Journal of
Polymer & Composites
ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 13, Special Issue 6, 2025
DOI (Journal): 10.37591/JoPC
https://journals.stmjournals.com/jopc
Review JoPC

Integration of Polymer Chemistry in the Development of an Occlusal Plane Analysis Device

Pronob Sanyal[1,*], Vishwajeet Deshmukh[2], Arem Sarath Kumar[3]

Abstract

Occlusal plane analysis has been transformed by the use of polymer-based materials in dental applications. The present study explores the integration of polymer chemistry into the design and manufacturing of a novel occlusal plane analysis device. Key polymeric materials such as polymethyl methacrylate (PMMA), polyetheretherketone (PEEK), and fiber-reinforced polymer composites (FRPCs) are assessed for ease of fabrication, mechanical qualities, and biocompatibility. The study also highlights the role of polymer processing techniques, including injection molding and 3D printing, in enhancing the device's accuracy and efficiency. Furthermore, smart polymers and nanocomposites offer promising advancements in dental diagnostic tools, improving durability and precision. Recent developments in polymer science allow for enhanced performance by incorporating bioactive agents and antimicrobial properties, further improving oral health outcomes. Additionally, the use of biodegradable polymers in disposable dental devices is explored as an environmentally sustainable alternative. The integration of polymer science into dental instrumentation demonstrates the potential for innovative, lightweight, and high-performance materials in modern dentistry. This study provides a comprehensive review of how polymer chemistry continues to shape advancements in occlusal plane analysis and its implications for the future of dental technology.

Keywords: Occlusal plane, photopolymerization, polymer chemistry, polymethyl methacrylate, polyetheretherketone.

INTRODUCTION

As a reference for occlusal adjustments, prosthetic fabrication, and craniofacial symmetry evaluations, the occlusal plane is essential in orthodontics, maxillofacial surgery, and dental prosthetics [1]. Traditional methods for analysing the occlusal plane rely on mechanical tools, such as the dental fox plane, which lack precision and adaptability [2]. These conventional methods often require subjective assessments, leading to inconsistencies and increased human error. Furthermore, traditional occlusal analysis tools are frequently made from metal or rigid plastics, which can be uncomfortable for patients and difficult to customize for individual anatomical variations [3].

Recent advances in material science, particularly in polymer chemistry, provide innovative solutions for occlusal plane analysis devices [4]. By incorporating polymer-based materials, the design and manufacturing of these devices can be significantly enhanced, allowing for improved flexibility, durability, and precision. Polymers such as polymethyl methacrylate (PMMA), polyetheretherketone (PEEK), and fiber-reinforced polymer composites (FRPCs) offer unique

*Author for Correspondence
Pronob Sanyal

[1]Professor & Head, Department of Prosthodontics and Crown & Bridge, School of Dental Sciences, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad, Maharashtra, India
[2]Researcher, Department of Prosthodontics and Crown & Bridge, School of Dental Sciences, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad, Maharashtra, India
[3]Researcher, Department of Prosthodontics and Crown & Bridge, School of Dental Sciences, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad, Maharashtra, India

Received Date: March 12, 2024
Accepted Date: April 11, 2025
Published Date: August 29, 2025

Citation: Pronob Sanyal, Vishwajeet Deshmukh, Arem Sarath Kumar. Integration of Polymer Chemistry in the Development of an Occlusal Plane Analysis Device. Journal of Polymer & Composites. 2025; 13(Special Issue 6): S180–S187p.

advantages, including superior biocompatibility, lightweight properties, and resistance to wear and microbial growth [5].

Additionally, the development of smart polymer-based occlusal analysis devices equipped with responsive properties—such as shape-memory behavior and electroactive functionalities—enables real-time data collection and adaptive adjustments. These advancements facilitate greater accuracy in dental diagnostics and treatment planning.

Beyond the material benefits, polymer-based occlusal plane analyzers offer ergonomic advantages. The lightweight nature of polymer components reduces strain on both the patient and the clinician during use [6]. Furthermore, polymers allow for enhanced customization, as digital fabrication techniques such as 3D printing enable patient-specific modifications. By incorporating antimicrobial and bioactive agents into polymer formulations, these devices can also improve patient hygiene and reduce the risk of infections [7].

The shift toward polymer-based solutions is part of a broader trend in modern dentistry, where advanced materials are integrated into diagnostic and therapeutic tools [8]. With ongoing research and development in polymer chemistry, new formulations continue to emerge that enhance device performance, extend durability, and introduce innovative functionalities.

This study aims to explore the role of polymer chemistry in improving occlusal plane analysis tools, detailing the latest material innovations, manufacturing techniques, and potential applications that enhance the efficiency and effectiveness of dental instrumentation [9]. The findings highlight the intersection of polymer science and dental technology, emphasizing the transformative potential of advanced materials in oral healthcare [10]. Figure 1 shows Custom made Broadrick occlusal plane analyzer attached on a semi adjustable articulator [11].

POLYMERIC MATERIALS IN DENTAL DEVICES

Polymeric materials have become an essential component in modern dental applications due to their versatility, durability, and biocompatibility [12]. They play a critical role in occlusal plane analysis devices, offering improved accuracy and patient comfort. Recent advancements in polymer science have led to the development of high-performance materials that enhance the efficiency of dental tools, reduce weight, and increase ease of fabrication. The incorporation of polymeric materials into dental devices provides significant advantages, including resistance to wear, chemical stability, and customization potential through modern fabrication techniques such as 3D printing and injection molding.[13] Moreover, the integration of antimicrobial agents into polymers can enhance the hygiene and longevity of occlusal analysis tools, reducing the risk of bacterial contamination in clinical environments.

Biocompatible Polymers

Biocompatible polymers are essential in modern dental applications due to their ability to interact safely with biological tissues while maintaining durability and functionality.[14] These polymers exhibit low cytotoxicity, excellent mechanical strength, and high resistance to degradation, making them ideal for occlusal plane analysis devices and other dental tools. Advances in polymer chemistry have led to the development of new formulations that enhance adhesion, flexibility, and antimicrobial properties, further improving patient safety and treatment outcomes [15].

Polymethyl Methacrylate (PMMA)

Used for its excellent transparency, ease of processing, and biocompatibility. It serves as an ideal material for components requiring dimensional accuracy and aesthetic properties. PMMA also offers high resistance to wear and chemical degradation, making it a preferred choice for long-term dental applications [16]. Additionally, PMMA can be modified with bioactive agents to promote tissue integration and antimicrobial effects.

ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

Figure 1. Custom made Broadrick occlusal plane analyzer attached on a semi adjustable articulator [11].

Polyetheretherketone (PEEK)

A high-performance polymer known for its exceptional strength, resistance to wear, and compatibility with intraoral applications [17]. It has emerged as a superior alternative to traditional metal-based materials, offering improved patient comfort and reduced weight while maintaining structural integrity. PEEK is also radiolucent, making it advantageous for use in diagnostic imaging without interference [18].

Polyurethane-based Materials

These offer flexibility and shock absorption, reducing patient discomfort during occlusal analysis. They also exhibit excellent mechanical properties that enhance the longevity of dental diagnostic devices, making them suitable for repeated use in clinical settings. Polyurethane materials can also be tailored for varying degrees of stiffness, ensuring optimal customization for different occlusal plane applications [19].

Silicone-based Polymers

Frequently used for their superior elasticity and adaptability in occlusal plane devices, ensuring patient comfort and precision in measurement [20]. Their soft and flexible nature allows for a more accurate fit, minimizing errors in occlusal analysis. Additionally, silicone polymers are resistant to temperature changes and chemical exposure, making them highly durable for extended clinical use.

Hydrogel-based Polymers

Emerging as a new frontier in dental applications, hydrogels possess the ability to retain large amounts of water while maintaining structural integrity [21]. These polymers can be used in customized dental impressions and occlusal devices that conform to patient-specific anatomical structures, offering improved diagnostic accuracy. Hydrogels are also being explored for their potential in drug delivery applications, where they can release therapeutic agents over time [22].

Antimicrobial Polymers

Incorporating antimicrobial agents, such as silver nanoparticles or quaternary ammonium compounds, into polymer matrices has proven to reduce bacterial colonization on dental devices [23]. This innovation enhances oral hygiene and extends the functional lifespan of occlusal plane analyzers, making them more reliable for long-term use. Future developments may involve self-sterilizing polymers, which actively inhibit microbial growth over extended periods [24].

Biodegradable Polymers

As sustainability becomes a priority in healthcare, biodegradable polymers are being explored for temporary dental applications. These materials gradually break down in the oral environment, reducing medical waste and eliminating the need for manual removal of disposable components. Biodegradable polymers are particularly useful for short-term occlusal analysis devices and pediatric dental applications [25].

Conductive Polymers

Advanced polymer research has introduced electrically conductive materials that can be integrated into smart dental devices [26]. These polymers enable real-time monitoring of occlusal forces and jaw movements, providing valuable data for clinicians to refine treatment strategies. Conductive polymers open the door to intelligent occlusal analysis tools that interface with digital diagnostic systems.

Composite Materials in Occlusal Plane Analysis

Composite materials have significantly contributed to advancements in occlusal plane analysis by enhancing mechanical properties, reducing weight, and improving durability [27]. These materials, which combine a polymer matrix with reinforcement elements, provide superior performance compared to traditional materials. Their integration into dental applications allows for greater precision, longevity, and comfort in occlusal analysis devices [28].

Fiber-Reinforced Polymer Composites (FRPCs)

These materials consist of high-strength fibers embedded in a polymer matrix, such as carbon or glass fibers. They provide enhanced mechanical stability, reduced weight, and increased flexibility, making them ideal for precision dental tools. The fibers improve resistance to deformation and wear, ensuring long-term reliability.[29].

Nanocomposite Polymers

These advanced materials incorporate nanoparticles like silver, titanium dioxide, or hydroxyapatite into polymer matrices, enhancing their antibacterial properties, mechanical strength, and resistance to microbial adhesion. Nanocomposites have proven beneficial in preventing biofilm formation on dental devices, improving patient hygiene and extending device lifespan.[30].

Bioactive Polymers

Designed to release therapeutic agents, bioactive polymers play a crucial role in promoting healing, preventing infections, and enhancing biological integration with tissues [31]. They are gaining prominence in occlusal analysis and restorative dentistry due to their ability to improve patient outcomes and contribute to regenerative treatments.

Hybrid Composites

Combining multiple reinforcement materials, hybrid composites offer tailored mechanical properties for specialized applications. These materials balance strength, flexibility, and biocompatibility, ensuring optimal performance in occlusal plane devices [32].

With continuous advancements in polymer chemistry, composite materials continue to drive innovation in dental technology, offering enhanced precision, patient comfort, and long-term reliability.

ADVANCED POLYMER PROCESSING IN DEVICE FABRICATION

Polymer processing techniques play a vital role in the fabrication of advanced dental devices, including occlusal plane analyzers.[33] The development of precise and customizable dental tools is highly dependent on the manufacturing methods used. Modern polymer processing methods offer enhanced control over material properties, ensuring high precision, durability, and patient comfort. The choice of processing technique directly influences the mechanical performance, biocompatibility, and aesthetic quality of the final dental product [34].

ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

Injection Molding

Used for mass production of high-precision components with consistent quality. This process allows for the efficient fabrication of durable polymer components with intricate geometries, minimizing material waste and reducing production costs. Advances in multi-material injection molding enable the creation of hybrid dental components with enhanced mechanical properties [35].

3D Printing with Photopolymers

Enables the fabrication of complex, customized geometries tailored to individual patient needs [36]. Digital Light Processing (DLP) and Stereolithography (SLA) techniques provide high resolution and excellent surface finish, making them ideal for dental applications. 3D printing also allows for rapid prototyping and iterative design modifications, improving the development of occlusal plane analyzers [37].

Photopolymerization Techniques

These improve structural stability and enable rapid prototyping for device development. Light-curing resins with tailored polymerization kinetics offer enhanced strength and reduced shrinkage, ensuring precise alignment and fit of dental devices [38].

Extrusion and Thermoforming

Extrusion processes allow for the continuous production of polymer sheets and tubes used in dental appliances. Thermoforming, which involves heating a polymer sheet and molding it into the desired shape, is widely used in creating occlusal splints and protective mouthguards [39].

Electrospinning for Nanofiber Scaffolds

A promising technique for the development of biocompatible and antimicrobial dental surfaces. Electrospun polymer nanofibers provide high surface area and enhanced bioactivity, making them suitable for integration into occlusal plane analyzers and other dental diagnostic tools [40].

Plasma Surface Modification

A technique that enhances the surface properties of polymer-based dental devices by improving wettability, adhesion, and antibacterial characteristics. Plasma-treated polymer surfaces exhibit improved osseointegration and resistance to biofilm formation, contributing to the longevity of occlusal plane analyzers [41].

FUTURE PROSPECTS: SMART AND BIODEGRADABLE POLYMERS

The future of dental materials lies in the development of smart and biodegradable polymers that can enhance diagnostic capabilities, improve patient comfort, and promote sustainability. Advances in polymer chemistry continue to push the boundaries of what is possible, enabling the creation of materials that respond dynamically to external stimuli and degrade naturally over time.

Shape-Memory Polymers (SMPs)

These innovative materials can change shape in response to temperature, moisture, or mechanical stress, allowing for improved patient-specific customization.[42] SMPs are particularly valuable in occlusal plane analysis devices, where adaptability to patient anatomy is crucial for accurate measurements.

Biodegradable Polymers

The increasing demand for sustainable materials has led to the development of biodegradable polymers for temporary and single-use dental applications. Materials such as polylactic acid (PLA) and polycaprolactone (PCL) degrade naturally, reducing medical waste and environmental impact [43].

Electroactive Polymers (EAPs)

These polymers can respond to electrical stimuli, making them suitable for real-time occlusal pressure monitoring and dynamic assessment of bite forces [44]. EAPs have the potential to revolutionize occlusal diagnostics by providing continuous, real-time data for clinicians.

Self-Healing Polymers

These materials can repair micro-damage autonomously, extending the lifespan of occlusal analysis devices and reducing the need for frequent replacements [45].

Bioactive Polymers

Designed to interact positively with biological tissues, bioactive polymers can release therapeutic agents to promote healing and prevent infections, further enhancing the functionality of occlusal plane analysis devices.[46].

CONCLUSION

The integration of polymer chemistry in the design of occlusal plane analysis devices enhances their functionality, durability, and precision. The use of high-performance polymers, advanced fabrication techniques, and emerging smart materials represents the future of dental diagnostic tools. By leveraging polymer-based innovations, the field of dental technology continues to advance towards more efficient and patient-friendly solutions. Advancements in polymer processing technology continue to push the boundaries of dental material science, enabling the production of highly efficient and patient-friendly occlusal plane analysis devices. Future developments are expected to integrate smart manufacturing techniques, such as AI-driven design optimization and automated precision molding, to further refine the performance of polymer-based dental tools. The continued development of these advanced polymer materials is expected to significantly enhance the efficiency, longevity, and sustainability of dental diagnostic tools, paving the way for the next generation of innovative dental solutions.

REFERENCES

1. Melsen B, Athanasiou AE, editors. Dentofacial and occlusal asymmetries. *John Wiley & Sons;* 2024 Aug 28.
2. Mazurkiewicz P, Oblizajek M, Rzeszowska J, Sobolewska E, Ey-Chmielewska H, Szymańska-Kozula R. Determining the occlusal plane: a literature review. CRANIO®. 2022 Jul 4;40(4):341-7.
3. Valenti C, Federici MI, Coniglio M, Betti P, Pancrazi GP, Tulli O, Masciotti F, Nanussi A, Pagano S. Mechanical and biological properties of polymer materials for oral appliances produced with additive 3D printing and subtractive CAD-CAM techniques compared to conventional methods: a systematic review and meta-analysis. Clinical Oral Investigations. 2024 Jun 25;28(7):396.
4. Nassif M, Haddad C, Habli L, Zoghby A. Materials and manufacturing techniques for occlusal splints: A literature review. *Journal of Oral Rehabilitation.* 2023 Nov;50(11):1348-54.
5. Oladele IO, Onuh LN, Siengchin S, Sanjay MR, Adelani SO. Modern applications of polymer composites in structural industries: a review of philosophies, product development, and graphical applications. *Applied Science and Engineering Progress.* 2024.
6. Darie-Niță RN, Râpă M, Frąckowiak S. Special features of polyester-based materials for medical applications. *Polymers.* 2022 Feb 27;14(5):951.
7. Choudhury M, Bindra HS, Singh K, Singh AK, Nayak R. Antimicrobial polymeric composites in consumer goods and healthcare sector: *A healthier way to prevent infection. Polymers for Advanced Technologies.* 2022 Jul;33(7):1997-2024.
8. Chaudhary S, Avinashi SK, Rao J, Gautam C. Recent advances in additive manufacturing, applications and challenges for dentistry: a review. *ACS Biomaterials Science & Engineering.* 2023 Jun 12;9(7):3987-4019.
9. Valenti C, Federici MI, Coniglio M, Betti P, Pancrazi GP, Tulli O, Masciotti F, Nanussi A, Pagano S. Mechanical and biological properties of polymer materials for oral appliances produced with additive 3D printing and subtractive CAD-CAM techniques compared to conventional methods: a systematic review and meta-analysis. *Clinical Oral Investigations.* 2024 Jun 25;28(7):396.

ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

10. Chojnacka K, Moustakas K, Mikulewicz M. Multifunctional cellulose-based biomaterials for dental applications: *A sustainable approach to oral health and regeneration. Industrial Crops and Products.* 2023 Nov 1;203:117142.
11. Gerard F, Dehurtevent M, Chai F, Zamorski N, Lefevre C. Effectiveness of a New Broadrick Flag Support for Assisting Students With the Design of an Occlusal Plane. *European Journal of Dental Education.* 2025 Feb;29(1):44-9.
12. Taymour N, Abd El-Fattah A, Kandil S, Fahmy AE, Al-Qahtani NH, Khaled A, Al-Dulaijan YA, Gepreel MA. Revolutionizing Dental Polymers: The Versatility and Future Potential of Polyetheretherketone in Restorative Dentistry. *Polymers.* 2024 Dec 31;17(1):80.
13. Singh AB, Khandelwal C, Dangayach GS. Revolutionizing healthcare materials: Innovations in processing, advancements, and challenges for enhanced medical device integration and performance. *Journal of Micromanufacturing.* 2024:25165984241256234.
14. Paradowska-Stolarz A, Wieckiewicz M, Owczarek A, Wezgowiec J. Natural polymers for the maintenance of oral health: Review of recent advances and perspectives. *International journal of molecular sciences.* 2021 Sep 25;22(19):10337.
15. Nakipoglu M, Tezcaner A, Contag CH, Annabi N, Ashammakhi N. Bioadhesives with antimicrobial properties. *Advanced Materials.* 2023 Dec;35(49):2300840.
16. Chuchulska B, Dimitrova M, Vlahova A, Hristov I, Tomova Z, Kazakova R. Comparative Analysis of the Mechanical Properties and Biocompatibility between CAD/CAM and Conventional Polymers Applied in Prosthetic Dentistry. *Polymers.* 2024 Mar 22;16(7):877.
17. Chuchulska B, Dimitrova M, Vlahova A, Hristov I, Tomova Z, Kazakova R. Comparative Analysis of the Mechanical Properties and Biocompatibility between CAD/CAM and Conventional Polymers Applied in Prosthetic Dentistry. *Polymers*. 2024 Mar 22;16(7):877.
18. Zhang J, Xu M, Zhang N, Wang T, Zhang Y, Yang Z, Wang Q. Advances and Applications of 4D-Printed High-Strength Shape Memory Polymers. *Additive Manufacturing Frontiers.* 2024 Jan 26:200115.
19. Benouhiba A, Holzer S, Konstantinidi S, Civet Y, Perriard Y. The elastic frontier: Dielectric elastomer actuators in healthcare technology. *Smart Materials and Structures.* 2025 Jan 24.
20. Khan F, Atif M, Haseen M, Kamal S, Khan MS, Shahid S, Nami SA. Synthesis, classification and properties of hydrogels: Their applications in drug delivery and agriculture. *Journal of Materials Chemistry B.* 2022;10(2):170-203.
21. Arora S, Das G, Alqarni M, Grover V, Manzoor Baba S, Saluja P, Hassan SA, Abdulla AM, Bavabeedu SS, Abullais SS, Chahal GS. Role of chitosan hydrogels in clinical dentistry. *Gels.* 2023 Aug 29;9(9):698.
22. Balcerak-Woźniak A, Dzwonkowska-Zarzycka M, Kabatc-Borcz J. A comprehensive review of stimuli-responsive smart polymer materials—recent advances and future perspectives. *Materials.* 2024 Aug 28;17(17):4255.
23. Featherstone JD. Dental restorative materials containing quaternary ammonium compounds have sustained antibacterial action. *The Journal of the American Dental Association.* 2022 Dec 1;153(12):1114-20.
24. Liu M, Bauman L, Nogueira CL, Aucoin MG, Anderson WA, Zhao B. Antimicrobial polymeric composites for high-touch surfaces in healthcare applications. *Current Opinion in Biomedical Engineering.* 2022 Jun 1;22:100395.
25. Xu Q, Fa H, Yang P, Wang Q, Xing Q. Progress of biodegradable polymer application in cardiac occluders. *Journal of Biomedical Materials Research Part B: Applied Biomaterials.* 2024 Jan;112(1):e35351.
26. Zhang Y, Zhang W, Yang M, Mengqi L, Zhou L, Liu Y, Liu L, Zheng Y. Comprehensive review of polyetheretherketone use in dentistry. *Journal of Prosthodontic Research.* 2025:JPR_D_24_00142.
27. Rathna RP, Kulandhaivel M. Advancements in wound healing: integrating biomolecules, drug delivery carriers, and targeted therapeutics for enhanced tissue repair. *Archives of Microbiology.* 2024 Apr;206(4):199.
28. Ijaz MH. Advances in CAD/CAM technology for chairside Restorative Dentistry: A workflow analysis. *Journal of dental care.* 2024 Dec 10;1(2):86-99.

29. Harle SM. Durability and long-term performance of fiber reinforced polymer (FRP) composites: A review. InStructures 2024 Feb 1 (Vol. 60, p. 105881). *Elsevier.*
30. Varma A, Warghane A, Dhiman NK, Paserkar N, Upadhye V, Modi A, Saini R. The role of nanocomposites against biofilm infections in humans. *Frontiers in Cellular and Infection Microbiology.* 2023 Feb 28;13:1104615.
31. Omkar Sakpal, Shivsagar Tewary, Shubha Joshi, Ajay Gaikwad, Abhijeet Kore. Development of Novel Polymeric Articulating Papers for Enhanced Occlusal Contact Assessment in Dentistry. *Journal of Polymer and Composites.* 2024; 13(01):1004-1011.
32. García Reyes M, Bataller Torras A, Cabrera Carrillo JA, Velasco García JM, Castillo Aguilar JJ. A study of tensile and bending properties of 3D-printed biocompatible materials used in dental appliances. *Journal of Materials Science.* 2022 Jan;57(4):2953-68.
33. Valenti C, Federici MI, Coniglio M, Betti P, Pancrazi GP, Tulli O, Masciotti F, Nanussi A, Pagano S. Mechanical and biological properties of polymer materials for oral appliances produced with additive 3D printing and subtractive CAD-CAM techniques compared to conventional methods: a systematic review and meta-analysis. *Clinical Oral Investigations.* 2024 Jun 25;28(7):396.
34. Chuchulska B, Dimitrova M, Vlahova A, Hristov I, Tomova Z, Kazakova R. Comparative analysis of the mechanical properties and biocompatibility between CAD/CAM and conventional polymers applied in prosthetic dentistry. *Polymers.* 2024 Mar 22;16(7):877.
35. Verma A, Kapil A, Klobčar D, Sharma A. A review on multiplicity in multi-material additive manufacturing: process, capability, scale, and structure. Materials. 2023 Jul 26;16(15):5246.
36. Yang H, Fang H, Wang C, Wang Y, Qi C, Zhang Y, Zhou Q, Huang M, Wang M, Wu M. 3D printing of customized functional devices for smart biomedical systems. *SmartMat.* 2024 Oct;5(5):e1244.
37. Chen YW, Omar A, Quoc-Kiet Ben T, Oula E T. Advancements in 3D-Printed Technology and Digital Workflows in Dentistry: Investigations into Occlusal Accuracy and Resin Performance for Prosthodontic Applications.
38. Guan X, Zhu T, Zhang D. Development in polymerization shrinkage control of dental light-cured resin composites: A literature review. *Journal of Adhesion Science and Technology.* 2023 Feb 16;37(4):602-23.
39. Nassif M, Haddad C, Habli L, Zoghby A. Materials and manufacturing techniques for occlusal splints: A literature review. *Journal of Oral Rehabilitation.* 2023 Nov;50(11):1348-54.
40. Uskoković V, Pejčić A, Koliqi R, Anđelković Z. Polymeric nanotechnologies for the treatment of periodontitis: A chronological review. *International Journal of Pharmaceutics.* 2022 Sep 25;625:122065.
41. Kligman S, Ren Z, Chung CH, Perillo MA, Chang YC, Koo H, Zheng Z, Li C. The impact of dental implant surface modifications on osseointegration and biofilm formation. *Journal of clinical medicine.* 2021 Apr 12;10(8):1641.
42. Pranjali Pokharkar, Namrata Gaonkar, Shashikiran N.D., Sachin Gugawad, Swapnil Taur, Savita Hadakar. Qualitative and Quantitative Effects of Non-Thermal Atmospheric Pressure Plasma and ErCr: YSGG Laser Activation on Surface Remineralization and Fluoride Release of Three Different Fluoride Varnishes. *Journal of Polymer and Composites.* 2024; 12(05):292-303.
43. Arif ZU, Khalid MY, Noroozi R, Sadeghianmaryan A, Jalalvand M, Hossain M. Recent advances in 3D-printed polylactide and polycaprolactone-based biomaterials for tissue engineering applications. *International journal of biological macromolecules.* 2022 Oct 1;218:930-68.
44. Kumar P, Suryavanshi P, Dwivedy SK, Banerjee S. Stimuli-responsive materials for 4D printing: mechanical, manufacturing, and biomedical applications. *Journal of Molecular Liquids.* 2024 Jul 16:125553.
45. Ardila CM, Jiménez-Arbeláez GA, Vivares-Builes AM. Efficacy of wireless sensors in assessing occlusal and bite forces: A systematic review. *Journal of Oral Rehabilitation.* 2024 Jul;51(7):1337-47.
46. Cui H, You Y, Cheng GW, Lan Z, Zou KL, Mai QY, Han YH, Chen H, Zhao YY, Yu GT. Advanced materials and technologies for oral diseases. *Science and Technology of Advanced Materials*. 2023 Dec 31;24(1):2156257.

