diagnosis of root fracture, the proper clinical and radiographic examination should be done like Intraoral periapical radiograph and cone-beam computed tomography. Pulp vitality and mobility of the coronal fragment also should be evaluated. On radiographic examination, a radiolucent line is seen which separates the coronal and the apical fragment. The angular displacement imaging technique is one of several techniques and diagnostic methods to identify the correct angulation of fracture.⁵

Splinting of teeth is done whenever required by repositioning and stabilizing the teeth in their correct position. Following this injury periodic checking of teeth is done to evaluate the vitality of pulp. But evaluation of pulp vitality can be difficult in these cases. Actual pulp vitality can be determined even after several months as

said by Feiglin.^{6,7} The vitality test actually does not indicate the true status of the pulp as here the nerve supply is damaged & non-functional but the blood supply remains intact.

Case report

A 57-year-old female patient reported to the Department of Conservative Dentistry and Endodontics, KMCT Dental College, Kozhikode, after trauma in the upper front region because of an accidental collision that happened when a child fell on to the patient, resulting in direct impact to the upper anterior region 1 month back. The patient complained of fractured teeth in the upper anterior region and desired to replace the same. Past medical history was not significant. On clinical examination, a complicated crown fracture of maxillary right central incisor was seen with grade II mobility of the coronal portion of the tooth according to Miller's classification of tooth mobility (Figure 1) and labially displaced 11 (Figure 2). On radiographic examination, the maxillary right central incisor revealed a horizontal root fracture at the cervical third of the crown labially (Figure 3). An intraoral periapical radiograph was taken using bisecting angle technique with Photostimulable Phosphor plate digital system.

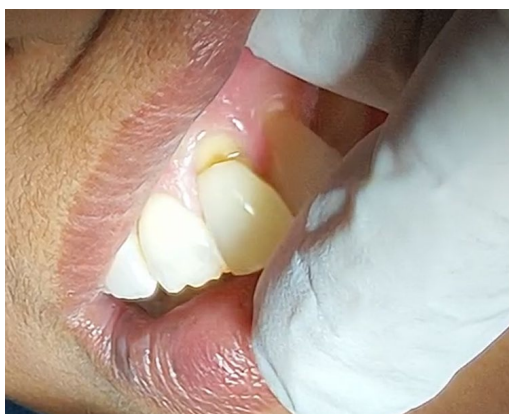


Figure 1 and 2: Preoperative clinical photograph demonstrating complicated crown fracture of maxillary right central incisor with labial displacement.



Figure 3: Preoperative radiograph showing horizontal root fracture at the cervical region of 11

The treatment plan was explained to the patient and her consent was obtained. Following clinical and radiographic evaluation, a flexible splint was fabricated extending from the maxillary right canine to the maxillary left canine using orthodontic ligature wire to stabilize the traumatized tooth and prevent further mobility (Figure 4). Root canal treatment was initiated in maxillary right central incisor. Access opening was done using round bur (BR45 Bur, Mani, Japan) and safe end bur (EX24 Bur, Mani, Japan) (Figure 5). Following pulp extirpation, working length was determined correctly using an electronic apex locator and radiograph. Working length of 11 was found to be 26mm. Both the coronal and apical fragments were cleaned and shaped using the K file in a step-back manner with apical file size #60. The canal was irrigated thoroughly using 3% sodium hypochlorite (PREVESTDenPro) and 0.9% normal saline for the removal of remaining pulp tissue and debris. This was done using a side vented irrigation needle. Calcium hydroxide iodoform paste was then placed as an intracanal medicament and a temporary pack was given (Orafil-G, PREVESTDenPro).



Figure 3: Tooth stabilized using ligature wire from 23 to 13



Figure 4: Access opening done in relation to 11

On the second visit, the patient reported back asymptomatic. The temporary dressing was removed and the canal was irrigated using saline to remove the calcium hydroxide iodoform paste from the canal. The working length was redetermined and the obturation was carried out in relation to 11 with lateral compaction technique (Figure 5).



Figure 5: Obturation done irt 11

On the third visit, post space was prepared up to 15 mm from the coronal reference point of 11 using a Peeso reamer from size 1 to 3. Glass fiber post fit was checked and was confirmed using a radiograph (Figure 6). A self-etch adhesive system was applied to the canal walls according to the manufacturer's instructions and gently air-thinned to ensure uniform distribution. A prefabricated fiber post of appropriate size was selected and trial-fitted to ensure passive adaptation. Dual-cure composite resin core build-up material (ParaCore) was injected into the canal using an automix syringe. The fiber post was coated with the same material and seated into the canal under gentle pressure. Excess material was removed, and light curing was performed to ensure adequate polymerization (Figure 6). The flexible splint extending from tooth 13 to 23 was removed following satisfactory clinical and radiographic evaluation. (Figure 7).



Figure 6: Post and core done irt 11



Figure 7: Flexible splint removed and tooth polished

Discussion

Preserving natural dentition and restoring its normal function is one of the goals of dentistry. Extraction of the tooth and its replacement with an osseointegrated implant should always be considered the last treatment option when all other means of retaining the natural tooth have been tried.⁸

In this case, a fiber post was used. The modulus of elasticity of fiber post is similar to that of dentin, which minimizes the chances of root fracture. According to Gurtu and Singhal using post provides

support and stability to the tooth.^{9,10} As the restoration is subjected to tangential stress, the post helps to retain the fractured fragment and also provides strength to the restoration complex. It also creates a monoblock between the post, reconstructive material, cement and the tooth. Also, it prevents dislodgement due to due to nonaxial forces. Fiber post is preferred as it provides good aesthetics and is able to restore the function of a such compromised tooth.

As the cement has higher viscosity and pressure is not applied, this helps in reducing the flow of resin. The amount of resin used should be limited such that a desirable bond is achieved between the post and the dentin. Glass fibre posts were selected as their modulus of elasticity is similar to that of dentin and also they have an added advantage of higher fatigue and tensile strength. When we consider the prognosis of permanent teeth with root fracture, this is related to the amount of dislocation, stage of root development at the time of injury and to some extent, it also depends upon whether the treatment was done.

Andreasen et al. proposed the sequelae to root fracture which can be divided into the following four types (Table 1).^{1,6} In such cases, long-term follow-ups are required to check if there is any pathological alteration.



Table 1. Sequelae to root fracture.

Sr no.	Sequela to Root fracture
1]	Healing with calcified tissue - there is close contact between fragments but the line can be seen radiographically.
2]	Healing with interproximal connective tissue - when seen radiographically, the separation between the fragments is seen as narrow radiolucent line and the fr edges appear narrow.
3]	Healing with interproximal bone and connective tissue - the separation between fractured fragment as seen radiographically is through distinct bony bridge.
4]	Interproximal inflammatory tissue without healing - fracture line seems to wide seen on radiograph.

Conclusion

“Preservation of natural dentition and restoration of the oral cavity to a normal functional state” is the primary goal in dentistry. Maintaining the position of fractured teeth in the dental arch is the main objective of treating such teeth. In recent times there has been tremendous improvement in bonding agents and restorative resin and also various new materials are available including the fibre post and dual-cure resin cement that has provided clinicians with different treatment options for the management of fractured roots.

References

1. Andreasen FM, Andreasen JO. Textbook and color atlas of traumatic injuries to the teeth. Copenhagen: Munksgaard; 2007. p. 219–256.
2. Bramante CM, Menezes R, Moraes IG, Bernardinelli N, Garcia RB, Letra A. Use of MTA and intracanal post reinforcement in a horizontally fractured tooth: a case report. Dent Traumatol. 2006;22:275–278. doi:10.1111/j.1600-9657.2006.00353.x.
3. Andrade ES, de Campos Sobrinho AL, Andrade MG, Matos JL. Root healing after horizontal fracture: a case report with a 13-year followup. Dent Traumatol. 2008;24:0. doi:10.1111/j.1600-9657.2008.00556.x.
4. Calışkan MK, Pehlivan Y. Prognosis of root-fractured permanent incisors. Endod Dent Traumatol. 1996;12:129–136. doi:10.1111/j.1600-9657.1996.tb00111.x.
5. Molina JR, Vann WF Jr, McIntyre JD, Trope M, Lee JY. Root fractures in children and adolescents: diagnostic considerations. Dent Traumatol. 2008;24:503–509. doi:10.1111/j.1600-9657.2008.00652.x.
6. Andreasen FM, Andreasen JO, Bayer T. Prognosis of root-fractured permanent incisors—prediction of healing modalities. Endod Dent Traumatol.



- 1989;5:11–22. doi:10.1111/j.1600-9657.1989.tb00331.x.
7. Feiglin B. Clinical management of transverse root fractures. *Dent Clin North Am.* 1995;39:53–78.
 8. Linkow LI. Theories and technique of oral implantology. Saint Louis: Mosby Co; 1970.
 9. Ham KA, Witherspoon DE, Gutmann JL, Ravindranath S, Gait TC, Opperman LA. Preliminary evaluation of BMP-2 expression and histological characteristics during apexification with calcium hydroxide and mineral trioxide aggregate. *J Endod.* 2005;31:275–279.
doi:10.1097/01.don.0000140584.65320.cc.
 10. Gurtu A, Singhal A, Mohan S. Management of horizontal fracture. *J Dent Sci.* 2012;48–50.



Case Report

ENDODONTIC MANAGEMENT OF MAXILLARY FIRST PREMOLAR WITH THREE ROOT CANALS: A CASE REPORT

*Dr.Amrutha.KP, **Dr.Elsy P.Simon, ***Dr.Ravi.SV, ****Dr.Chandini Raveendran.

Abstract

Effective and successful endodontic treatment requires dentists to have adequate information on the clinical variations in root canal anatomy. The maxillary first premolar exhibiting the greatest variation in root canal morphology, with three-canal configurations being a rare but clinically significant finding. This case report presents a 44-year-old female patient diagnosed with chronic periapical abscess in tooth #14, confirmed to have three root canals which underwent endodontic treatment-

Keywords: Root canals, Anatomical variation, Maxillary first premolar, Three roots, CBCT, Endodontic treatment.

Corresponding author: Dr.Amrutha.KP(amruthakolarad@gmail.com)

*Postgraduate student, **Professor, ***Professor & HOD ****Associate Professor, Department of Conservative Dentistry and Endodontics, KMCT Dental College.

Introduction

Identification, negotiation, disinfection, and blockage of the whole root canal system are key elements of the success of root canal treatment by clinicians.¹ Variations in the root canal morphology

may pose challenges to the clinician during the operative stages. Additional canals, C-shaped, unusual curvatures, canal calcifications, dens invaginatus, and taurodontism often present considerable diagnostic and treatment challenges. Failure to identify and manage of such

complexities can lead to a persistent infection and poor treatment outcomes.

The maxillary first premolar is a two-cusped tooth with the buccal cusp being prominently larger than the palatal cusp. This tooth is widely regarded as exhibiting the greatest variation in root anatomy and root canal morphology.^{2,3} Although it most commonly presents with two canals, three canals may be encountered, and this third canal can easily be overlooked during treatment.

This article reports a rare finding of three canals in a maxillary first premolar during root canal treatment, highlighting a unique anatomical variation of this tooth that clinicians should be aware of.

Case report

A 44 yrs old female patient reported to the department of Conservative dentistry and Endodontics with a chief complaint of severe pain associated with the upper right back tooth.

The patient reported swelling and pain for the past 3 months. The pain was gradual in onset, localized, intermittent and dull aching in nature. The patient consulted in a private clinic and took medication for the same, following which the pain relieved. However, the intensity of pain increased over the past 2 weeks. The patient had undergone filling corresponding to the same tooth 1 year ago, which fractured a

few months back. The patient had undergone few restorations and extractions previously, all of which were uneventful. No relevant medical history was reported. Clinical examination revealed a soft tissue swelling of approximately 8*4 mm over the right buccal lateral vestibule in respect to apical region of #14 (**figure 1.1**).



Figure 1.1 Intraoral soft tissue swelling over the right buccal lateral vestibule #14

No color change was noted over the overlying skin. The swelling was firm and tender on palpation. Hard tissue examination showed Class II deep caries on disto-occlusal aspect of tooth #14 (**figure 1.2**), tenderness on vertical percussion, Grade I mobility (Miller's classification) and normal probing depth.



Figure 1.2-ClassII disto-occlusal caries in #14

The preoperative radiograph revealed radiolucency involving the enamel, dentine and approximating pulp in the distal aspect of tooth #14 along with break in the lamina dura and widening of periodontal ligament space apically. Root canal splitting was noted radiographically, raising suspicion of three canals(**figure1.3**).



Figure 1.3 Preoperative intra oral periapical radiograph of #14

CBCT images were analyzed and revealed the following findings: coronal hypodensity is noticed involving enamel, dentin and approximating the pulp suggestive of deep dental caries in tooth #14. An ill-defined periapical hypodensity is noticed at the root apices suggestive of periapical pathology (periapical abscess). Loss of buccal cortex also observed (**figure 1.41**).

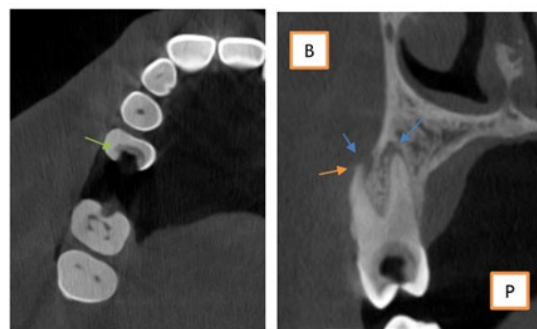


Figure 1.41 Three-dimensional cone-beam computed tomographic (CBCT) images of tooth #14

The axial section revealed the presence of three canals in tooth #14 - mesio-buccal, disto-buccal and palatal (**figure 1.42**)

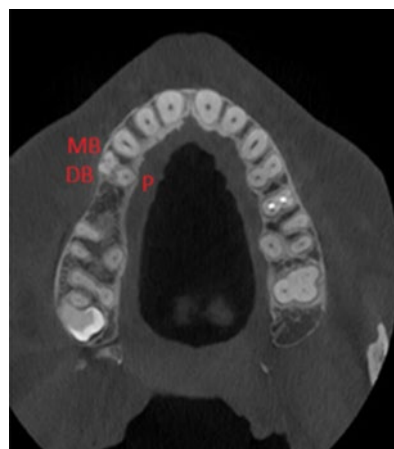


Figure 1.42 Three-dimensional cone-beam computed tomographic (CBCT) images of tooth #14 three root canals

Cold vitality test revealed no response. A final diagnosis of chronic periapical abscess was established to tooth #14, and root canal therapy was planned. The treatment plan was explained to the patient in detail and written informed consent was obtained prior to the initiation of therapy.

The tooth was isolated using a rubber dam following infiltration with local anesthesia (2% lidocaine with 1:100000 epinephrine). Caries excavation was performed using a round bur, and access opening was achieved using an Endo-access bur. Three canal orifices located using DG-16 explorer -mesiobuccal (MB), distobuccal (DB) and palatal(P).

The conventional access cavity was modified to triangular shape with a base facing the buccal aspect (**figure 2.1,2.2**).

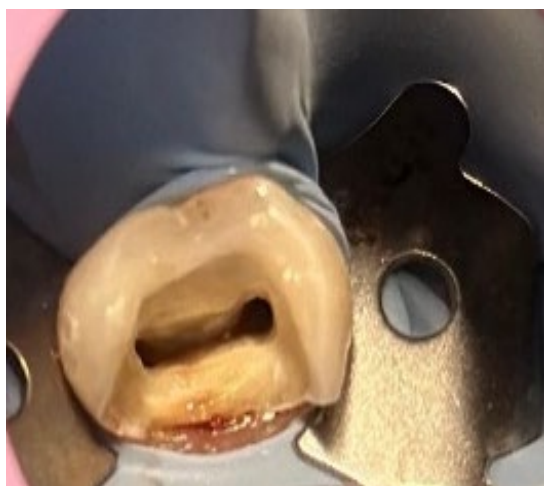


Figure 2.1 Access cavity preparation

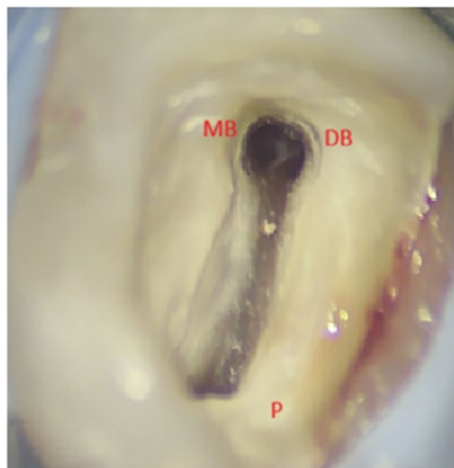


Figure 2.2 Access cavity preparation showing 3 canal orifices- mesiobuccal (MB), distobuccal (DB) and palatal(P).

Canal exploration was performed using # 8 K and #10 K files. The working extents of three root canals were measured using apex locator and verified radiographically, confirming a Type VIII Vertucci root canal morphology (**figure 3**). The canals were dried with paper points and a closed dressing done.

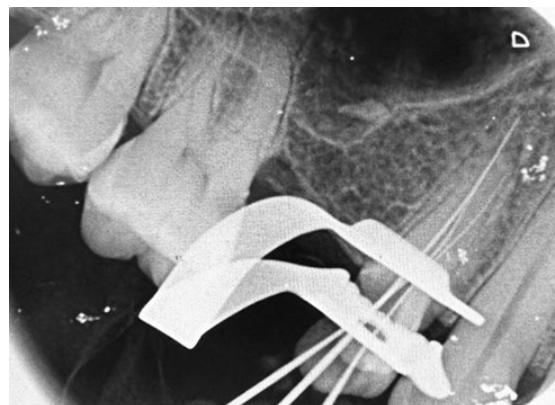


Figure 3 Radiographic confirmation of working length #14

A week later, the patient was reviewed and, she felt slight tenderness to percussion with the base of the mouth mirror but assessing the canals, they were found to be dry and

uninfected. Biomechanical preparation was carried out using the crown down technique with recapitulation to the original working length. Buccal canals were shaped to size 25.04 and palatal canal to size 30.04, under copious irrigation with 3% sodium hypochlorite, 17% EDTA and 2% CHX, with normal saline in between. The canals were dried using paper points.

Calcium hydroxide (RC Cal) was placed as an intracanal medicament, and the access cavity restored with temporary filling material over cotton wool pledget.

At the subsequent appointment after 2 weeks, intracanal medicament was removed with copious saline irrigation. Final flush was performed with 17% EDTA followed by 3% sodium hypochlorite. Master apical cone selected: 4% 30GP – Palatal canal, 4% 25 GP- MB, DB canal and confirmed radiographically (**figure 4**).

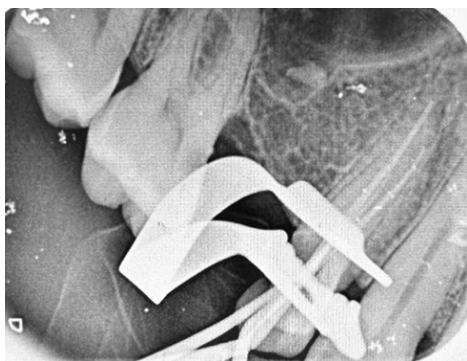


Figure 4 Radiographic confirmation of master cone #14.

Manual dynamic activation of irrigants was performed prior to obturation.

The canals were dried using absorbent points. Subsequently, obturation was completed using the lateral condensation technique with zinc oxide eugenol-based sealer (Zical) and gutta-percha (**figure 5.1**), followed by composite resin restoration (**figure 5.2**).

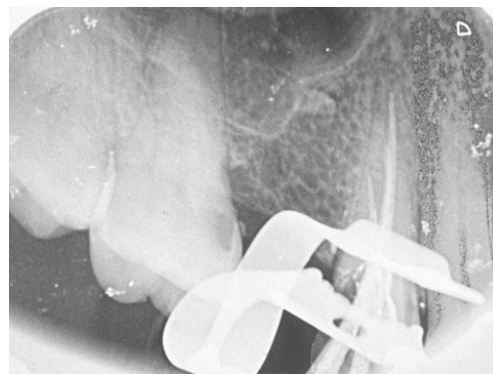


Figure 5.1 Post-obturation radiograph #14



Figure 5.2 Final radiograph after restoration

Discussion

Endodontic therapy of premolar teeth is particularly challenging due to the high probability of supernumerary root canals.⁴ The maxillary first premolar is well known for exhibiting the greatest variation in root anatomy and root canal morphology. Two



distinct types of three canal maxillary premolars presentations: two-rooted three canal and three-rooted three canal teeth. A maxillary premolar with three canals has been described by various terminologies, including “Small molars” and “Minimolar” as described by Miabbaum or ‘Radiculous’ as described by Goon.^{5,6}

The prevalence of single root ranges from 22.0-49.4%; two roots from 50.6-72% and three roots from 0-6%.⁷⁻⁹ Researches related to the canal structure of the first maxillary premolars have demonstrated that the majority of cases present with two canals (73.3- 92%), while teeth with one or three canals occur less frequently (8-26.2% and 0-6%, respectively).¹⁰ Mariusz et al found 9.2% of first maxillary premolars with three canals.¹¹

The most common root canal morphologies for M1Ps were Type IV according to Vertucci’s classification and 2MP B1 P1 according to Ahmed’s classification. Type IV was found in 60.3% of right and 56.8% of left premolars, while 2MP B1 P1 was noted in 54.6% of right and 51.6% of left premolars.¹²

Good quality radiographs are mandatory for accurate detection of canals especially when analyzing the anatomic details of the root that are not clearly visible or distinct.¹³ Radiographic indicators suggestive of a third canal or root include disappearance or sudden narrowing root canals (fast break),

abrupt straightening or broadening of the canal path, a mesio-distal width of the mid-root equal to or greater than that of the crown, and an endodontic instrument appearing eccentric within the root on radiographic examination.¹⁴

Three-dimensional imaging modalities such as cone beam computed tomography (CBCT) are highly reliable in identifying variant anatomical configurations. However, routine use of CBCT is limited due to economic constraints and radiation-exposure concerns.

Root canal orifices serve as the primary guide in determining the outline form of the access cavity. The maxillary first premolar has an ovoid outline form in the buccopalatal direction. An eccentric canal orifice is an important indicator of the presence of an additional canal. In three-canal maxillary premolars, the buccal orifices are situated close proximity to each other and therefore difficult to locate. As suggested by Balleri et al. (1997), a third canal orifice should be anticipated by making a cut at the bucco-proximal angle, extending from the entrance of the buccal canals to the cavosurface angle.¹⁵ A pulp chamber that appears triangular in shape or too large in a mesiodistal plane should raise suspicion of more than one root canal. A T designed cavity is perfect for debridement and achieving straightforward entrance to three rooted premolars. Additionally,



proper tactile sensitivity and adequate pre-curving of the file are essential during canal negotiation.¹⁶

The location of canal orifices is best achieved under good illumination with a dry pulp floor. Magnification using loupes or a dental operating microscope (DOM) is considered beneficial, with the DOM being particularly advantageous for the detection of additional orifices.¹⁶

In certain instances, the two buccal canals originate from a narrow common main canal extending from the pulp chamber, creating an “S”- shaped configuration that restricts instrumentation. This situation can be effectively managed by troughing to a depth of 1–2 mm in an apical direction and between the two buccal canals, similar to the preflaring technique used in endodontic preparation. This maneuver effectively straightens the “S”-shaped canal, rendering apical instrumentation more efficient and effective, and should be carried out following access preparation.

Narrow buccal canals should be enlarged with caution, as excessive removal of radicular dentin may result in a strip perforation. The safest approach involves the use of small endodontic file till the full working length, followed by step-back flaring, reverse flaring, and reverse filing as clinically indicated, after which the canal obturation is performed.¹⁷

Conclusion

In addition to having adequate knowledge on the variations of the root canal anatomy, periapical radiographs from different angles, including CBCT, careful examination of the pulp chamber floor, and use of dental operation microscope during the procedure are also important factors that contribute to identification of additional roots and canals and successful outcome in root canal therapy.

References

1. Arya A. Management of Complex Root Canal Anatomy: Clinical Strategies and Case Reports, ISSN: 2320-9267 Indian Journal of Pharmaceutical and Biological Research (IJPBR) Published: 22/12/2021
2. Al-Abdulwahhab B. Maxillary First Premolar with Three Canals: Case Report. Smile Dental Journal | Volume 5, Issue 3 - 2010
3. Abraham D, Kumar P. Radiculous premolar. Endodontology. 2011;23(2):95. doi:10.4103/0970-7212.352047
4. Bürklein S, Heck R, Schäfer E. Evaluation of the root canal anatomy of maxillary and mandibular premolars in a selected German population using cone-beam computed tomographic data. J Endod. 2017;43(9):1448–52. doi:10.1016/j.joen.2017.03.044.
5. Miabbaum WW (1989) Endodontic treatment of a ‘radiculous’ maxillary first



pre molar : a case report : Gen Dentistry 37, 340-1.

6. Goon WW (1993) The “radiculous” maxillary premolar: recognition, diagnosis and case report of surgical intervention. Northwest dent, 72, 31-33.

7. Remya M, Singh VP. Cone Beam Computed Tomography a Novel Innovation for assessing the Canal Morphology of Maxillary First Bicuspids. Conserv Dent Endod J. 2017;2(1):4-7.

8. Siddiq M, Shakeel J, Khan BN, Mehdi SZ, Hameed S, Chaudhary FA. Root morphology of maxillary 1st premolar teeth in orthodontic extraction cases presenting in a tertiary care hospital: Taxilla Cantt. Prof Med J. 2021;28(07):1013-7.

9. Caramêsa J, Mataa A, Versianif MA. Second root and second root canal prevalence in maxillary first and second premolars assessed by cone beam computed tomography—a systematic review and meta-analysis. Soc Port Estomatol Med Dent. 2019;60:1-14.

10. Sadaf A, Huma Z, Javed S, Masood A. Maxillary premolar teeth: root and canal stereoscopy. Khyber Med Univ J. 2019;11(4):240-7.

11. Mariusz L, Krysof W, Ryta L, Mangorzata T. Root canal morphology of the first human maxillary premolar. Durh. Anthro. J. 2005;12:2–3.

12. Pertek Hatipoğlu F, Magat G,

Karobari MI, Madarati AA, Tulegenova I, Hatipoğlu Ö, et al. Root and canal configurations of maxillary first premolars in 22 countries using two classification systems: a multinational cross-sectional study. Sci Rep. 2025 Jun 2;15(1):19290. doi:10.1038/s41598-025-02669-6

13. Bellizzi R, Hartwell G. Radiographic evaluation of root canal anatomy of in vivo endodontically treated maxillary premolars. J Endod 1985;11:37-9.

14. Sieraski SM, Taylor GN, Kohn RA. Identification and endodontic management of three-canal maxillary premolars. J Endod. 1985;15(1):29–32.

15. Balleri P, Gesi A, Ferrari M. Primer premolar superior com tres raices. Endod Pract 1997;3:13-5.

16. Maxillary Permanent First Premolars With Three Canals: Incidence Analysis Using Cone Beam Computerized Tomographic Techniques Jeyaraman Venkataraman Karunakaran Journal of Pharmacy and Bioallied Sciences | Volume 11 | Supplement 2 | May 2019.

17. Agwan AS, Sheikh Z. IDENTIFICATION AND ENDODONTIC TREATMENT OF THREE- CANALLED MAXILLARY FIRST PREMOLAR. J Ayub Med Coll Abbottabad. 2016;28(3):627–9



Review article

FLIPPED CLASSROOM MODEL IN DENTAL EDUCATION: A NARRATIVE REVIEW

*Dr Shruthi Nambiar, *Dr Aparna T K,**Dr Abhishek S.Nair

Abstract

The flipped classroom model has emerged as an innovative pedagogical approach in health professions education, including dental education. Unlike traditional lecture-based teaching, the flipped classroom reverses the instructional process by delivering core content outside the classroom through digital resources while using classroom time for active learning activities. This narrative review aims to examine the concept, implementation, benefits, and challenges of the flipped classroom model in dental education. Literature suggests that flipped learning promotes active engagement, enhances critical thinking, and improves students' satisfaction and learning outcomes. However, challenges such as increased faculty workload, technological requirements, and the need for student self-discipline remain barriers to its implementation. Despite these limitations, the flipped classroom is increasingly recognized as an effective strategy to enhance competency-based dental education.

Keywords: Flipped classroom, dental education, active learning, blended learning, innovative teaching methods

Corresponding author: Shruthi Nambiar (shrikanthshruthi@gmail.com)

*Associate Professor, **Assistant Professor, Department of Periodontology, KMCT Dental College.

Introduction

Dental education has traditionally relied on

lecture-based teaching methods in which instructors deliver theoretical content during classroom sessions. However,



advances in educational technology and the growing demand for competency-based training have led educators to explore more interactive teaching strategies.¹

The flipped classroom model represents a form of blended learning in which instructional content is delivered before class through online resources such as videos, podcasts, and reading materials. Classroom time is then dedicated to active learning activities including case-based discussions, problem-solving exercises, and clinical simulations. This approach encourages student participation, self-directed learning, and deeper understanding of concepts.

Recent studies have demonstrated increasing adoption of flipped classrooms in dental curricula, as educators seek to improve student engagement and learning outcomes.¹

2. Methodology of the Narrative Review

This narrative review was conducted through a literature search of electronic databases including **PubMed, Scopus, Google Scholar, and Web of Science**. Keywords used included *flipped classroom, flipped learning, dental education,*

innovative teaching methods, and blended learning. Articles published between **2015 and 2025** were included. Studies examining the application, effectiveness, and perception of flipped classroom models in dental education were reviewed. Relevant systematic reviews, randomized studies, and observational studies were included to provide a comprehensive overview of the topic.

3. Concept and Principles of the Flipped Classroom

The flipped classroom is a teaching strategy that reverses the traditional learning sequence. In this model, students review learning materials before attending class, while class time is devoted to interactive activities.

The core principles of flipped learning include:

1. **Pre-class preparation:** Students access lecture videos, reading materials, or multimedia resources before class.
2. **Active classroom learning:** Classroom sessions focus on discussions, case-based learning, and collaborative problem solving.



3. **Instructor facilitation:** Teachers act as facilitators guiding student learning rather than delivering lengthy lectures.
4. **Continuous assessment:** Quizzes, reflection exercises, and feedback mechanisms are used to evaluate learning.

This model aligns with **Bloom's taxonomy**, where lower-order cognitive tasks (remembering and understanding) occur before class, while higher-order skills (analysis and application) are developed during class activities.²

4.Application of Flipped Classroom in Dental Education

The flipped classroom approach has been implemented in multiple dental disciplines including orthodontics, endodontics, oral medicine, prosthodontics, and dental anatomy.

In orthodontics education, flipped learning has been used to improve students' skills in interpreting cephalograms and understanding orthodontic concepts. Studies have reported improved knowledge acquisition, practical skills, and student satisfaction following the implementation of flipped teaching methods.³

Similarly, studies evaluating emerging teaching models in dental education report that flipped classroom approaches often produce higher engagement and better academic performance compared with traditional lecture-based learning.

The model is particularly effective in clinical disciplines where students can apply theoretical knowledge to case-based discussions and treatment planning exercises during classroom sessions.⁴

5.Advantages of Flipped Classroom in Dental Education

5.1 Enhanced Student Engagement

Active learning strategies used in flipped classrooms encourage students to participate in discussions and collaborative learning, improving engagement.⁵

5.2 Improved Critical Thinking

Case-based discussions and problem-solving exercises help students develop analytical skills required for clinical decision-making.⁴

5.3 Self-Directed Learning

The flipped model encourages students to take responsibility for their own learning by



reviewing materials at their own pace.⁵

5.4 Better Knowledge Retention

Active learning methods have been shown to improve knowledge retention compared to passive lectures.

5.5 Flexibility in Learning

Digital resources allow students to revisit lecture materials multiple times, improving understanding of complex topics.

Studies evaluating innovative teaching methods report that approaches such as flipped classrooms and simulation-based learning improve student performance and satisfaction in dental education.⁶

6. Challenges and Limitations

Despite its advantages, the flipped classroom model also presents several challenges.

6.1 Increased Faculty Workload

Developing pre-class materials such as video lectures and online modules requires significant time and effort.

6.2 Student Adaptation

Some students may initially resist the

flipped model due to unfamiliarity with self-directed learning.⁷

6.3 Technological Barriers

Implementation requires access to digital learning platforms, reliable internet connectivity, and technical support.⁷

6.4 Uneven Student Preparation

The success of flipped learning depends on students completing pre-class materials, which may not always occur.

Research evaluating flipped classroom models also notes that while student satisfaction is generally high, the impact on examination scores and skill development varies across studies.

7. Strategies for Effective Implementation

For successful integration of flipped classrooms in dental education, the following strategies are recommended:

- Development of concise and engaging pre-class video lectures
- Use of learning management systems to monitor student participation



- Incorporation of formative assessments such as quizzes
- Design of clinically relevant case-based discussions
- Providing feedback and guidance during classroom activities
- Faculty training in educational technology.⁸

faculty workload, and student readiness exist, proper implementation and institutional support can facilitate successful adoption of this innovative teaching model.

8. Future Perspectives

Future research should focus on evaluating long-term outcomes of flipped classroom implementation, including its impact on clinical competence, patient care, and professional skills. The integration of flipped learning with simulation technologies, virtual reality, and digital dentistry may further enhance dental education.⁸

Conclusion

The flipped classroom model represents a promising pedagogical approach in dental education. By shifting basic knowledge acquisition outside the classroom and emphasizing active learning during class time, it promotes deeper understanding, student engagement, and critical thinking. Although challenges related to technology,

References

1. Gianoni-Capenakas S, Lagravere M, Pacheco-Pereira C, Yacyshyn J. Effectiveness and perceptions of flipped learning model in dental education: A systematic review. *J Dent Educ.* 2019;83(8):935–945.
2. Vanka A, Vanka S, Wali O. Flipped classroom in dental education: A scoping review. *Eur J Dent Educ.* 2020;24(2):213–226
3. Karandish M, Karimian Z, Parastar M. Dental students in an orthodontic course flipped classroom: A semi-experimental study on knowledge, practice, attitude, and satisfaction. *Clin Exp Dent Res.* 2024.
4. Wei Y, Peng Z. Application of the flipped classroom model based on Bloom's taxonomy in endodontics education. *PeerJ.* 2025.
5. Baherimoghadam T, Naseri N, Tabesh A, et al. The influence of learning styles on the efficacy of



flipped classroom in dental education. *BMC Med Educ.* 2025.

6. Dong H, Guo C, Zhou L, et al. Application of emerging teaching models in dental education: A systematic review and meta-analysis. *Int Dent J.* 2024.
7. Innovative teaching methods versus traditional lectures in dental education: A systematic review and meta-analysis. *J Dent Educ.* 2026.



Review

MICRONEEDLES IN THE PERIODONTAL POCKET: A NEW FRONTIER IN LOCAL DRUG DELIVERY

*Dr Aishwarya Pradeep, ** Dr. Harish Kumar VV, *** Dr Navia George, ****Dr Sruthi VG, ****Dr Sunanda Sudhakaran, ****Dr Aswathi S

Abstract:

Local drug delivery in periodontal therapy continues to face major limitations, particularly because gingival crevicular fluid rapidly washes away therapeutic agents and biofilms restrict drug penetration. Microneedle technology, originally developed for painless transdermal administration, is now being explored as a method to achieve deeper, more controlled delivery into gingival tissues. Early laboratory evidence shows that microneedles enhance tissue permeation, improve drug retention, and offer a minimally invasive approach that may overcome many drawbacks of current periodontal delivery systems. While clinical studies remain limited, the emerging science suggests that microneedles could occupy an important place in the future of precision periodontal therapy.

Keywords:

Local Drug delivery, Microneedles, Minimal invasive Periodontics

Corresponding author: Dr Aishwarya Pradeep(aishwarya.p99@gmail.com)

* Post graduate student, * * Professor, ***Associate Professor, ****Assistant Professor
Department of Periodontics, KMCT Dental College, Kozhikode, Kerala

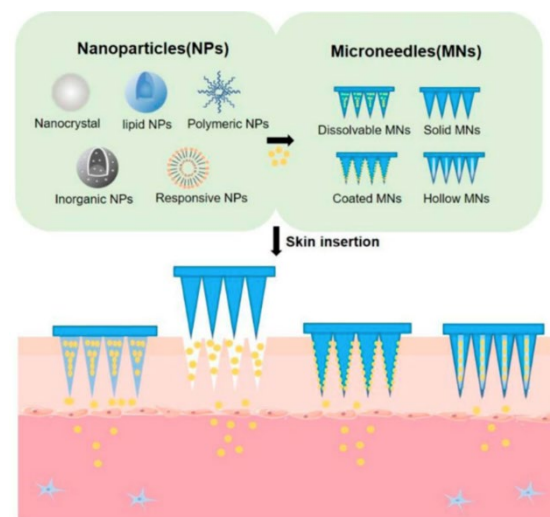
Introduction

Periodontal pockets are uniquely difficult

environments for effective drug delivery because they are narrow, moist, and continually exposed to gingival crevicular



fluid, which dilutes and removes topical medicaments.¹ Although gels, chips, fibres, and microspheres have been used for decades, many fail to sustain therapeutic levels long enough to significantly disrupt established biofilms.² The persistence and structural complexity of biofilms create an additional obstacle by reducing the diffusion of antimicrobial agents and increasing bacterial resistance.³ These challenges have led researchers to explore alternative delivery systems that bypass superficial barriers and transport active agents directly into periodontal tissues. Microneedles, which have proven effective in dermatology and vaccine delivery, have recently attracted interest in dentistry because they can create controlled micro-channels allow drugs to enter tissues more efficiently while causing minimal discomfort.⁴ Their potential to deliver drugs within the periodontal pocket represents a novel approach that aligns well with the trend toward minimally invasive periodontics.⁵ As gingival tissues are relatively accessible and richly vascularized, they provide an attractive target for microneedle-assisted delivery systems. This review explores the scientific background, emerging evidence, and clinical implications of using microneedles for periodontal drug delivery.



The schematic representation of nanoparticle transdermal distribution using microneedles (Jiang et al., 2022)

Microneedles as Micro-Precision Delivery Tools

Microneedles are tiny projections, typically a few hundred microns in length, engineered to penetrate the superficial layers of tissue without causing significant pain or bleeding.⁴ They may be solid, coated, hollow, dissolvable, or hydrogel-forming, and each design offers distinct advantages for drug loading, stability, and release kinetics.⁶ Their primary function is to create microscopic pores or channels that bypass the epithelial barrier, a feature particularly valuable in periodontal therapy where passive diffusion alone is insufficient for deep tissue penetration.⁷ When applied to gingival tissues, microneedles have the potential to deposit antimicrobials, anti-inflammatory agents, or regenerative biomolecules directly into target layers while minimising drug loss to the oral environment.



Overcoming Periodontal Barriers Through Micro-Channel Innovation

The suitability of microneedles for periodontal drug delivery arises from several biological and mechanical advantages. The creation of micro-channels can modestly disrupt biofilm structure, thereby improving the interaction between antimicrobials and bacterial communities.³ By delivering agents beneath the superficial layer, microneedles may also reduce the rate of washout by gingival crevicular fluid, allowing drugs to persist for longer periods at therapeutic concentrations.⁴ Furthermore, the ability to design microneedles in varying lengths and flexibilities makes it theoretically possible to tailor them to different pocket depths or anatomic locations, including curved gingival surfaces.⁷ These features collectively suggest that microneedles could offer a level of precision that is not achievable with conventional delivery systems.

Emerging Evidence from Laboratory and Prototype Studies

Emerging laboratory evidence provides early support for these concepts. In vitro studies demonstrate that microneedle arrays significantly enhance the penetration

of antimicrobials and nanoparticles into soft tissues and biofilm structures.⁸ Hydrogel-forming microneedles are biocompatible and capable of sustained drug release in animal models, which could translate into longer therapeutic action within periodontal pockets.⁶ Experimental prototypes designed for flexible or tissue-conforming application further strengthen the possibility of adapting microneedle technology to the anatomical complexity of the oral cavity.⁹ Although human trials are still scarce, these foundational studies indicate a promising trajectory for periodontal applications.

Clinical Considerations in Bringing Microneedles Chairside

From a clinical perspective, several considerations must be addressed before microneedles can be used chairside. Access to deep posterior pockets, furcation areas, and narrow intra-bony defects may require specially engineered devices capable of angulation or curvature. Safety



data from dermatology and transdermal applications indicate minimal discomfort and low tissue trauma, suggesting that gingival use is likely to be well tolerated, although direct clinical evaluation in periodontal patients is still needed.⁴ Practical factors such as sterilization, cost, ease of handling, and compatibility with existing periodontal instruments will also influence adoption. Despite these challenges, the potential of microneedles to enhance precision, reduce dosing frequency, and improve patient comfort makes them an appealing future adjunct.

A Comparison with Established Local Delivery Approaches

When compared with current local drug delivery systems, microneedles offer several conceptual advantages. Drugs delivered below the epithelial surface are less susceptible to dilution by crevicular fluid, potentially improving retention and bioavailability.⁵ Micro-channel formation enhances biofilm penetration, addressing one of the key limitations of many conventional agents.³ Additionally, microneedles avoid the bulk, placement

difficulty, or patient awareness associated with traditional chips or fibres. At the same time, the absence of robust clinical evidence remains the primary limitation and underscores the need for carefully designed human trials before widespread clinical implementation.¹⁰

Future Pathways for Smart and Responsive Periodontal Therapies

Future research is expanding toward smart microneedles capable of releasing drugs in response to environmental cues such as pH changes or bacterial enzymes, which may allow selective targeting of active disease sites. The incorporation of nanoparticles, antimicrobial peptides, or regenerative molecules into microneedle opens the door for multifunctional periodontal therapies.⁵ Combination approaches, such as microneedling paired with photodynamic therapy, are also being explored to enhance antimicrobial effectiveness. These innovations suggest a future in which microneedles may serve not only as delivery tools but also as a responsive therapeutic platform within periodontal pockets.

Conclusion



Microneedle technology represents an innovative and promising direction for periodontal drug delivery. By enabling deeper, more targeted deposition of therapeutic agents and offering potential advantages in penetration, retention, and patient comfort, microneedles address many of the limitations of current local delivery methods⁵. Although significant clinical work remains to validate safety, effectiveness, and feasibility in human periodontal therapy, the emerging evidence indicates substantial potential for integration into future minimally invasive periodontal practices. As scientific development continues, microneedles may evolve into a valuable tool for periodontists seeking greater precision and efficacy in managing periodontal disease.

References

1. Medlicott NJ, Rathbone MJ, Tucker IG, Holborow DW. *Delivery systems for the administration of drugs to the periodontal pocket. Advanced Drug Delivery Reviews.* 1994;13(1–2):181–203.
2. Bano S, Hassan N, Rafiq M, Hassan F, Rehman M, Iqbal N, et al. *Biofilms as battlefield armor for bacteria against antibiotics. Microorganisms.* 2023;11(10):2595.
3. Xu J, Danehy R, Cai H, Ao Z, Pu M, Nusawardhana A, et al. *Microneedle patch-mediated treatment of bacterial biofilms. ACS Applied Materials & Interfaces.* 2019;11(16):14640–14646.
4. Prausnitz MR, Langer R. *Transdermal drug delivery. Nature Biotechnology.* 2008;26(11):1261–1268.
5. Ita K. *Transdermal delivery of drugs with microneedles. Journal of Drug Delivery Science and Technology.* 2015;29:16–23.
6. Li Y, Bi D, Hu Z, Yang Y, Liu Y, Leung WK. *Hydrogel-forming microneedles for oral disease management. Materials.* 2023;16(13):4805.
7. Yadav PR, Munni MN, Campbell L, Mostofa G, Dobson L, Shittu M, et al. *Translation of polymeric microneedles. Pharmaceutics.* 2021;13(8):1132.
8. Migdadi EM, Donnelly RF. *Microneedles for transdermal drug delivery. In: Imaging Technologies and Transdermal Delivery in Skin Disorders.* 2019:223–270.



9. *Sutradhar SC, Shin H, Kim W, Jang H. Hydrogel films in biomedical applications.*
10. *Qu Y, Zeng H, Wang L, Ge Z, Liu B, Fan Z. Microenvironment-regulated dual-layer microneedle patch. Advanced Functional Materials. 2025;35(19):2418076.*



Review

ADVANCED POLYMERS: REVOLUTIONIZING DENTAL RESTORATIONS

*Dr Anila.K, **Dr Sheejith.M, *** Dr Swapna.C, **** Dr Akhila Aboobacker

Abstract:

Polyaryletherketones (PAEKs) are a class of high-performance thermoplastic polymers that have gained increasing attention in dentistry due to their favourable mechanical properties, chemical stability, and biocompatibility. Among them, polyetheretherketone (PEEK) and polyetherketoneketone (PEKK) have emerged as promising alternatives to conventional metallic and ceramic dental materials. Recent advances in surface modification, reinforcement strategies, and adhesive protocols have expanded their clinical applicability, particularly in prosthodontics and implant dentistry. This review consolidates current evidence on the structure, properties, modifications, and dental applications of PEEK, PEKK, and PAEK-based blends, drawing from recent literature. The advantages, limitations, and future prospects of these materials in oral rehabilitation are also discussed.

Key words: Polyaryletherketone, PEEK, PEKK, Dental biomaterials, Prosthodontics, CAD-CAM dentistry

Corresponding author: Dr Anila.K (anilavimalmadhav@gmail.com)

*Post graduate Student; **Professor and Head, *** Professor, **** Reader, Department of Prosthodontics and Crown and Bridge, KMCT Dental College.

Introduction

The continuous evolution of dental biomaterials aims to achieve optimal biomechanical compatibility, esthetics, and long-term clinical success. Traditional materials such as metals and ceramics, while clinically reliable, exhibit inherent drawbacks including stress shielding, corrosion, hypersensitivity reactions, and esthetic limitations. This has led to increasing interest in high-performance polymers, particularly polyaryletherketones (PAEKs).¹

PAEKs are semicrystalline thermoplastics characterized by aromatic rings linked by ether and ketone groups. Their unique molecular architecture confers excellent thermal stability, chemical resistance, and mechanical strength. Among this family, PEEK and PEKK have demonstrated significant potential in dental applications ranging from removable prostheses to implant-supported restorations.²

Classification and Chemistry of Polyaryletherketones

PAEKs consist of repeating aromatic units interconnected by ether (–O–) and ketone (–CO–) linkages. Variation in the ratio and arrangement of these linkages results in different polymers with distinct physical and mechanical characteristics.

- **PEEK (Polyetheretherketone):**

Contains two ether groups and one ketone group per repeating unit.¹

- **PEKK (Polyetherketoneketone):**

Contains one ether group and two ketone groups, leading to increased rigidity and higher melting temperature.²

- **PAEK Blends:** Combinations of PEEK or PEKK with fillers or reinforcements to enhance specific properties.³

The ketone-to-ether ratio plays a critical role in determining crystallinity, stiffness, thermal resistance, and processability.



Polyetheretherketone (PEEK): Properties and Dental Relevance

1. Mechanical Properties

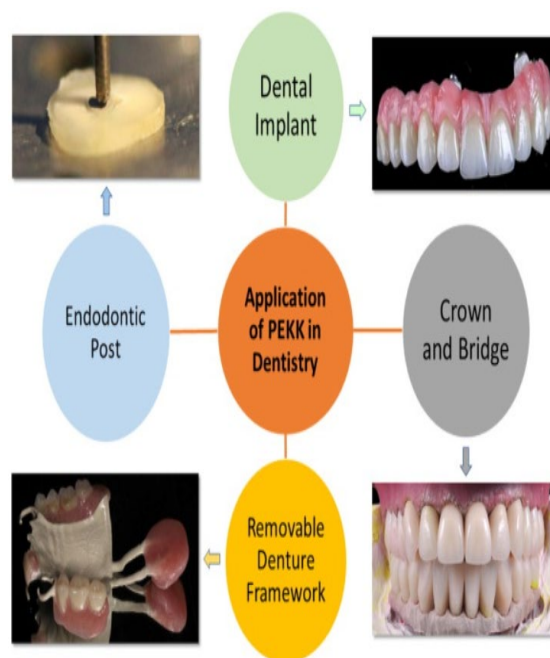
PEEK exhibits an elastic modulus of approximately 3-4 GPa, which closely resembles that of cortical bone. This biomechanical similarity reduces stress shielding and promotes favorable load transfer, particularly in implant-supported restorations. Reinforced PEEK variants, such as carbon fiber-reinforced PEEK (CFR-PEEK), demonstrate significantly higher stiffness and strength.²

2. Biological Properties

PEEK is chemically inert, radiolucent, and biocompatible. Studies report minimal cytotoxicity and favorable tissue response. However, its bioinert surface limits direct osseointegration unless surface modification is employed.⁴

3. Dental Applications

- Frameworks for removable partial dentures
- Implant abutments and provisional implants
- Fixed dental prostheses
- CAD-CAM milled crowns and bridges



Despite these advantages, unmodified PEEK exhibits poor bonding to resin cements and veneering composites, necessitating surface treatments.⁶

Advances in Mechanical and Adhesive Properties of PEEK

Recent research highlights strategies to overcome PEEK's limitations, especially regarding adhesion and esthetics.

1. Surface Modification Techniques

- Sandblasting
- Plasma treatment
- Sulfuric acid etching
- Laser surface modification

These methods increase surface roughness and surface energy, improving bonding efficacy.



2. Reinforcement Strategies

The incorporation of fillers such as carbon fibers, glass fibers, and ceramic particles enhances mechanical strength, wear resistance, and fatigue performance, making PEEK suitable for long-span prostheses.²

Polyetherketoneketone (PEKK): An Emerging Dental Biomaterial

PEKK differs structurally from PEEK by having a higher ketone content, resulting in increased stiffness, hardness, and thermal resistance.

1. Mechanical and Thermal Characteristics

PEKK exhibits superior compressive strength and a higher glass transition temperature compared to PEEK. These properties make it particularly suitable for high-load-bearing dental applications.⁵

2. Clinical Applications

- Implant frameworks
- Fixed prosthodontic frameworks
- Implant-supported full-arch prostheses

PEKK also demonstrates improved surface reactivity, allowing better adhesion to veneering materials compared to PEEK.¹

Polyaryletherketone-Based Blends and Modifications

PAEK blends are developed to tailor material properties for specific clinical demands. Blending PEEK or PEKK with bioactive fillers such as hydroxyapatite enhances osteoconductivity, while polymer-polymer blends improve toughness and machinability. Such modifications allow clinicians to balance rigidity, esthetics, and biological performance according to the prosthetic requirement.³

Advantages of PAEKs in Dentistry

- Excellent biocompatibility
- Bone-like elastic modulus
- Radiolucency
- Chemical and thermal stability
- Compatibility with CAD-CAM technology
- Lightweight and metal-free.⁶

Limitations and Challenges

- Limited intrinsic esthetics
- Poor bonding without surface treatment



- Higher cost compared to conventional polymers

- Limited long-term clinical data.⁴

Future Perspectives

Ongoing research focuses on improving bioactivity through nanocomposites, surface coatings, and additive manufacturing techniques. With continued development and long-term clinical validation, PAEKs are expected to play a significant role in next-generation dental prosthetics.²

Conclusion

Polyaryletherketones represent a promising class of dental biomaterials that bridge the gap between metals and ceramics.¹ PEEK and PEKK, in particular, offer favorable mechanical and biological properties suitable for a wide range of prosthodontic applications.² Advances in surface modification and material blending have significantly expanded their clinical utility. However, further long-term clinical studies are essential to establish standardized protocols and ensure predictable outcomes.⁴

References

1. Moharil S, Reche A, Durge K. Polyetheretherketone (PEEK) as a biomaterial: An overview. Cureus. 2023;15(8):e44307.

2. Luo C, Liu Y, Peng B, et al. PEEK for oral applications: Recent advances in mechanical and adhesive properties. Polymers. 2023;15:386.
3. Korycki A, Carassus F, Tramis O, et al. Polyaryletherketone based blends: A review. Polymers. 2023;15:3943.
4. Maloo LM, Toshniwal SH, Reche A, et al. A sneak peek toward polyaryletherketone (PAEK) polymer: A review. Cureus. 2022;14(11):e31042.
5. Alqurashi H, Khurshid Z, Syed AUY, et al. Polyetherketoneketone (PEKK): An emerging biomaterial for oral implants and dental prostheses. J Adv Res. 2021;28:87–95.
6. Skirbutis G, Dzingute A, Masiliūnaite V, Sulcaite G, Zilinskas J. A review of PEEK polymer's properties and its use in prosthodontics. Stomatologija. 2017;19(1):19-23. PMID: 29243680.



Systematic Review

DIGITAL FABRICATION TECHNOLOGIES OF REMOVABLE PARTIAL DENTURES: A SYSTEMATIC REVIEW

*Dr Nihal Ashraf, **Dr Nicholas Mathew, ***Dr Sheejith M ****Dr Namitha AP

Abstract:

Introduction

Traditionally, removable partial denture (RPD) frameworks have been fabricated using the conventional lost-wax and casting technique. Although this method has served as the foundational approach in prosthodontics for decades, it remains highly technique-sensitive and susceptible to multiple sources of inaccuracy. Distortions arising from wax pattern deformation, investment and casting variables may adversely affect the dimensional accuracy, fit, strength, stability, support and retention of the final framework

The advent of computer-aided design and computer-aided manufacturing (CAD–CAM) technology provides a contemporary solution to these limitations. CAD–CAM–generated frameworks demonstrate superior fit accuracy, enhanced mechanical properties, and improved surface finish compared with conventionally cast counterparts.

Methodology

A comprehensive manual and electronic search was conducted from 2010 to 2025 across 3 databases (PubMed/Medline, EBSCOhost, and Google Scholar) using the key words Computer-Aided Design, Computer-Aided Manufacturing, removable partial dentures, CAD-CAM frameworks, CAD-CAM RPD

Conclusion

CAD–CAM technologies yield removable partial denture frameworks with enhanced dimensional precision, trueness, and overall fit when compared with those produced through conventional casting. These improvements are reflected in retention characteristics, superior adaptation of critical components, and a reduction in fabrication-related discrepancies.



However, differences in accuracy and surface quality between subtractive (milling) and additive manufacturing approaches, the relative high cost of equipment, requirement for trained personnel limits widespread adoption. Additional research is necessary to establish the long-term clinical reliability of digitally fabricated frameworks and to refine and standardize digital protocols across various CAD–CAM systems

Keywords - Digital dentistry, CAD/CAM frameworks, Removable partial dentures, CAD/CAM Cast partial dentures

Corresponding author: Dr Nihal Ashraf (dr.nihal.02@gmail.com)

*Post graduate student, ** Reader, *** Professor and Head, **** Assistant Professor, Department of Prosthodontics and Crown and Bridge, KMCT Dental College.

Digital Manufacturing Techniques for Removable Partial Dentures: Materials, Accuracy, and Clinical Implications

1. Introduction

Conventional lost-wax casting techniques for fabrication of Removable partial denture (RPDs), although clinically reliable, are associated with dimensional inaccuracies and limited compatibility with contemporary materials. In contrast, digital workflows incorporating reductive and additive manufacturing enable improved accuracy, reproducibility, and consistency in the fabrication of both metal and non-metal RPD frameworks by minimizing processing-related discrepancies. This review summarizes current digital manufacturing techniques for RPDs,

including milling, stereolithography, selective laser melting, and selective laser sintering, and compares their accuracy, material properties, clinical performance, advantages, limitations and future directions for enhancing digital workflows and material development.¹

Traditional lost-wax casting techniques are well established for metallic RPD frameworks; however, they are not easily transferable to novel non-metal materials such as aryl ketone polymers. With the increasing demand for metal-free, lightweight, and esthetic prostheses, digital manufacturing technologies have gained prominence. These technologies may be broadly categorized into reductive (subtractive) and additive manufacturing methods.²



2. Reductive (Subtractive) Manufacturing

2.1 Milling Technology

Reductive manufacturing in removable prosthodontics primarily involves computer numerical control (CNC) milling. Denture frameworks or baseplates are milled from pre-fabricated material blanks using CAD/CAM software that controls tool sequencing, motion, and direction. Three-axis milling systems are most commonly used in dentistry for fabrication of crowns, five-axis milling is more suitable for fabrication of RPD frameworks and they yield higher accuracy and adaptability than 3- or 4-axis systems for fabrication of complex RPD designs.^{3,4} The various milling workflows Used for RPD Frameworks are

Dry Milling Systems	Used mainly for polymer-based frameworks; reduces contamination and simplifies workflow	PEEK, PMMA, acetal
Wet Milling Systems	Utilizes coolant for metal and ceramic materials to prevent overheating	Co–Cr, Ti, hybrid ceramics
Hybrid Milling (Wet + Dry)	Combines both; found in systems like <i>Ceramill Motion 2</i>	Co–Cr, zirconia, polymers

Technology / Workflow	Description	Materials commonly fabricated
5-Axis CNC Milling (Subtractive CAD/CAM)	Removes material from solid disks with multi-directional milling burs; ideal for complex RPD designs	Co–Cr, titanium, PEEK, PMMA, zirconia

Comparative investigations of removable partial denture clasp materials indicate that milled clasps fabricated using 5-axis CNC milling technology demonstrate improved manufacturing consistency and surface integrity compared with conventionally cast cobalt–chromium (Co–Cr) clasps. Although the elastic modulus of milled Co–Cr remains similar to that of cast alloys, 5-axis milling enables precise control of clasp geometry, resulting in more predictable flexibility and fracture behavior.⁵



Gray et al. highlighted that the choice between dry and wet milling workflows is largely dependent on the material used for removable partial denture fabrication. Dry milling is particularly suitable for modern metal-free polymeric materials such as PMMA and polyaryletherketones (PAEKs), including PEEK and PEKK, as it simplifies the workflow, avoids coolant contamination. In contrast, wet milling is required for harder materials due to heat generation during machining, but is less commonly indicated for polymer-based RPD frameworks.^{6,7}

2.2 Accuracy and Limitations

5-axis CNC milling, technology provides high accuracy and reproducibility, enables access to complex geometries such as rests and clasps, and reduces the need for manual finishing. However, it is associated with high material waste, prolonged milling times, significant tool wear, difficulty milling very thin clasp arms in metals and high equipment costs. Moreover, milling Co–Cr frameworks remain technically challenging and less efficient than additive manufacturing techniques.⁸

Dry milling systems are primarily used for polymers such as PEEK, PMMA, acetal resin, and pre-sintered zirconia. They offer clean workflow without coolant contamination, faster processing, and are particularly suitable for polymer-based

frameworks. The main limitations include heat generation restricting their use to polymers, unsuitability for metals, and potential surface damage if milling parameters are not carefully optimized.⁹

Wet milling systems are preferred for harder materials such as titanium, Co–Cr (limited), glass/hybrid ceramics, and zirconia. The use of coolant prevents overheating and reduces bur wear. Despite these advantages, milling metal RPD frameworks is time-consuming, tool wear remains significant, and complex framework geometries can exceed milling efficiency. For Co–Cr frameworks, wet milling is generally inferior to selective laser melting techniques.¹⁰

Hybrid milling systems, capable of both wet and dry milling, provide versatility for laboratories handling multiple materials, reducing the need for multiple machines. Nevertheless, these systems require careful workflow optimization, as compromise settings may reduce material-specific accuracy, and maintenance costs are higher. Studies have demonstrated that milled restorations may exhibit inferior marginal fit compared with cast prostheses. Milled titanium crowns have shown larger marginal discrepancies than cast titanium crowns, and milled lithium disilicate veneers demonstrate greater marginal gaps than pressed counterparts, potentially increasing microleakage.¹



Milling is more economically viable for high-impact polymers such as polyetheretherketone (PEEK) and polyetherketoneketone (PEKK), or for producing burnout resin patterns for conventional casting.¹¹

3. Additive Manufacturing (3D Printing)

Additive manufacturing builds objects layer-by-layer from digital design data, enabling the fabrication of complex geometries with reduced material waste. The various additive manufacturing techniques currently in practice are:

Technology	Principle	Materials commonly used for	Key Advantages
Selective Laser Melting (SLM)	Laser melts metal powder layer by layer	Co–Cr , Ti, alloys	High density, strong mechanical properties , excellent fit

Selective Laser Sintering (SLS)	Sintering (not full melting) of polymer or metal powders	Nylon, PEEK, PMMA	Fast production, low residual stress
Direct Metal Laser Sintering (DMLS)	Similar to SLM, optimized for dental alloys	Co–Cr, Ti alloys	Precise surface detail, biocompatibility
Electron Beam Melting (EBM)	Electron beam fuses powder in a vacuum	Titanium	Strong frameworks, minimal oxidation
Digital Light	UV light cures	Photopolymer resin	Used for pattern printing



Processing (DLP)	resin in layers		before casting
Stereolithography (SLA)	Laser cures resin with high accuracy	Dental resin	Used for resin prototype or investment pattern

Alqutaibi et al. (2025) evaluated the application of **selective laser melting (SLM) and direct metal laser sintering (DMLS)** for the fabrication of cobalt–chromium and titanium removable partial denture frameworks. Their study demonstrated high framework density, favorable mechanical properties, and clinically acceptable accuracy compared with conventionally cast frameworks.¹²

Bradfield et al. (2025) investigated multiple **digital fabrication techniques**, including SLM, SLA, and DLP, for removable partial dentures. They reported that SLM-produced metal frameworks exhibited superior fit and reproducibility, while SLA and DLP were most effective for producing accurate resin patterns and prototypes prior to conventional casting.⁷

Nogueira et al. (2020) focused on the **dimensional accuracy and reproducibility** of SLM-fabricated cobalt–chromium RPD frameworks. Their findings indicated improved consistency and reduced distortion when compared with traditional lost-wax casting techniques.

Hassan (2025) examined the use of **selective laser sintering (SLS)** for polymer-based materials such as nylon, PEEK, and PMMA. The study highlighted advantages including rapid fabrication and reduced residual stress, although mechanical properties were inferior to those of metal frameworks.

Yan (2025) assessed **SLS, DLP, and SLA technologies** in removable prosthodontics, emphasizing their role in fabricating polymer frameworks and resin patterns. The author concluded that these techniques are most suitable for provisional frameworks or as intermediates in hybrid digital workflows.

Miyazaki et al. (2023) evaluated **electron beam melting (EBM)** for titanium RPD frameworks. Their study demonstrated that EBM produced strong, oxidation-resistant frameworks under vacuum conditions, supporting its potential use for metal RPD fabrication (12). The principal additive techniques relevant to RPD fabrication include stereolithography (SLA), selective laser melting (SLM), and selective laser sintering (SLS).^{8, 13}



4. Rapid Prototyping Techniques

Rapid prototyping (RP) refers to the automated layer-by-layer fabrication of dental components directly from CAD designs, eliminating wax patterns and manual casting errors. In dentistry, RP is primarily implemented via additive manufacturing (3D printing) for *RPD* frameworks, diagnostic models, wax patterns, and trial dentures.

RP is a subset of Additive Manufacturing (AM), but the term is used when the printed object serves as a prototype, mold, or pattern for final casting or milling.

4.1 Stereolithography (SLA)

SLA was the first additive technique used for dental applications. It employs ultraviolet laser beams to polymerize photosensitive resin layer-by-layer. In prosthodontics, SLA is primarily used to fabricate resin patterns for subsequent conventional casting, eliminating errors associated with manual wax-ups.¹⁴

SLA produces reproducible and consistent patterns but remains time-consuming due to post-processing and casting steps. The need for support structures and sensitivity to laser parameters and resin properties further limits its efficiency. Nevertheless, SLA remains a cost-effective alternative for laboratories without access to high-end metal printing systems.¹⁵

4.2 Selective Laser Melting (SLM)

SLM is an additive manufacturing technique in which fine metal powders are selectively melted using a high-energy laser to produce fully dense metal components directly from CAD data. Initially developed for aerospace and automotive industries, SLM is now widely adopted in dentistry.

SLM eliminates multiple conventional steps such as spruing, investing, casting, and deinvesting. Although initial capital costs are high, SLM offers superior efficiency in terms of labor, time, material utilization, and reproducibility. However, outcomes are highly dependent on CAD file quality, build orientation, and material-specific laser parameters.

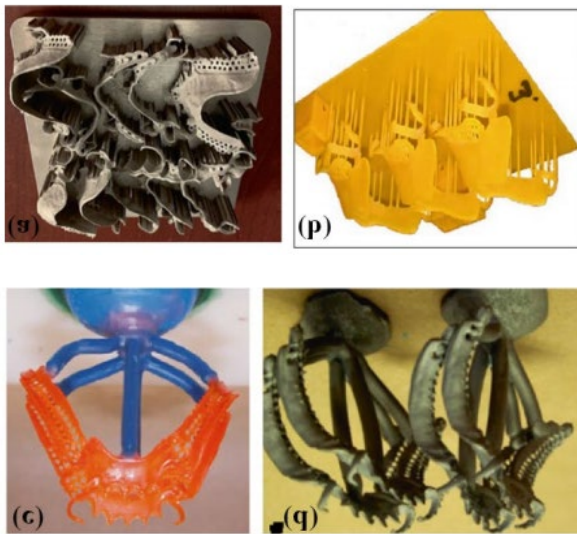
Mechanical properties of SLM-fabricated Co–Cr and titanium alloys have been shown to surpass those of cast alloys. Nevertheless, the technique remains sensitive to processing variables, and post-processing steps are often required.¹⁶

4.3 Selective Laser Sintering (SLS)

SLS uses a CO₂ laser to sinter powdered materials, including polymers, ceramics, and metals, into three-dimensional objects. Unlike SLM, SLS does not fully melt the powder, allowing its application to thermoplastic polymers.

A key advantage of SLS is that the surrounding powder supports the object during fabrication, eliminating the need for

support structures and enabling complex geometries. Unfused powder can be recycled, reducing waste. SLS-fabricated frameworks have demonstrated superior fatigue resistance and mechanical properties compared with cast frameworks and allow high-precision fabrication of components as small as 0.5 mm.¹⁷



(a) Fabrication of the framework. a PRDP frameworks in the building platform processed by laser-sintering technology (b) 3D-printed resin patterns of partial removable dental prostheses (c) resin pattern of PRDP framework with wax sprue ready for casting (d) metal frameworks of Partial removable dental prosthesis cast from 3D-printed resin patterns

Clinical application

The most significant rapid prototyping technologies for RPD fabrication are:

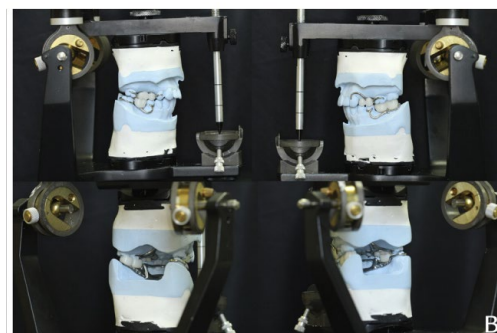
- SLA and DLP — for high-resolution resin pattern fabrication
 - SLS and SLM — for direct metal or polymer framework fabrication
- These RP methods improve accuracy, efficiency, and reproducibility over traditional casting and are rapidly becoming the industry standard for digital removable prosthodontics.

5. Hybrid Milling and Casting Techniques

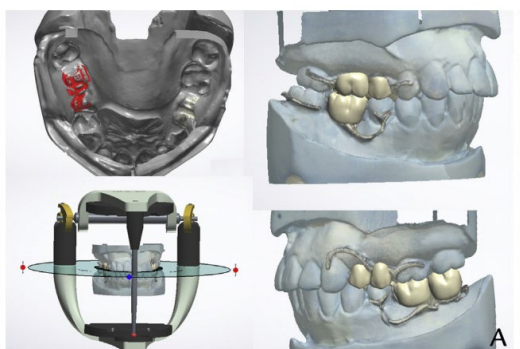
Prefabricated denture teeth are produced in various shapes and sizes and can be adjusted to fit an edentulous area. However, even with the available range of tooth forms, significant modification is often necessary to adapt the teeth to the available space. In cases with severe discrepancies in the edentulous area, adjusting prefabricated teeth can be inefficient and time-consuming.

An alternative approach involves the use of digital technology to design and fabricate customized denture teeth directly for the cast metal framework. When replacing multiple missing teeth, the edentulous region is designed as a splinted unit with connectors, similar to a fixed partial denture. The customized teeth are milled from a double cross-linked polymer and used for a wax try-in. After clinical verification, the RPD is

processed using heat-polymerized acrylic resin. Additional adjustments to the milled teeth are performed after wax elimination to enhance bonding and reduce the risk of acrylic resin debonding.¹⁷



A, Fit of teeth on cast metal framework evaluated to ensure engaging fit. B, Occlusion verified



A, Tooth designed to fit over cast metal framework and occlusion optimized. B, Prosthetic teeth milled in double-cross-linked polymer



For practitioners experienced with traditional removable partial denture fabrication, this approach offers a relatively simple way to incorporate digital tooth arrangement into their workflow. This technique can be advantageous in cases with limited interocclusal or interarch space, as it helps reduce the extensive grinding.

However, Clinicians with limited experience in CAD-CAM technology may find that scanning, designing, and milling custom teeth initially requires more time than modifying prefabricated denture teeth and may not completely eliminate the need for occlusal adjustments.

Overall clinical time savings are moderate due to the continued need for casting, finishing, and fitting. High equipment costs initially limited adoption, but hybrid workflows remain a practical transitional solution for many laboratories.¹⁸

6. Development of Metal-Free



Denture Materials

Early metal-free alternatives to PMMA included polyamides and acetal resins. These materials are fabricated using injection molding, which reduces polymerization shrinkage and improves dimensional stability. Polyamides offer excellent esthetics, flexibility, patient comfort, and retention without metal clasps.¹⁹

However, their low rigidity, increased surface roughness, difficulty in bonding to repair resins, and susceptibility to biofilm accumulation limit their long-term clinical performance. The tissue-borne nature of these dentures may also contribute to alveolar resorption and occlusal instability, particularly in distal extension cases.^{20,21}

7. Advantages and Challenges of Digital RPD Fabrication

7.1 Advantages

Digital workflows simplify denture design by enabling virtual surveying, undercut analysis, and path of insertion determination. CAD/CAM enhances precision, reproducibility, communication among stakeholders, and ease of prosthesis duplication. Digital fabrication reduces clinical appointments, improves fit, minimizes microbial colonization, and supports standardization in clinical research.

Additive manufacturing techniques also reduce material waste and enable environmentally sustainable production through powder recycling.²⁰

7.2 Challenges

Limitations remain in the accurate digital capture of soft tissue contours, particularly in edentulous areas particularly in Kennedy Class 1 and Kennedy Class II cases. Border Moulding movements to record functional areas are not accurately captured during intra oral scanning. High initial equipment costs, steep learning curves, and the continued need for manual finishing and polishing prevent complete replacement of conventional workflows. Additive manufacturing may also produce surface roughness due to the stair-step effect, necessitating post-processing.²⁰

8. Accuracy, Fit, and Material Performance

8.1 Digital Impressions and Jaw Relations

Digital impression accuracy decreases with increasing edentulous span, although artificial landmarks can improve trueness and precision. Digital maxillomandibular relation records are most accurate in minimally edentulous arches and less reliable in extensive edentulism.



8.2 Framework Fit and Surface Characteristics

SLM frameworks generally demonstrate higher trueness than cast frameworks, although clinical fit varies depending on design, relief, and build orientation. Casting remains superior for overall fit in Co–Cr frameworks, while SLM shows advantages for titanium frameworks. Hybrid processing improves surface roughness compared with either technique alone.

8.3 Mechanical Properties

SLM-fabricated Co–Cr and titanium alloys exhibit superior yield strength, tensile strength, and fatigue resistance compared with cast alloys. Fatigue resistance is influenced by build orientation, with optimal results achieved when clasp arms are oriented perpendicular to the build direction.

9. Denture Bases and Artificial Teeth

Digitally fabricated denture bases commonly use PMMA-based materials, while artificial teeth may be fabricated from PMMA, composite resin, zirconia, or PEEK. Printing orientation influences flexural strength and surface roughness. Nano-filler incorporation has shown promise in enhancing mechanical and antibacterial properties. Bond strength remains highest with heat-cured PMMA systems.

10. Future Directions

Future research should focus on:

1. Automated CAD software for framework design
2. Predictive digital treatment planning
3. Improved bonding between frameworks and denture bases
4. Development of denture base materials superior to PMMA
5. Reduction in system and fabrication costs

Conclusion

Digital manufacturing has significantly advanced removable partial denture fabrication, offering improved precision, material performance, and workflow efficiency. While challenges remain in soft tissue capture, cost, and surface quality, ongoing advancements in materials, software, and additive manufacturing technologies are expected to expand the clinical applicability of digital RPDs.

or topical analgesics may be beneficial.

References

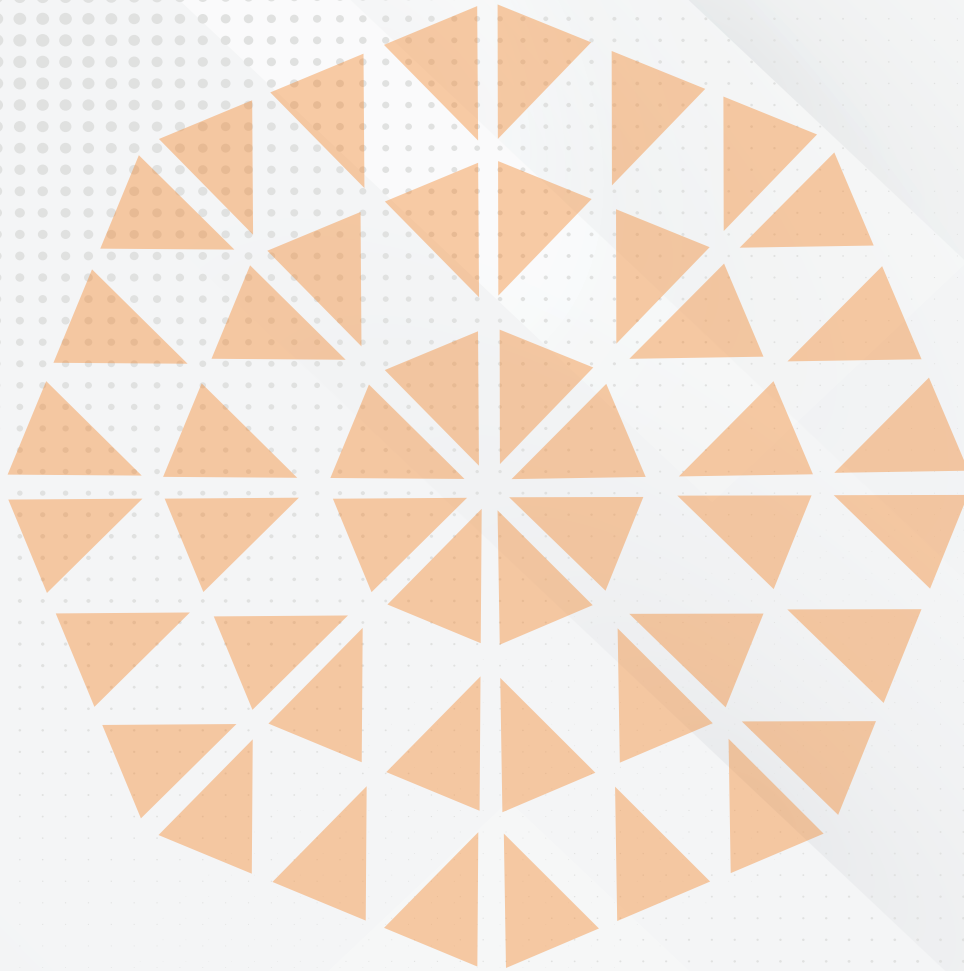
1. Abduo J, Lyons K, Bennamoun M. Trends in computer-aided manufacturing in prosthodontics: a review of the available streams. *Int J Dent*. 2014;2014:783948.



2. The Glossary of Prosthodontic Terms 2023: Tenth Edition. J Prosthet Dent. 2023 Oct;130(4 Suppl 1):e1–3.
3. Han HS, Yang HS, Lim HP, Park YJ. Marginal accuracy and internal fit of machine-milled and cast titanium crowns. J Prosthet Dent. 2011 Sept;106(3):191–7.
4. Pilecco RO, Machry RV, Baldi A, Tribst JPM, Sarkis-Onofre R, Valandro LF, et al. Influence of CAD-CAM milling strategies on the outcome of indirect restorations: A scoping review. J Prosthet Dent. 2024 May;131(5):811.e1-811.e10.
5. Abduo J, Lyons K, Swain M. Fit of zirconia fixed partial denture: a systematic review. J Oral Rehabil. 2010 Nov;37(11):866–76.
6. Gray D, Barraclough O, Ali Z, Nattress B. Modern partial dentures - part 2: a review of novel metal-free materials and innovations in polymers. Br Dent J. 2021 June;230(12):813–8.
7. Bradfield C, Sykes LM, Mmutlana TI, Warren N. A comparison of the flexibility and fracture point of cast cobalt-chromium, milled cobalt-chromium, laser printed cobalt-chromium and milled Polyetherketoneketone partial denture clasps. South Afr Dent J. 2025 Mar 25;80(01):20–8.
8. Alqutaibi AY, Al-Gabri RS, Al-Zaghruri AS, Farghal AE, Alnazzawi AA, Alghauli MA. Clinical performance, accuracy, and physical-mechanical properties of 3D-printed removable partial denture metal frameworks compared with conventionally and partially digitally produced frameworks: A systematic review. J Prosthodont Res. 2025 Sept 3;
9. Zoidis P, Papathanasiou I, Polyzois G. The Use of a Modified Poly-Ether-Ether-Ketone (PEEK) as an Alternative Framework Material for Removable Dental Prostheses. A Clinical Report. J Prosthodont Off J Am Coll Prosthodont. 2016 Oct;25(7):580–4.
10. Kalberer N, Mehl A, Schimmel M, Müller F, Srinivasan M. CAD-CAM milled versus rapidly prototyped (3D-printed) complete dentures: An in vitro evaluation of trueness. J Prosthet Dent. 2019 Apr;121(4):637–43.
11. Lima JMC, Anami LC, Araujo RM, Pavanelli CA. Removable partial dentures: use of rapid prototyping. J Prosthodont Off J Am Coll Prosthodont. 2014 Oct;23(7):588–91.
12. Elhadery SS, Alhadj MN, Yunus N, Ibrahim N, Abidin ZZ, Ahmad SF, et al. Adaptation of cobalt chromium



- frameworks fabricated by conventional versus selective laser melting techniques: An in vitro and clinical assessment. *J Prosthet Dent*. 2025 Nov;134(5):1836–42.
13. Quadri S, Kapoor B, Singh G, Tewari R. Rapid prototyping: An innovative technique in dentistry. *J Oral Res Rev*. 2017;9(2):96.
 14. Almufleh B, Tamimi F, Caron E, Alageel O. 3D-Printed Removable Partial Dentures. In: Tamimi F, Hirayama H, editors. *Digital Restorative Dentistry: A Guide to Materials, Equipment, and Clinical Procedures* [Internet]. Cham: Springer International Publishing; 2019 [cited 2025 Oct 12]. p. 95–113. Available from: https://doi.org/10.1007/978-3-030-15974-0_5
 15. Alifui-Segbaya F. Additive Manufacturing: A Novel Method for Fabricating Cobalt-Chromium Removable Partial Denture Frameworks. *Eur J Prosthodont Restor Dent*. 2017 June 1;(25):73–8.
 16. Koutsoukis T, Zinelis S, Eliades G, Al-Wazzan K, Rifaiy MA, Al Jabbari YS. Selective Laser Melting Technique of Co-Cr Dental Alloys: A Review of Structure and Properties and Comparative Analysis with Other Available Techniques. *J Prosthodont Off J Am Coll Prosthodont*. 2015 June;24(4):303–12.
 17. Muralidharan C, Schneider RL, Kotowske S. CAD-CAM denture teeth made on cast metal removable partial denture frameworks. *J Prosthet Dent*. 2024 June;131(6):1029–33.
 18. Torabi K, Farjood E, Hamedani S. Rapid Prototyping Technologies and their Applications in Prosthodontics, a Review of Literature. *J Dent Shiraz Iran*. 2015 Mar;16(1):1–9.
 19. Liu Q, Schmitt S, Leu MC. Rapid Prototyping in Dentistry: Technology and Application. *Int J Adv Manuf Technol* [Internet]. 2006 June 1; Available from: https://scholarsmine.mst.edu/mec_aer_eng_facwork/1794
 20. Aly Sadek S, Dehis WM, Hassan H. Comparative Study Clarifying the Most Suitable Material to Be Used as Partial Denture Clasps. *Open Access Maced J Med Sci*. 2018 June 20;6(6):1111–9.
 21. Vojdani M, Giti R. Polyamide as a Denture Base Material: A Literature Review. *J Dent Shiraz Iran*. 2015 Mar;16(1 Suppl):1–9.



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