The Evolution of Composite as a Direct Restorative Material; "a Journey through Innovation".

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INTRODUCTION

Resin-based composite (RBC) materials are becoming more popular for restoring posterior teeth due to their esthetic tooth-colored properties and mercury-free formulations. These materials offer several advantages, however; their shortcomings, such as polymerization shrinkage (PS), recurrent caries, and technique sensitivity have been a source of concern, leading to the development of advanced RBCs to address these drawbacks. This review aimed to provide a brief history of RBC evolution with a focus on newly developed RBCs.

HISTORY

Since their introduction in the 1960s, RBCs have undergone significant evolution to meet the dual demands of aesthetic quality and functional strength. Macrofill composites offered enhanced durability but fell short on aesthetics. This led to the development of microfill composites that provided improved surface finish and color match. Advancements continued with Hybrid composites, which increased filler content without sacrificing appearance. The advent of nanocomposites marked a breakthrough, offering superior aesthetics, strength, and wear resistance by utilizing nano-sized filler particles. Today's composites include sophisticated formulations that balance aesthetics, strength, and durability, meeting the increasingly demanding requirements of modern dentistry.(Fifure-1)

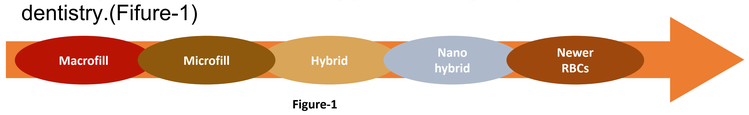

Figure-1

IMPROVMENT IN RBCs COMPOSITION

Filler Modification:

- ❑ Nano-sized fillers improve polish ability and wear resistance.
- ❑ Smaller fillers mitigate shrinkage stress, enhancing mechanical properties.(Figure-2)

Monomer Modification: Traditional meth acrylates like Bis GMA offer fast polymerization but raise biocompatibility concerns due to potential leaching.

- ❑ Silorane-based composites reduce polymerization shrinkage substantially, less than 1%, through cationic ring-opening polymerization.
- ❑ Ormocers, with inorganic-organic copolymers, offer lower shrinkage and improved compatibility, pre-polymerized for reduced shrinkage during curing.(Figure-2)

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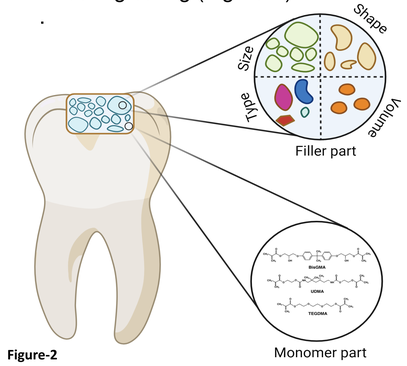


Figure-2

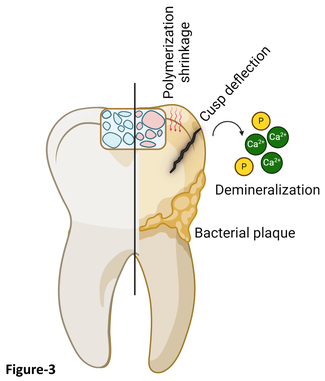


Figure-3

ADVANCED RBCs MATERIALS

Low-shrinkage RBCs

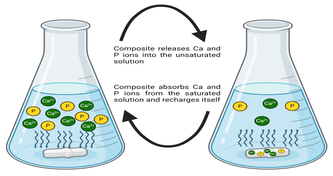
To address PS in RBCs, recent developments include increasing inorganic filler content and exploring new materials like POSS and zinc oxide to reduce PS. High-molecular-weight monomers, such as dimer acid-based monomers, have been introduced to decrease PS and enhance material conversion. Bulk fill RBCs further reduce PS by optimizing filler size and content, adding more photo initiators, and employing high-molecular-weight monomers. These advancements ensure better mechanical properties and less shrinkage, making RBCs more effective and durable for dental restorations. Technologies like silorane, ormocer-based composites, and spiro-orthocarbonates are also used to minimize shrinkage effectively.(Figure-3)

Bioactive RBCs

1-Remineralizing

Initially contained amorphous calcium phosphate (CaP) fillers but without sufficient mechanical properties.

- ❑ Nowadays, calcium phosphate nanoparticles (NACP) with sufficient mechanical and remineralizing properties.
- ❑ Recently, bioactive glass (BAG) enhanced have been developed, showing Ca and P ion release and antimicrobial properties against Streptococcus sobrinus and mutans, and Enterococcus faecalis.
- ❑ Rechargeable resin composites which are capable of repeatedly recharging and re-releasing Ca and P ions.(Figure-4)



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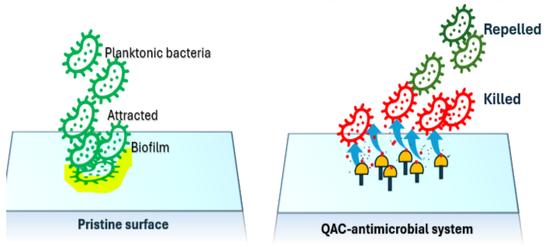

Figure-5

2. Anti-microbial

- ❑ Leachable agents: QAMs, CHX, Triclosan.
- ❑ Polymerized monomer: quaternary ammonium methacrylates, Quaternary ammonium polyethyleneimine, and dimethyl amino hexadecyl methacrylate (DMAHDM) showing antimicrobial efficacy in direct contact with bacteria.
- ❑ Surfaces with protein depletion properties such as RBC containing 2-methacryloyloxyethyl phosphorylcholine (MPC) to prevent the bacterial adhesion and biofilm formation.(Figure-5)

Enhanced-Strength RBCs

- ❑ RBCs with added glass/ carbon/ or polyethylene fibers, mostly used for splinting
- ❑ Increasing degree of conversion by adding different co-initiators than amine such as iodonium salts (increasing the number of radicals produced per CQ molecule but mechanical properties is still below the conventional RBCs)
- ❑ RBCs containing nanoparticles.(Figure-6)

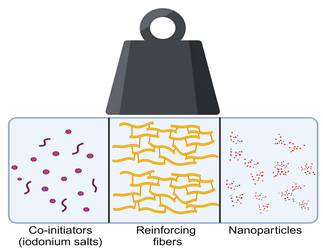

Figure-6

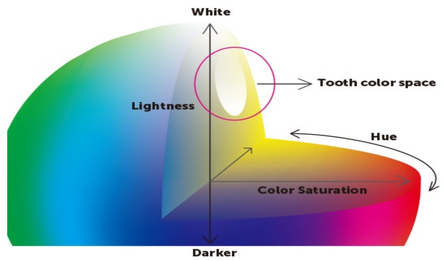

Figure-7

Universal RBCs:

Universal composites are increasingly favored in restorative dentistry for their esthetic and conservative properties, cost-effectiveness, and good mechanical attributes suitable for various clinical applications. A recent trend in composite material technology is the development of "universal" or "single-shade" composites. Such composites are designed to simplify the color matching process in anterior restorations, potentially reducing clinical errors and chair time. Universal composites like Omnichroma claim to match a wide range of tooth shades by utilizing structural color phenomena. This is based on the interaction of incident light with nanostructured particles within the composite, allowing it to mimic the color of the surrounding dentition. However, some research indicates that while universal composites like Omnichroma may simplify clinical procedures, multi-shade composites still excel in achieving precise color matching with natural dentition.(Figure-7)

FUTURE ADVANCES

- ❑ Self-healing RBCs: fill the crack by releasing of resin-containing capsules inside the material
- ❑ Smart RBCs: react to stimulus such as low pH, mechanical stress, and temperature and moisture change
- ❑ Self-adhesive RBCs with improved bonding and mechanical properties.(Figure-8)

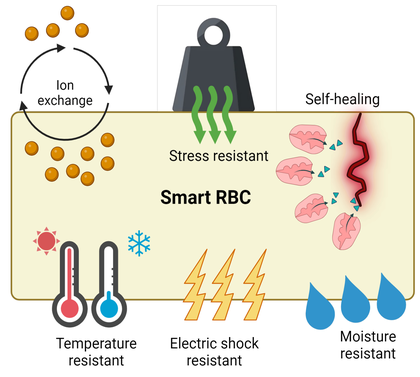

Figure-8

CONCLUSION

RBC formulations and properties have improved significantly since their invention in the 19th century, and these materials continue to evolve to address their shortcomings by modifying the monomer and filler particles in their compositions.

REFERENCES

OKU Sutro Excellence Day Project Cover Sheet

Project Title

The Evolution of Composite as a Direct Restorative Material; "a Journey through Innovation".

Full name(s) and class year(s) of all project collaborators

Example: Jane Smith, DDS 2022; John Smith, DDS 2022

Nazgol Zamanian, IDS 2025; Madiha Fatima, IDS 2025; Niyousha Rafeie, IDS 2025

Project Category

IDS - 1st Year Literature Review

Enter your abstract text here (max 300 words)

Abstract:
Objectives: The present review study aimed to provide a brief history of resin-based composites (RBC) as direct restorative materials and their evolution from macrofill to nanohybrid RBCs, as well as newly developed RBCs with bioactive, antimicrobial, and remineralizing properties.

Methods: PubMed, Medline, Google Scholar, and Scopus were searched using the appropriate keywords. Case reports and non-peer-reviewed articles were excluded.

Results: Among the 80 papers initially resulting from the literature search, 35 studies were reviewed and included. The application of resin composite as a direct restorative material has increased significantly due to its higher esthetics compared to amalgam and fewer biocompatibility concerns. To improve RBC properties, new resin monomers such as TCD-urethane-based monomers, silorane-based monomers, and Ormocers have been developed and introduced. Additionally, the size, shape, and volume of filler particles have been modified to enhance RBC properties. These advances have resulted in new resin composite materials, including bioactive RBCs with remineralizing potential, smart RBCs with the ability to release ions in decreased pH, antimicrobial RBCs with various filler particles such as newly green silver nanoparticles, nano Cerium Oxide, and silver/Zinc Oxide (Ag/ZnO) nanoparticles, and self-adhesive RBCs.

Conclusions: RBCs have evolved significantly since their invention in the 1900s. Newly developed RBCs have compelling physical and mechanical properties in in vitro settings. However, further studies are needed to evaluate their safety and longevity in the oral conditions.

Acknowledgment: We would like to express our deepest appreciation to our mentor, Dr. Ganesh, whose invaluable guidance, unwavering support, and insightful critiques have been pivotal in the success of this research.