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Review

Dental restorative composite materials: A review

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A R T I C L E I N F O

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A B S T R A C T

Background: This review article discusses the effect of reinforcements in the parent dental restorative materials that results in enhanced performance in real-time situations.
Highlight: The review article includes the details of the properties of different reinforced dental composite materials such as mechanical strength, thermal properties, physical/chemical properties, tribological performance.
Conclusion: It revealed that nanofiller particles enhance the properties of various dental composite materials. The hybrid dental composites also contribute significantly in increasing the mechanical and tribological properties. A silane-treated filler improved the dental composite bonding strength.

Contents

1. Introduction

In today's scenario, people suffer from certain common dental issues such as dental decay, cavities, and root canal infections. All these issues are due to bacterial infection of the teeth, which damage the tooth structure [1]. For treatment of the affected tooth, dentists recommend the removal of the dental caries and filling of the cavities with appropriate materials. Dental amalgams are leached out from the tooth during mastication and it also affects human health. Currently, polymer composites are widely used as dental restoration materials owing to their superior properties, such as biocompatibility, excellent esthetics, antibacterial, and nontoxic characteristics, when compared to old filling materials. It demonstrates good physical, mechanical, thermal, and tribological properties [2]. Bisphenol A-glycidyl methacrylate (Bis-GMA) based dental polymer composites are the first choice of the dentist for anterior and posterior tooth filling. It has low polymerization shrinkage, low volatility, and high viscosity. Urethane dimethacrylate has lower viscosity but higher toughness than Bis-GMA. It can be used as a substitute for Bis-GMA. To reduce the viscosity, triethylene glycol dimethacrylate (TEGDMA) and 2-hydroxyethyl methacrylate (HEMA) are used as diluents in dental composites

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[3–6]. Recently, reinforcements based on nanofillers with silane treatment are being widely used in dental polymer composites [7].

2. Materials and methods

Bis-GMA, perfluorobutyryl chloride with Bis-GMA, ethoxylatedbisphenol-A-dimethacrylate, TEGDMA, camphorquinone (CQ), ethyl-4-dimethylaminobenzoate (EDMAB), diphenyl phosphine oxide, N–N-dimethyl aminoethyl methacrylate (DMAEMA), 3-(Trimethoxysilyl) Propyl Methacrylate (γ-MPS), dihydroxyethyl-para-toluidine, butylated hydroxytoluene (BHT), poly (ethylene glycol)dimethacrylate, HEMA, MMA (Methyl methacrylate), TEOS (Tetraethoxysilane), PMMA (Polymethylmethacrylate), 4-dimethylaminopyridine, and benzoyl peroxide are used in dental composite materials. The fabrication methodology for dental composite is as follows:

I. Prepare mixture of monomer and diluents in appropriate proportions
II. Add initiator and accelerator/co-initiator in appropriate amount to the resinous mixture
III. Select filler that are either fiber or ceramic (treated or not treated) and mix properly with matrix
IV. Select mold and fill the dental composite material; use light curing unit for curing.

The review article has been categorized on the following aspects of dental resin composite:

2.1 Effect of reinforcement on the physical and chemical properties of a dental composite material
2.2 Effect of reinforcement on the mechanical properties of a dental composite material
2.3 Effect of reinforcement on the thermal properties of a dental composite material
2.4 Effect of reinforcement on the tribological properties of a dental composite material

2.1. Effect of reinforcement on the physical and chemical properties of a dental composite material

This section highlights the effect of reinforcement on the physical and chemical properties, such as degree of polymerization, degree of conversion, translucency, depth of cure, water sorption and solubility, flowability, and radiopacity. Shiraishi and Watanabe [8] discussed the effects of thickness on the light transmittance, opalescence, and translucency in the dental ceramic restorations. A three-disk sample of fully sintered zirconia/alumina nanocomposites were used for the experiment. The disk diameter was 16 mm and the thickness range was from 0.2 to 0.6 mm including an increment of 0.1 mm. The average transmittance, opalescence, and translucency parameters were marginally influenced for both the nanocomposites. Dafar *et al.* [9] aimed to reinforce titanium dioxide nanotubes ($nTiO_2$) in flowable dental composites. The commercially available flowable composites were used in this study. An alkaline hydrothermal process was used for the synthesis of $nTiO_2$. From the results, it was observed that the $nTiO_2$ was successfully reinforced in the flowable dental composite. The fracture toughness and dynamic Young's modulus were improved. Flowability and radiopacity demonstrated a marginal decrease. Sun *et al.* [10] determined the polymerization and potential leakage effects for the dental composite restoration. The five composites were prepared using Bis-GMA/TEGDMA (1:1 by mass) and a photoinitiator of 0.2% CQ and 0.8% EDMAB. Fumed amorphous silica (0.04 μm) with silanized glass beads (0.4 μm) as fillers was used in the dental composite.

RameshBabu *et al.* [11] reported the effect of the alumina microfibers (AMFs), Ceria nano fibers (CNFs), and silk microfibers (SMFs) as inorganic materials in the dental composites. The dental resin composite was fabricated using Bis-GMA/TEGDMA (49.5/49.5wt%), CQ (0.2wt%), and EDMAB (0.8wt%) as the organic materials and the fillers (different mass fractions of 10% AMFs, 3.33% CNFs, and 5% SMFs) as inorganic materials. The maximum viscosity was identified in dental composites with 5% SMFs. The maximum depth of cure and change in mass were determined in the control-based composite and the minimum values in the 3.33% CNF-based composite. Meerreis *et al.* [12] examined the performance of phenylbis (2,4,6-trimethylbenzoyl) phosphine oxide (BAPO) as the photoinitiator in the dental resin composite. Four different photoinitiators BAPO, CQ, ethyl 4-dimethylaminobenzoate (EDAB), and diphenyliodonium hexafluorophosphate (DPIHFP) were employed with different forms (unitary, binary, ternary, and quaternary). The maximum rate of polymerization was revealed in the BAPO with 1 mol%. The maximum degree of conversion was identified in the ternary (BAPO (1 mol%)+EDAB + DPIHFP) based composite.

Garoushi *et al.* [13] suggested the effect of a short fiber as the filler on the physical and depth of cure properties of dental restorative composite materials and compared it with eight other commercial dental composites. Silica, barium silicate glass, barium glass, barium borosilicate glass, zirconia, and short E-glass fiber as fillers were used in dental composites. The depth of cure (4.6 mm) of short E-glass was determined to be higher than other hybrid dental composites. Chen *et al.* [14] evaluated the effect of halloysite nanotubes (HNTs) on the dental resin composite materials. The dental resin composite was comprised of Bis-GMA/TEGDMA (49.5/49.5wt%), CQ/EDMAB (0.2/0.8wt%), and inorganic materials. An elastic modulus demonstrated significant results in the HNT-based composite when compared to non-glass-based composite. By increasing the percentage of HNTs, the shrinkage volume of dental composites was also increased.

2.2. Effect of reinforcement on the mechanical properties of a dental composite material

This section presents the effect of reinforcement on the mechanical properties of a Bis-GMA-based dental composite material, such as flexural strength, compressive strength, hardness, flexural modulus, diametral tensile strength, fracture toughness, and elastic modulus. Noushad *et al.* [15] observed the effect of nano hybrid silica as the filler in dental composites. Nanohybrid silica is obtained from rich hush ash. In this case two different composite matrixes were observed i.e., matrix A (Bis-GMA/TEGDMA (60/40wt%)) and matrix B (Bis-GMA/TEGDMA (50/50wt%)). The values of the various mechanical properties were obtained from the experimentations on composite B, such as flexural strength (107 MPa), flexural modulus (62 GPa), compressive strength (191 MPa), Vickers hardness (39HV1), and surface roughness (0.057Ra). Srivastava and Sun [16] synthesized the borosilicate-based glass powder modified with silver sulfadiazine for identifying the effects on mechanical properties in dental restorative materials. Bis-GMA (49wt%), TEGDMA (49wt%), and CQ/EDMAB (0.2/0.8wt%) were employed as the basic resin. The resin/filler ratio was 30/70% by weight. The first composite was manufactured from basic resin and original commercial glass and was denoted as S–C. The second composite was fabricated with modified glass powder (A-Glass-CyCl-SD-Ag) of 2, 5, and 10wt%, which were denoted as S-2, S-5, and S-10, respectively. From the experiment, it was determined that the descending order of the values of the maximum compressive strength and flexural strength for the different composites were S-2>S-10>S-5>S–C.

Ramos *et al.* [17] examined the microstructure characteristics of four dental CAD/CAM ceramics and also determined their susceptibility to stress corrosion. In this study, Poisson's ratio, elastic modulus, density, and fracture toughness were analyzed. Moreover, feldspathic ceramic, polymer-infiltrated ceramic (PIC), lithium disilicate ceramic, and zirconia-reinforced lithium silicate ceramic were used for the study of slow crack growth. It was observed that the lowest elastic modulus was determined in PIC disc pieces. Aljosa *et al.* [18] determined the influence of a light curing system on the mechanical behavior of dental restorative materials. Nano-filled hybrids, nano hybrids, and micro hybrids were used as inorganic materials in the three dental composites. The results revealed that the first two dental composites had higher compressive strength in soft start rather than standard light curing mode. Musanje *et al.* [19] analyzed the effect of the concentrations of the photoinitiator, CQ, and EDMAB on the material properties of the dental resin-based composites. In this experiment five dental resin-based composite formulations were prepared with varying CQ concentration (0.1, 0.2, 0.4, 0.8, and 1.6wt% of the organic material). The results revealed that the maximum hardness was obtained at CQ/EDMAB at 1.44/0.42wt% and the highest degree of conversion at CQ/EDMAB of 2.40/0.83 wt%.

Samuel *et al.* [20] analyzed the use of mesoporous silica and nonporous spherical silica (500 nm) as a filler in dental resin composites. The dental composite consisted of Bis-GMA/TEGDMA (50/50wt%), CQ (0.5wt%), and DMAEMA (0.5wt%). The ratio of the resin/filler was approximately 30/70. The results revealed that the composite that contained the combination of mesoporous and nonporous fillers demonstrated better mechanical properties than the composite with individual fillers. Taheri *et al.* [21] analyzed the effect of fluoridated hydroxyapatite (FHA) as the inorganic material on the mechanical behavior of the dental restorative material. The results revealed that the maximum values of diametral tensile strength (45 MPa), flexural modulus (2.5 GPa), and flexural strength (99.8 MPa) were identified in the 0.2wt% FHA-based dental composite and not the neat (control-based composite) and other FHA-based dental composites.

Alsharif *et al.* [22] studied the influence of alumina (Al_2O_3) as a filler on the mechanical behavior of dental restorative composites. The dental resin composite was fabricated with Bis-GMA/TEGDMA (75/25wt%), CQ/DMAEMA (0.5/0.5wt%), and different ratios of treated fillers (40, 50, and 60wt%). The results revealed that the maximum values of Vickers hardness (23.5 kg/mm^2) and flexural modulus (5.7 GPa) were determined in the 60% filler-loaded composite when compared to the neat or control-based composites. Liu *et al.* [23] demonstrated the effect of polymer grafted hydroxyapatite whisker (PGHW), as the reinforcement, on the mechanical and physical behaviors of dental restorative composites. This dental resin composite was fabricated using Bis-GMA/TEGDMA (49.5/49.5wt%) and CQ/EDMAB (0.2/0.8wt%). Four experiments were performed with different time duration (1 h, 3 h, 7 h, and 18 h) and denoted as PGHW-1h, PGHW-3h, PGHW-7h, and PGHW-18 h, respectively. The maximum values of compressive strength, flexural strength, and flexural modulus were observed in PGHW-1h and minimum values in PGHW-18 h at 48wt% filler-loaded composite.

2.3. Effect of reinforcement on the thermal properties of a dental composite material

This section highlights the effect of reinforcement on the thermal properties of the Bis-GMA-based dental composite material, such as storage modulus, loss modulus, and tan delta. The interpretation of the results is also presented. Kumar *et al.* [24] reported the influence of marble dust reinforcement on the thermo mechanical behavior of dental restorative materials. The dental matrix was fabricated with Bis-GMA/TEGDMA (50/49wt%), CQ (0.2wt%), and EDMAB (0.8wt%). The maximum and minimum values of loss modulus were determined at 200 °C in 3 and 9wt% of marble dust-filled dental composites, respectively. Meena *et al.* [25] reported the effect of nano-hydroxyapatite and mineral trioxide aggregate (MTA) on the thermo mechanical behavior of dental resin composites. The dental composite matrix was fabricated with Bis-GMA (52wt%), TEGDMA (45wt%), BHT (2wt%), CQ/DMAEMA (0.2/0.8wt%). Five dental composites were fabricated with different amount of MTA wt% (0, 5, 10, 15, and 20wt%) and denoted as MTA-0, MTA-5, MTA-10, MTA-15, and MTA-20, respectively. The results revealed that the maximum and minimum values of weight loss were observed in MTA-20 and MTA-5-based dental composites at 250 °C, respectively.

Kumar *et al.* [26] evaluated the influence of silane microsized gypsum reinforcement on the thermo mechanical behavior of the dental resin composites. The dental sample (composite) was fabricated using Bis-GMA, TEGDMA, CQ, EDMAB with 0–3% of silane microsized gypsum as filler. The results demonstrated that the maximum values of storage modulus (approximately 58 MPa), loss modulus (approximately 4 MPa), and tan delta (approximately 0.7) were observed in 2, 1, and 1%of silane gypsum-based dental composites, respectively, at 250 °C. The maximum thermal stability was observed in the 2% silane gypsum-based dental composite. Kilambi *et al.* [27] described the new mono-methacrylates as diluents for the dental resin composites. Phenyl carbonate methacrylate and morpholine carbonyl methacrylate were used as diluents in Bis-GMA-based dental composites. Further, 2,2-dimethoxy-2-phenylacetophenoneat 0.1wt% as initiator and barium glass (4 μm) at 70wt% as filler were used in the dental composite. The results demonstrated that both the new mono-methacrylate-based composites improved the storage moduli when compared to the TEGDMA-based composite.

Vouvoudi *et al.* [28] reported the thermal degradation using thermogravimetric analysis (TGA) on the dental resin-based nanocomposites. Four different heating temperatures (150, 400, 500, and 700 °C) were used in TGA analysis. The results revealed that the thermal stability depended on the percentage ratio of the polymer matrix and its structure. Chen *et al.* [29] evaluated the effect of dicalcium phosphate anhydrous (DCPA) as a reinforcement on the dental resin composite through thermal cycles. The thermal cycle was varied between 5 and 55 °C for 600 and 2400 cycles in the deionized water. After 600 cycles, the strength and moduli of the nano-crystal-treated DCPA composite demonstrated significant results. Escamilla *et al.* [30] examined the influence of hybrid silica/poly (methylmethacrylate) (PMMA) on the thermal behavior of dental restorative composites. It was observed that the thermal stability of the hybrid composite decreased with increasing amounts of PMMA. According to the TGA, the silica particles were thermally stable, and 2% mass loss was observed at 700 °C. Bindu *et al.* [31] demonstrated the influence of combinations of microsized and nanosized hybrid silica as inorganic materials on the thermo mechanical behavior of dental restorative composites. Two combination of silica (7 nm+2 μm and 14 nm+2 μm) were used in dental composites. The percentage of the micro size (2 μm) was varied as 0, 2, 5, and 10wt%. The dental resin matrix was fabricated using Bis-GMA/TEGDMA (49.5/49.5wt%) and CQ/DMAEMA (0.2/0.8wt%). For the experiment different dental composites were prepared and named as neat composite (N), hybrid silica (7 nm+2 μm) based composites (Hy_7^0, Hy_7^2, Hy_7^5, and Hy_7^{10}), and another combination of hybrid silica (14 nm+2 μm) based composites (Hy_{14}^0, Hy_{14}^2, Hy_{14}^5, and Hy_{14}^{10}). The storage modulus revealed that the maximum value (3700 MPa) was observed in Hy^{0}_{14}-based composite and the minimum value (2300 MPa) was observed in N. The loss modulus values revealed that the maximum value (170 MPa) was observed in Hy^{0}_{7}-based composite and minimum (120 MPa) in Hy^{2}_{7}-based composite.

2.4. Effect of reinforcement on the tribological properties of a dental composite material

This section highlights the effect of reinforcement on the tribological performance of Bis-GMA-based dental composite materials. It also discusses the specifications of the wear tester and the medium used between the in dental composite sample and wear tester plate. For the tribological characteristic, several factors and levels were employed in the dental simulator, which are listed in Table 1. Chadda *et al.* [32] evaluated the fracture toughness and wear performance of the dental resin matrix of Bis-GMA/TEGDMA (69.5/29.5wt%) reinforced with micro-filled and micro-hybrid filled dental composites in the visible-light curing system. A wear test (sliding) was performed on a pin-on-disk tribometer. Two series, namely hydroxyapatite (H0, H20, H30, H40, and H50) and hybrid silica/hydroxyapatite (SH0, SH20, SH30, SH40, and SH50), were prepared with 0,20, 30, 40, and 50wt% for each series. The sliding wear rates of the dental composite specimens were observed in the descending order of H50 > H0>H20 > H40 > H30 and SH50 > SH0>SH20 > SH30 > SH40.

Altaie *et al.* [33] investigated the tribological behavior of six resin-based composites (RBC) as the dental restorative material. In this study, a comparison was performed between the original pin-on-disk wear test apparatus and a modified pin-on-disk test apparatus. From the experiments, it was observed that the maximum mean volume loss (mm^3) was demonstrated by the Filtek Supreme RBC and no significant differences were observed among other types of RBC. From the scanning electron microscope analysis, other wear facets were identified. Souza *et al.* [34] examined four commercial dental restorative composites on abrasive and sliding wear behavior. Four dental composites were fabricated with different mass fraction of filler (73, 56, 82, and 54wt %) and denoted as composite A, composite B, composite C, and composite D, respectively. The minimum wear volume after micro-scale abrasion test was obtained from composite C. The minimum wear volume after the reciprocating sliding test was approximately 0.3 mm^3 for composite C. Sonal *et al.* [35] examined the effect of nanoparticulate silica reinforcement on the wear characteristic of dental restorative materials. Silane-treated nano-silica was used with 0-9wt% in the dental composite. A two-body abrasive wear test was performed using the medium of artificial saliva. The results revealed that minimum wear was observed for the 9wt% filler content.

Ayatollahi *et al.* [36] reported the effect of temperature change and beverage on the tribological and mechanical properties of dental restorative materials. A soft drink and black tea were included under the category of beverage. The maximum wear resistance was identified in nanohybrid dental composite (0.26 ± 0.02 in tea and 0.25 ± 0.01 in soft drink). Ramalho *et al.* [37] demonstrated the effect of temperature on the tribological and mechanical properties of dental-based resin restorative composites. Three commercial dental materials (Synergy, Surefil, and Alert) and reinforcements were executed at different temperatures (5, 10, 20, 30, 40, and 50 °C). The maximum wear volume was observed in the Alert-based commercial composite, at temperatures of 30 and 40 °C. Kleczewska and Bielinski [38] analyzed the friction with wear performance of dental resin materials. A wear test was performed using a T-05 block-on-ring tribometer. The maximum values of wear volume (8.2%) and micro hardness (0.96 GPa) were observed in the Valux Plus commercial dental resin composite.

Arsecularatne *et al.* [39] examined the wear behavior of dental restorative materials. Three different Bis-GMA-based composites were prepared with three different nanofillers (alumino silicate glass (50–1000 nm), strontium glass (50–2000 nm), and silica (20–100 nm)). Alumino silicate glass-, strontium glass-, and silica-based dental composites were denoted as DC-1, DC-2, and DC-3, respectively. The wear test was performed using a tribometer with a reciprocating module. The maximum wear volume was observed in DC-2 polished specimen. The maximum values of hardness and elastic modulus were observed in DC-1 composite. Gan *et al.* [40] evaluated the friction with wear performance of the dental restorative material-based composite. Distilled water, artificial saliva, and a soft drink were used as the oral environments. Five Bis-GMA-based dental composites were prepared for the experiment. Two body-type wear tests were performed on a ball-on-flat rig. The wear resistance was observed to be better for Filtek P60 when compared to other nano-filled dental composites. The minimum coefficient of friction at steady state condition was observed for the VITA ZETA (under distilled water) dental composite. Souza *et al.* [41] analyzed the wear mechanism using ball-on-plate (ball crater) and pin-on-plate (linear reciprocating) rigs for dental restorative material composites. Two different Bis-GMA-based dental composites with organic materials (barium aluminoborosilicate, colloidal silica, and silica glass) were employed for the experiment. The results revealed that the wear volume varied from 0.0 to 0.4 mm^3 at varying number of cycles (0–25,000).

Hu *et al.* [42] investigated the two-body wear characteristic of dental materials. A sliding wear test was conducted using a pin-on-disk apparatus. Artificial saliva was used as the medium in the wear test. The abrasive counter face was manufactured from steatite ceramic. The results revealed that the maximum volume wear loss was observed in the P-60 light-cured composite and the minimum in the Au–Pd alloy-based dental material. The maximum and minimum values of volume wear loss on an abrasive ceramic wheel were observed in the Au–Pd alloy-based dental material and P-60 light-cured composite, respectively. Amer *et al.* [43] examined the three-body wear characteristics of yttria-stabilized zirconia (YSZ) as the dental restorative material. Three surface treatments named as glazed, rough, and smooth were implemented in this experiment. A three-body wear simulator (with 50,000 cycles) was used for the experiment. The results revealed that the maximum and minimum wear areas were observed in the glazed YSZ-based composite and smooth YSZ-based samples, respectively. Preis *et al.* [44] demonstrated the wear characteristic of surface-treated dental ceramics. Two different types of zirconia, a lithium disilicate glass ceramic, and veneering porcelain were used for preparing the samples. Two-body wear tests were conducted on the pin-on-block test apparatus considering the thermal cycle (2min/cycle, 5–55 °C). Zirconia ceramic demonstrated the lowest wear depth when compared to the lithium disilicate glass ceramic and

Table 1
Tentative factors and levels for dental wear simulator.

Control Factors	LEVEL				
	I	II	III	IV	V
A: Filler Content (F)	F1	F2	F3	F4	F5
B: Chewing Load (C)	C1	C2	C3	C4	C5
C: Sliding Speed (S)	S1	S2	S3	S4	S5
D: Chamber Temperature (CT)	CT1	CT2	CT3	CT4	CT5
E: Profile Speed (P)	P1	P2	P3	P4	P5
F: Mastication cycles (M)	M1	M2	M3	M4	M5

Numbers 1–5 denote the levels of the control factors.

veneering porcelain. The polished zirconia samples demonstrated the lowest wear when compared to the treated zirconia samples.

D'Arcangelo *et al.* [45] presented a comparative study of two-body wear resistance between gold alloy, human enamel, and five different dental ceramics. The wear resistance was measured in volume loss and vertical substance loss. The mastication simulator used 120,000 cycles, 49 N force, and 1.6 Hz frequency. The results revealed that the wear depth of human enamel (0.217 mm) was closer to gold alloy (0.223 mm). It also observed that the wear resistance was higher in milled Celtra Duo when compared to the human enamel or gold alloy. Zandparsa *et al.* [46] described the wear performance between ceramics and a human enamel antagonist. Four ceramics (IPS e. max Press, IPS e. max CAD, Noritake Super Porcelain EX-3, and LAVA Plus Zirconia) and one human enamel (control-based) were considered for the test. The wear test was performed by a vertical friction device (TA-317C). The results demonstrated that the maximum and minimum values of mean volume loss were observed in LAVA Plus Zirconia-based composite material (48.66 μm^3) and IPS e. max CAD-based composite material (39.75 μm^3), respectively. In the enamel, mean volume loss was 37.08 μm^3.

3. Results and conclusion

The above study on dental restorative composite materials has derived certain significant conclusions:

1. Bis-GMA is the potential dental resin material that is widely used for dental applications along with TEGDMA, which acts as a diluent, CQ, which acts as the photoinitiator, and EDMAB or DMAEMA, which act as the accelerator, in the polymerization of the resin.
2. The reinforcement of fibers or particulates significantly lead to the enhancement of physical, mechanical, thermal, and tribological properties of the dental resin matrix.
3. The silane surface treatment method of particulate fillers with γ-MPS further resulted in the enhancement of interfacial bonding between the resin matrix and particulate filler; consequently, the overall performance of the dental composite material was improved.
4. Finally, the size (micro/nano), shape (spherical/whisker etc.), and proportion of dental resin and reinforcement resulted in significant enhancement of overall performance; however, their content is required to be ascertained for optimized performance, subjectively and quantitatively (using design of experiment/multi-criteria decision making techniques) via experimentation.

Ethical statement

I testify that ethical approval is not required for this review.

Conflict of interest

All authors declare that they have no competing financial interests and no conflicts of interest.

CRediT authorship contribution statement

Ramkumar Yadav: Writing - original draft. **Mukesh Kumar:** Supervision.

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