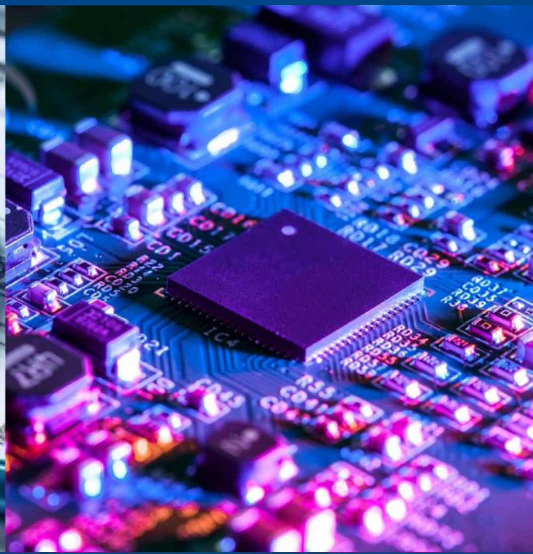
ISSN: 2582-7219

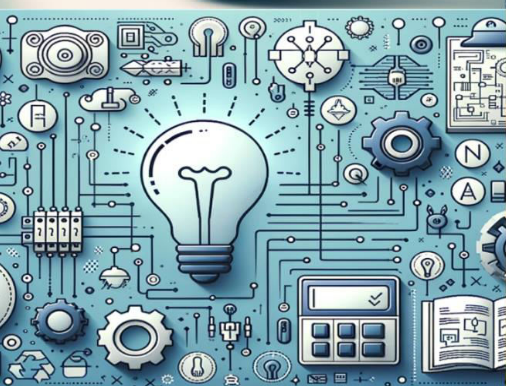




International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 7.521

Volume 8, Issue 1, January 2025

© 2025 IJMRSET | Volume 8, Issue 1, January 2025| DOI: 10.15680/IJMRSET.2025.0801019

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Polymer-Infiltrated Ceramic Network (PICN)' Material- A Succinct Review

Dr. LakshmanaRao Bathala[1], Dr. Murali Mohan Thota[2]

Professor & HOD, Department of Prosthodontics, Lenora Institute of Dental Sciences, Rajahmundry, A.P., India [1]

Professor, Department of Conservative Dentistry & Endodontics, Govt. Dental College and Hospital, Vijayawada, A.P., India [2]

ABSTRACT: A new class of dental biomaterials called polymer-infiltrated ceramic network (PICN) materials is intended to replicate the biomechanical and cosmetic characteristics of real teeth. By infusing a porous ceramic network with a polymer matrix, PICNs—which have a dual-phase structure—combine the resilience and flexibility of polymers with the strength and durability of ceramics. This interpenetrating structure, which closely resembles the natural enamel-dentin complex, provides improved mechanical qualities such as balanced wear resistance, intermediate elastic modulus, and improved fracture toughness. Excellent aesthetics, outstanding translucency, and natural color matching are guaranteed by the special composition of PICN materials. Crowns, bridges, veneers, and implant-supported restorations are just a few of the dental applications that can benefit from the materials' exceptional biocompatibility, stress distribution, and repairability. Recent developments have concentrated on enhancing production processes using 3D printing and vacuum-assisted infiltration, optimizing the ceramic and polymer phases, and adding bioactive ingredients for remineralization. By offering a biomimetic solution that overcomes the drawbacks of traditional ceramics and composite resins, PICN materials represent a paradigm leap in restorative dentistry. They are a key component of contemporary dental material science because of their creative design, which holds promise for long-lasting, minimally intrusive, and patient-centered restorations.

I. INTRODUCTION

The hybrid materials known as Polymer-Infiltrated Ceramic Network Materials (PICNs) are made of a ceramic network that has been penetrated by a polymer or resin. They combine the advantageous qualities of polymers (such as flexibility, resilience, and shock absorption) with ceramics (such as high strength, stiffness, and resistance to wear). PICNs are a potential material for dental applications because of their dual-phase structure, which replicates the mechanical properties and natural composition of dentin and enamel. **[1]**

Composition:

Ceramic Network: Usually composed of glass or feldspathic ceramics, this material offers aesthetic translucency, wear resistance, and rigidity. **[1-3]**

Polymer Phase: Usually a resin or polymer that gives elasticity and toughness, including methacrylate-based resins (like Bis-GMA).

While the polymer phase improves flexibility and absorbs stress, preventing cracks from spreading, the ceramic structure guarantees strength.

Applications in Dentistry [1-4]

1.Indirect Restorations: veneers, inlays, onlays, and crowns because of their exceptional mechanical and aesthetic qualities. Because PICNs transfer stress more evenly than pure ceramics, they are especially helpful for repairing teeth in load-bearing places.

2.Implant-Assisted Prosthetic Devices: utilized in bridges and implant crowns because PICNs' elastic modulus is better in line with bone's, lowering stress shielding and extending implant life.

3.Endodontic Restorations: mimics the natural characteristics of dentin and offers structural strengthening for teeth that have undergone endodontic treatment.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

4.Minimally Invasive Dentistry:They are perfect for minimally invasive operations because of their machinability and bonding ability to tooth structure.
Prosthetic components: PICNs can provide a compromise between durability and aesthetics in removable prosthodontics for denture bases or hybrid designs.

Advantages:
high aesthetic quality because of its natural look and translucency. Dentin-like mechanical behavior combined with biomimetic qualities. reduced brittleness and improved fracture resistance with comparison to pure ceramics. Good machinability and CAD/CAM system compatibility. less damage to the opposing dentition than traditional ceramics.
Limitations:
There are not many long-term clinical studies available. possibility of long-term polymer deterioration. intricate manufacturing procedure that demands accuracy.

Classification of PCIN Materials [2-4]
A new family of biomimetic materials called PICN materials is intended to mimic the structural, mechanical, and aesthetic qualities of real teeth. They closely resemble dentin and enamel in composition, consisting of a linked network of ceramic and polymer phases.

Fabrication and Structure
Materials for PICN are produced by:
a). Ceramic Framework: Sintering or 3D printing are methods used to create a porous ceramic network, usually made of glass ceramic or feldspathic.
b).Polymer Infiltration: To fill the gaps and produce a hybrid material, a polymer or resin, such as methacrylate-based resins (such Bis-GMA or UDMA), is injected into the porous ceramic.
Special mechanical qualities are provided by the dual-phase structure:
Strength, resistance to wear, and aesthetic translucency are provided by the ceramic phase.
c).Polymer Phase: Offers resilience, toughness, and flexibility.

II. CLASSIFICATION OF PICN MATERIALS

PICN materials can be categorized according to:
1. Ceramic Network Type
Feldspathic Ceramic-Based PICN: Because of its aesthetic appeal and translucency, feldspathic ceramics are frequently utilized.
Glass Ceramic-Based PICN: Due to their exceptional machinability and high strength, glass ceramics such as leucite-reinforced ceramics or lithium disilicate are preferred.
Zirconia-Based PICN: Due to their exceptional mechanical qualities, zirconia frameworks are sometimes utilized, albeit they can need specific processing.

2. Polymer Type
Methacrylate-Based Resins: Because of their mechanical qualities and compatibility, Bis-GMA, TEGDMA, and UDMA are often used resins.
Composite Resins: Incorporate fillers to enhance strength and wear resistance.
High-Performance Polymers: Polymers like PEEK (polyether ether ketone) are being explored for enhanced durability.

3. Processing Method
Direct Polymer Infiltration: Polymer infiltration is performed directly into the porous ceramic network.
Dual-Cure Polymerization: Combines light and chemical curing for better infiltration and polymerization of resin.
Pre-Ceramic Polymerization: The polymer and ceramic are combined before final sintering and curing.

4. Application-Based Classification
Restorative PICNs: For crowns, bridges, inlays, and onlays.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Implant PICNs: Used for implant-supported restorations where stress distribution is critical.
Prosthodontic PICNs: Applied in removable prostheses for improved esthetics and flexibility.
Advantages of PICN Materials
Biomimetic Properties: Mimic the elastic modulus and mechanical behavior of natural tooth structures.
Improved Esthetics: Translucent ceramics combined with resin provide a natural appearance.
Superior Mechanical Properties: Balanced combination of strength (ceramic) and toughness (polymer).
Minimized Abrasiveness: Cause less wear to opposing teeth compared to traditional ceramics.
Machinability: Compatible with CAD/CAM systems for precise restorations.
Stress Distribution: The polymer phase helps in shock absorption, reducing stress concentration on teeth and restorations.
Limitations of PICN Materials
Complex Manufacturing Process: Necessitates accuracy and specific methods.
Possible Polymer Degradation: Oral circumstances have the potential to cause polymers to deteriorate over time.
Increased Costs: As a result of sophisticated materials and fabrication methods.
Limited Clinical Data: There are currently few long-term trials available.
Physical and Chemical Properties of Polymer-Infiltrated Ceramic Network (PICN) Materials [5-8]
PICN materials combine the best properties of ceramics and polymers to achieve a balance between strength, toughness, esthetics, and resilience. Below is a detailed description of the physical and chemical properties of PICN materials, classified by their ceramic and polymer components.

III. PHYSICAL PROPERTIES

1. Mechanical Properties
A.Flexural Strength: The combination of ceramic and polymer phases provides a flexural strength range of 100–150 MPa, depending on the ceramic type (feldspathic or glass ceramics).
B. Elastic Modulus: Elastic modulus (~20–40 GPa) is intermediate between pure ceramics (60–70 GPa) and dentin (~18–20 GPa), making PICNs biomimetic.
C. Fracture Toughness: Higher toughness compared to conventional ceramics due to polymer infiltration, reducing the risk of brittle fracture.
D. Wear Resistance: Comparable to natural tooth enamel, with lower abrasiveness to opposing teeth compared to zirconia or feldspathic ceramics.

2. Esthetic Properties
A. Translucency: Ceramic's translucency is enhanced by the polymer phase, mimicking enamel's optical properties.
B. Color Stability: Long-term color stability is slightly lower than pure ceramics but superior to traditional composites.

3. Thermal Properties
A. Thermal Conductivity: Lower than ceramics but higher than pure polymers, providing insulation closer to natural teeth.
B. Coefficient of Thermal Expansion (CTE): The CTE of PICN materials (~7–10 × 10^{-6}/°C) closely matches that of dentin, reducing the risk of marginal gaps or debonding.

4. Porosity and Density
A. Porosity: Controlled porosity in the ceramic phase ensures adequate polymer infiltration and influences mechanical performance.
B. Density: Lower density than ceramics alone, making them lighter and more suitable for various prosthetic applications.

IV. CHEMICAL PROPERTIES

1. Bonding and Interfacial Strength
a. Chemical Bonding: Strong micromechanical interlocking occurs at the ceramic-polymer interface. Silanization of the ceramic phase enhances adhesion between ceramic and polymer.

© 2025 IJMRSET | Volume 8, Issue 1, January 2025| DOI: 10.15680/IJMRSET.2025.0801019

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

b. Adhesive Compatibility: PICNs exhibit high bonding compatibility with resin-based cements and adhesives due to their polymer component.

2. Polymer Phase Properties
a. Polymerization Shrinkage: Minimal polymerization shrinkage compared to direct composite resins because the polymer infiltrates pre-existing ceramic networks.
b. Water Absorption: Polymer infiltration reduces water absorption, improving hydrolytic stability compared to conventional composite resins.
c. Degradation Resistance: Polymer phase is susceptible to wear and hydrolysis over time, but the ceramic framework provides structural support.

3. Ceramic Phase Properties
a. Chemical Stability: Ceramic phase remains inert in oral environments, resisting acid erosion.
b. Filler Composition: The choice of ceramic (e.g., feldspathic, lithium disilicate) influences reactivity and mechanical integration with the polymer.

4. Biocompatibility
a. Non-Toxicity: Both the ceramic and polymer phases are biocompatible when high-quality materials and manufacturing processes are used.
b. Low Cytotoxicity: Proper polymerization and material processing reduce the risk of cytotoxic residual monomers.

V. DIFFERENCES BETWEEN CONVENTIONAL MATERIALS AND POLYMER-INFILTRATED CERAMIC NETWORK (PICN) MATERIALS

The key differences between conventional restorative materials (ceramics, composites, and metals) and PICN materials lie in their composition, mechanical properties, esthetics, and behavior in clinical applications. Below is a detailed comparison

1.Composition [5]

Aspect	Conventional Material	PICN Material
Base Composition	Single-phase materials: pure ceramics, metals, or polymers	Dual-phase material: a porous ceramic network infiltrated with polymer.
Material Structure	Homogeneous structure with no interaction between phases.	Interpenetrating network of ceramic and polymer.
Biomimicry	Limited ability to mimic natural dentin/enamel.	Closely mimics the structure and mechanical behavior of teeth.

2. Mechanical Properties [6]

Aspect	Conventional Material	PICN Material
Flexural Strength	Higher in ceramics and metals (~150–400 MPa).	Moderate (~100–150 MPa).
Fracture Toughness	Ceramics: Brittle, prone to sudden failure.	Improved toughness due to the polymer phase reducing crack propagation.
Elastic Modulus	Ceramics/Metals: High (~60–200 GPa).	Intermediate (~20–40 GPa), closer to dentin (~18–20 GPa).
Wear Resistance	Ceramics: Highly resistant, but abrasive to opposing teeth.	Balanced wear resistance with reduced abrasiveness.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

3.Esthetic Properties [7]

Aspect	Conventional Material	PICN Material
Translucency	Limited in composites and metals; high in ceramics.	Highly translucent due to dual-phase structure.
Color Matching	Good with ceramics; limited in composites and metals.	Excellent color-matching capabilities due to polymer-ceramic blend.
Long-Term Esthetics	Ceramics maintain esthetics; composites may stain over time.	PICNs combine ceramic esthetics with improved stain resistance.

4.Biological Properties [8]

Aspect	Conventional Material	PICN Material
Biocompatibility	Ceramics and metals: Highly biocompatible.	Highly biocompatible due to ceramic framework and inert polymers.
Stress Distribution	Ceramics and metals: Cause stress concentrations.	PICNs distribute stress evenly, reducing the risk of fractures.
Cytotoxicity	Composites may leach residual monomers.	PICNs exhibit low cytotoxicity due to thorough polymerization.

5.Clinical Performance [6]

Aspect	Conventional Material	PICN Material
Preparation Technique	Ceramics require aggressive tooth preparation; composites are conservative.	PICNs support minimally invasive techniques due to superior bonding.
Longevity	Ceramics: High longevity; composites: Moderate.	PICNs offer a balance of durability and ease of repair.
Bonding Strength	Good with ceramics and composites.	Excellent bonding strength due to resin phase compatibility.
Repairability	Limited for ceramics; easy for composites.	Easily repairable using composite resins.

VI. MODIFICATIONS OF POLYMER-INFILTRATED CERAMIC NETWORK (PICN) MATERIALS [6, 8-12]

PICN materials have evolved significantly through research and technological advancements, leading to improved mechanical properties, esthetics, and clinical performance. Modifications in PICN materials are focused on optimizing the ceramic and polymer phases, improving their interaction, and enhancing their clinical applicability.

1. Modifications in Ceramic Phase

a. Porosity Optimization

Objective: Achieve better polymer infiltration while maintaining structural integrity.

Modification: Controlled pore size and distribution in the ceramic network using advanced fabrication techniques (e.g., freeze casting, 3D printing).

Outcome: Improved polymer penetration and better mechanical performance.

b. Advanced Ceramic Types

Modification: Transition from feldspathic ceramics to high-strength ceramics like lithium disilicate and zirconia-based frameworks.

Outcome: Increased strength and fracture resistance.

c. Surface Functionalization

Modification: Pre-treatment of ceramic surfaces with silanes or other bonding agents to enhance polymer adhesion.

Outcome: Improved interfacial bonding and durability.

© 2025 IJMRSET | Volume 8, Issue 1, January 2025| DOI: 10.15680/IJMRSET.2025.0801019

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

2. Modifications in Polymer Phase
a. Polymer Chemistry
Modification: Use of advanced resins such as Bis-GMA, UDMA, or silorane-based monomers.
Outcome: Reduced polymerization shrinkage, improved wear resistance, and better esthetics.
b. Nanofillers in Polymer
Modification: Incorporation of nano-sized fillers (e.g., silica, zirconia) into the polymer matrix.
Outcome: Enhanced mechanical properties and wear resistance.
c. Dual-Polymer Systems
Modification: Use of dual-polymer systems with different viscosities to improve infiltration and bonding with the ceramic network.
Outcome: Higher toughness and reduced voids at the interface.

3. Hybridization Techniques
Technique: Combining different types of ceramics and polymers into a single PICN material to achieve a balance of properties.
Example: Incorporating bioactive glass particles to improve remineralization and compatibility with natural tissues.
Outcome: Improved biomimicry and biological performance.

4. Manufacturing Process Enhancements
a. Additive Manufacturing (3D Printing)
Advancement: 3D printing of the ceramic framework followed by polymer infiltration.
Benefits: High precision, reduced waste, and customizable designs.
b. Hot Isostatic Pressing (HIP)
Advancement: Use of high-pressure sintering to enhance the density and strength of the ceramic network before polymer infiltration.
Benefits: Better mechanical performance and reduced porosity.
c. Vacuum-Assisted Infiltration
Advancement: Application of vacuum techniques to ensure complete polymer infiltration into the ceramic network.
Benefits: Reduced voids and improved interfacial bonding.

VII. RECENT ADVANCEMENTS IN PICN MATERIALS

A. Bioactive PICN Materials
Incorporation of bioactive glass or hydroxyapatite into the ceramic network to promote remineralization and osseointegration.
Example: Development of materials for bone grafts and dental implants.
Improved Polymer Infiltration
Advances in polymer chemistry (e.g., use of low-viscosity resins) for better infiltration.
B. Smart PICNs
Development of materials with self-healing properties or stress-responsive behavior.
Example: Polymers that repair microcracks under mechanical stress.
C. Nanotechnology Integration
Use of nanostructured ceramics and polymers for enhanced strength, wear resistance, and esthetics.
D. Digital Workflow Compatibility
PICN materials are now being developed to be compatible with CAD/CAM systems, enabling efficient milling and finishing.

Special Note on Advancements in Biocompatibility
The addition of antimicrobial agents (e.g., silver nanoparticles) to the polymer phase improves resistance to bacterial colonization.
Research into fluoride-releasing PICN materials offers potential benefits for preventing secondary caries.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.521| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

VIII. CONCLUSION

A notable development in dental biomaterials, polymer-infiltrated ceramic network (PICN) materials provide a special combination of mechanical strength, durability, and superior aesthetics that closely resembles the structure of natural teeth. PICN materials overcome the drawbacks of traditional restorative solutions, such as brittleness in ceramics and low durability in composites, by fusing the advantageous qualities of ceramics and polymers.

Better stress distribution, less wear on opposing teeth, and improved biocompatibility are made possible by their biomimetic design. Recent developments have increased their clinical utility and made them a flexible option for a range of restorative applications, including bioactive alterations, incorporation of nanotechnology, and compatibility with CAD/CAM systems.

PICN materials, which offer minimally invasive, long-lasting, and aesthetically beautiful restorations, are a prime example of how material science and clinical requirements can come together. PICNs are positioned to become a key component of restorative and prosthetic dentistry in the future, bridging the gap between functional and aesthetic perfection in dental care, as long as continuous research continues to improve their qualities and uses.

REFERENCES

1. Swain, M. V., and He, L. H. (2011). A new ceramic dental material that has been penetrated with polymers. 527–534 in Dental Materials, 27(6). 10.1016/j.dental.2011.02.002

2.Guess, P. C., Bilkhair, A., Coldea, A., and Swain, M. V. (2016). A review of biomimetic PICN performance. Dental Research Journal, 95(4), 392–400. 10.1177/0022034515621344 ..

3.Elnaghy, A. M., and Elsaka, S. E. (2016). mechanical characteristics of novel materials with polymer-infiltrated ceramic networks (PICNs). Journal of Dental Materials, 35(5), 785–791. 10.4012/dmj.2015-378 .

4.Ferrari, M., Louca, C., Capperucci, A., Carrabba, M., Vichi, A., and Sedda, M. (2014). impact of polymer infiltration on a ceramic network's mechanical characteristics. e163-e172 in Dental Materials, 30(7). 10.1016/j.dental.2014.04.002.

5. He, L. H., & Swain, M. V. (2011). A novel polymer-infiltrated ceramic dental material. Dental Materials, 27(6), 527–534.

6.Swain, M. V., Coldea, A., Bilkhair, A., & Guess, P. C. (2016). Performance of biomimetic PICNs: A review. Journal of Dental Research, 95(4), 392–400.

7.Elsaka, S. E., & Elnaghy, A. M. (2016). Mechanical properties of innovative polymer-infiltrated ceramic network (PICN) materials. Dental Materials Journal, 35(5), 785–791.

8.Sedda, M., Vichi, A., Carrabba, M., Capperucci, A., Louca, C., Ferrari, M. (2014). Influence of polymer infiltration on the mechanical properties of a ceramic network. Dental Materials, 30(7), e163–e172.

9. Coldea, A., Swain, M. V., Thiel, N. (2013). Mechanical properties of polymer-infiltrated ceramic networks (PICN): Influence of composition. Journal of the Mechanical Behavior of Biomedical Materials, 26, 34–42.

10.lsaka, S. E., & Elnaghy, A. M. (2016). Mechanical properties of innovative polymer-infiltrated ceramic network (PICN) materials. Dental Materials Journal, 35(5), 785–791.

11.Zhang, H., Zhang, L., Chen, F. (2020). Recent advancements in polymer-infiltrated ceramic networks (PICNs) for dental applications. Materials Science and Engineering C, 110, 110710.

12.Kim, S., Jang, J., Park, H. (2021). 3D printing of polymer-ceramic hybrid materials for dental applications. Journal of Advanced Dental Materials, 12(3), 456–467.

INNO SPACE
SJIF Scientific Journal Impact Factor

ISSN
INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

निस्केयर
NISCAIR

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY