

Resin-Based Composite Materials and Various Selected Material Comparative Analysis of Clinical Efficacy in Posterior Tooth Restoration

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Abstract:

Resin-Based Composite Materials (RBCMs) are pivotal in dental restorative and filling practices owing to their varying properties influenced by the matrix, reinforcing agents, and curing techniques. This study aims to detail the advancements in RBCMs, comparing, and evaluating the clinical efficacy of four prominent dental materials employed in posterior tooth restoration via Bayesian network meta-analysis. An extensive search was conducted across Chinese and English databases, including CNKI, Wanfang, and VIP, to gather studies on the clinical efficacy of posterior tooth restorations. Relevant literature was meticulously selected, data extracted, and the risk of bias assessed. The analysis was conducted utilizing RevMan 5.4.1 and R software's Gemtc package for network meta-analysis (NMA). Results: From the initial screening, 12 clinical studies were deemed suitable, encompassing a total of 1064 participants. The NMA outcomes indicated that machined ceramics outperformed in efficacy for posterior tooth restoration, ranked as follows: Machined Ceramics > Nano Resin-Based Composite Materials (NanoRBCMs) > Standard RBCMs > Glass Ionomer Cements. In terms of clinical efficacy for posterior tooth restoration, machined ceramics lead in performance followed closely by Nano RBCMs. Standard RBCMs also show commendable efficacy but are outperformed by their nano counterparts. Cement, however, lags in the efficacy evaluation. These findings highlight the continuous evolution and diverse efficacy of resin-based composite materials in dental restorations, providing valuable insights for clinical decision-making.

Keywords:

Resin-Based Composite Materials, Network Meta-Analysis, Clinical Efficacy

1. Introduction

The prevalence of dental caries has always been ranked first among oral diseases, and modern medicine mainly treats dental caries by filling and repairing them. Therefore, a widely used oral filling and repair material has become a natural need for people. At first, people tended to use materials such as amalgam for filling and repairing, but due to its aesthetic and functional limitations, amalgam gradually faded out of people's sight. In 1962, American scholar Bowen R.L. invented a dental composite resin with bisphenol A-dimethacrylate glycidyl ester (Bis-GMA) resin as the matrix and silica as the filler. Zhang Zengming et al. [1] believed that bisphenol A-dimethacrylate glycidyl ester resin had the advantages of color similar to tooth tissue, good mechanical properties, relatively low polymerization shrinkage of about 6%, and fast light curing speed, so it was rapidly and widely used in dental filling and repair. Resin-Based Composite Materials (RBCMs) are currently a more ideal dental caries repair material. Its most prominent advantages are good aesthetic properties, simple treatment operation, and economical and effective treatment. However, the disadvantages of traditional Bis-GMA composite resin are also very obvious. It has a large curing shrinkage rate, a large linear expansion coefficient, and poor wear resistance. If mixed inorganic fillers are added to enhance its mechanical properties, it will lead to a decrease in its aesthetics. It cannot fully meet people's expectations for the increasing performance of dental materials. Therefore, people began to study and improve RBCMs. RBCMs is a composite material composed of three parts: organic resin matrix, inorganic filler, and initiator system. Studies have found that changing the composition of the three parts, especially the resin matrix and inorganic filler, will greatly change the physical and chemical properties of the resin [2].

In terms of the resin matrix, Chinese medical experts began to use epoxy resin to replace traditional RBCMs for oral treatment in the 1980s. In 1974, the First Hospital of Beijiao, Tianjin published a research article in the Tianjin Chemical Industry Journal, pointing out that the performance of denture bases made of epoxy resin is significantly better than that of traditional resins, and has the potential to replace traditional resin materials [3]. In 2011, Meng Shujuan pointed out that the shrinkage of epoxy resin during the curing process is significantly smaller than that of traditional RBCMs, which is beneficial to improve marginal adhesion [4]. In addition, Li Runyi et al. [5] found through clinical research that epoxy resin materials also have the advantage of less damage to the periodontal tissue of patients undergoing root canal treatment. This material can effectively reduce the leukocyte swallowing function, leukocyte infiltration function, inflammatory exudation, etc., thereby reducing damage to the periodontal tissue; there are many studies on reinforced materials. In 2001, Wang Zhigang et al. [6] found that in periodontal splints, the fracture failure rate of fiber-reinforced acrylic resin restorations was significantly lower than that of unreinforced restorations. The flexural strength of the reinforced base resin reached 936MPa, while that of the unreinforced base was only 79-86MPa.

In 2002, Wang Guoqing's team from Wuhan University School of Stomatology found that glass fiber can effectively enhance the flexural strength and impact strength of denture base resin [7]. In 2003, Professor Chen Xi, also from Wuhan University School of Stomatology, said [8] that previous reinforcement materials were mainly filled with large quartz particles, which made them difficult to polish. However, the use of nanofillers between 20-100nm can significantly improve the X-ray radiopacity of the material and reduce shrinkage stress, thereby enhancing the performance of the material. In 2023, Zhang Hailong et al. summarized a large number of practical proofs

in recent years [9] and stated that the basic RBCMs showed the characteristics of low strength and high polymerization shrinkage, which caused the repair effect to fail to meet expectations. In contrast, nano-resin materials have higher surface activity and smaller particle sizes, which are easier to combine with tooth substrates, improve the mechanical properties and wear resistance of RBCMs, and are expected to become the main oral filling and repair materials in the new era. In addition, multiple studies have shown [10-14] that it is beneficial to improve the incidence of dentin sensitivity after restoration, improve aesthetic effects, reduce periodontal sensitivity, reduce pulp stimulation, improve pain symptoms and the incidence of tooth sensitivity, and have fewer complications. The curing of RBCMs is generally divided into two systems: chemical curing and light curing. The commonly used initiator systems for chemical curing RBCMs are peroxide/p-toluene sulfonate and tributyl boron. The peroxide/tertiary amine system can be cured at room temperature and has good biocompatibility. It is currently widely used in clinical practice [15]. However, the residual amine is easily oxidized or complexed with phenolic inhibitors to produce color, so the color stability is relatively poor.

The photosensitizer for visible light curing resins is usually α -diketones or aromatic ketones, and the reducing agent is aromatic amines, aldehydes, or thiols. In recent years, the new photosensitizer 1-phenyl-1,2-propane has been considered to have the function of improving the color of resin materials, and it cooperates with camphor quinone to make the photopolymerization process more complete. Some studies have also found that the curing system will also affect the physical and chemical properties of RBCMs. In 2002, Zheng Gang, Xu Hengchang, Zhao Qi, and others showed in their study [16] that the amount of shrinkage during the curing of RBCMs is related to the type of curing light source, and the amount of shrinkage produced by irradiation with a high-energy xenon light source is the smallest. Guo Bin's team at the West China School of Stomatology, Sichuan University, conducted a random experiment on 73 ex vivo teeth and found that light-emitting diode light curing lamps may have a better ability to reduce microleakage [17].

In addition, glass ionomer cement and alumina glass-infiltrated porcelain restorations (ceramics) toughened with iodine are commonly used materials for filling cavities in posterior teeth. Generally, traditional glass ionomer cement (cement) has good bonding properties to enamel and dentin and can release fluoride ions in the oral environment to form fluorapatite, which improves the anti-caries ability of teeth and has good aesthetic properties. The tetragonal iodine in ceramic restorations has a stress-induced phase change toughening effect, and the bending strength can be as high as 650Mpa, but its aesthetic properties are poor, and it is generally used for posterior tooth restorations. Regarding clinical efficacy, although there have been many comparative studies on clinical efficacy in the past, there are few studies on the comprehensive evaluation of the efficacy of multiple therapies. Based on a network meta-analysis, this study compared the clinical efficacy of four common oral materials in posterior tooth filling and restoration in the past five years, providing evidence and data basis for the selection of oral materials in clinical practice and subsequent related research.

2. Materials and Methods

2.1. Inclusion Criteria

(1) The language of the research literature is Chinese; (2) The research is a prospective cohort and randomized controlled trial; (3) The research samples must all be diagnosed as patients with posterior tooth restoration, with combined clinical indications and no other oral diseases; (4) The comprehensive efficacy evaluation of the study adopts treatment success (no damage after the filling is completed, and there is no gap at the edge, and no pressure on the patient's gums. X-ray examination shows that the patient's root apex and periodontium are normal, there is no periodontal or pulp inflammation, and harder food can be chewed. Effective is that the filling material used by the patient is better and can complete the chewing of soft food.) Otherwise, it is unsuccessful, or the same standard is used, and the results include but are not limited to the three-category variable representation of the sample as "significantly effective, effective, and ineffective". (5) For RCT studies, the oral materials used in the intervention group and the control group are ceramics, NanoRBCMs, RBCMs, and cement, and the treatment measures of the intervention group and the control group are different.

2.2. Exclusion criteria

(1) The outcome evaluation index does not include the three-category variables of "significant effect, effective, and ineffective"; (2) The intervention measures are materials other than ceramics, nano-resins, RBCMs, and glass ionomer cement, or mixed materials other than the four materials mentioned in the inclusion criteria; (3) The articles are reviews, systematic reviews, experience summaries, conference papers, dissertations, etc.; (4) The literature language is a language other than Chinese.

2.3. Search strategy

Using "posterior tooth filling and restoration", "clinical efficacy", "composite resin", "glass ionomer cement", "nano-resin", "ceramics", and "efficacy" as search terms, and search the mainstream Chinese and English databases such as CNKI, Wanfang, and VIP by computer, and adjust the database search plan according to the actual situation. The search time is from August 31, 2019 to August 31, 2024.

2.4. Literature screening and data extraction

Two reviewers independently searched the database according to the pre-established search strategy. If there is a disagreement between the two reviewers during the screening process, the third person will judge whether to include the study. The extracted data included author name, publication year, number of study samples, intervention measures, control group treatment measures, number of categorical variables in comprehensive efficacy evaluation, etc.

2.5. Study bias risk assessment

Two reviewers evaluated the study in accordance with the Cochrane bias risk assessment requirements using RevMan5.4.1. If the opinions could not be unified, the third researcher would evaluate the study.

2.5. Data statistical processing

This study used a binary network meta-analysis model and performed a Bayesian methodology-based NMA analysis using the Gemtc package in R. The Rajas package was used to perform an NMA analysis on the four intervention measures. RevMan5.4.1 software was used to draw a funnel plot to detect publication bias.

3. Results

3.1. Literature search results

A total of 392 relevant articles were retrieved, and 12 articles that met the inclusion criteria were finally selected based on the search process.

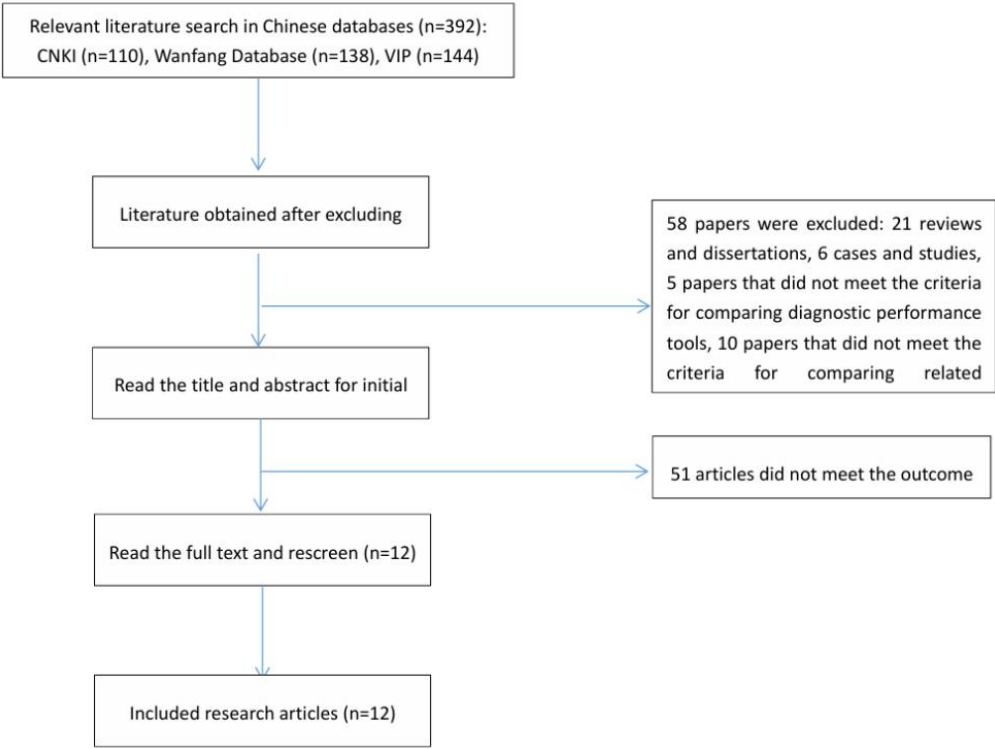


Figure 1. Flow diagram.

3.2. Baseline characteristics and bias risk assessment of included literature

A total of 21 articles were included, with 1064 samples. The detailed information of the study is shown in Table 1, and the results of the literature bias risk are shown in Figure 2.

Table 1. Baseline data of the included studies.

First author	Sample	Treatment	Follow-up period (months)	Measurement indicators
	Control group / Intervention group	Control group / Intervention group		
Na W. ^[18]	50/50	RBMCs/Nano RBMCs	3	B/C/E
Yandan C. ^[19]	38/38	Cements / RBMCs	24	B/C/D/E
Gongqing Y. ^[20]	41/41	Cements / RBMCs	None Mentioned	B/C/D
Jinjin D. ^[21]	40/40	Cements / RBMCs	6	A/B/C/E
Hui L. ^[22]	43/43	Cements / RBMCs	None Mentioned	A/B/C
Yahua C. ^[23]	46/50	Cements / RBMCs	None Mentioned	A/C
Chongli G. ^[24]	41/45	RBMCs / Ceramics	6	A/C
Yanli C. ^[25]	51/50	Ceramics / RBMCs	None Mentioned	A/C
Yanwen Y. ^[26]	48/48	Cements / RBMCs	12	A/C/D/E

Yanqing H. ^[27]	40/40	RBCMs / Nano RBCMs	None Mentioned	A/C/D
Tian Z. ^[28]	40/40	Cements / RBCMs	24	B/C/D/E
Yu C. ^[29]	45/46	Cements / RBCMs	None Mentioned	A/B/C

* A: Periodontal condition B: Complications C: Treatment effect evaluation D: Chewing function E: Aesthetic score

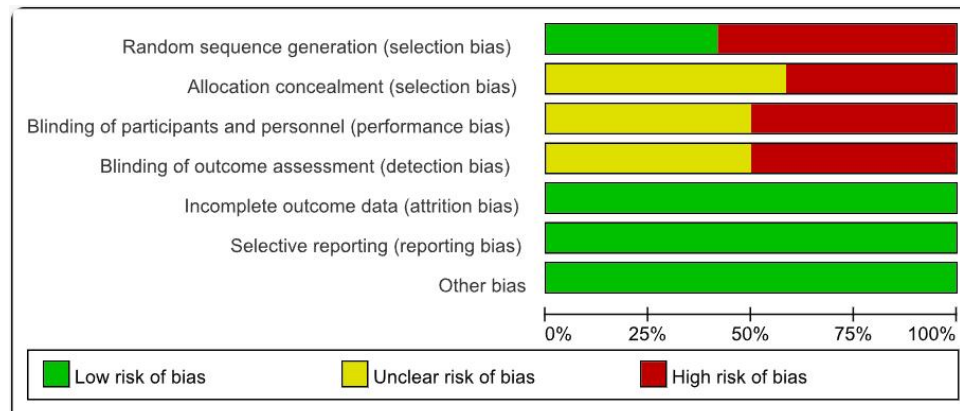


Figure 2. Risk of bias.

3.3. Efficacy analysis

3.3.1. Intervention efficacy network diagram

The results of the efficacy network diagram are shown in Figure 3.

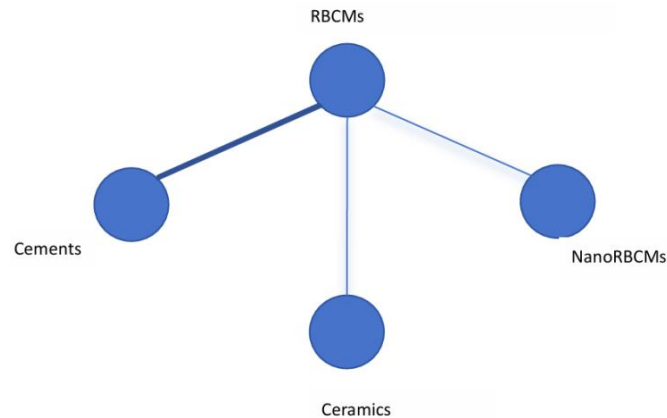


Figure 3. Network evidence plot.

3.3.2. Consistency and heterogeneity test

The node-splitting method was used for the test, and the results showed that there was no statistically significant difference in the direct and indirect comparison results between the intervention measures ($P > 0.05$), indicating that the direct and indirect comparison results were consistent. The heterogeneity of the effect size $I^2 = 9\%$. Since $I^2 < 50\%$, it can be considered that the heterogeneity of the model is small. Combined with the above test results, the consistency model was used for NMA analysis.

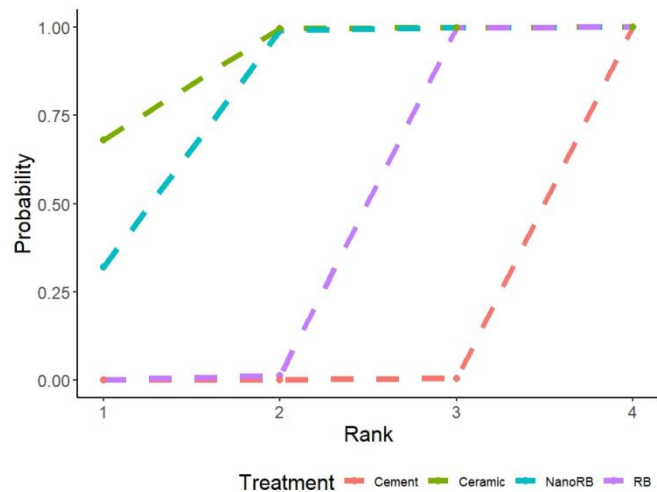
3.3.3. Results of network meta-analysis

As shown in Table 2 and Figure 4, compared with glass ionomer cement, nano-resin efficacy (OR=-0.2986, 95% CI[-1.094,1.673]), RBCMs efficacy (OR=1.432, 95% CI[0.4591,2.486]), ceramic (OR=2.197, 95% CI[1.122,3.356]). According to the SUCRA chart, the order of Rank 1 to 4 is ceramics > Nano RBCMs > RBCMs > cement. This result suggests that ceramics have better efficacy.

A	-1.132 (-2.132, -0.2362)	-1.899 (-3.012, -0.9004)	0.2986 (-1.094, 1.673)
1.132 (0.2362, 2.132)*	B	-0.7603 (-1.229, -0.3181)	1.432 (0.4591, 2.486)
1.899 (0.9004, 3.012)*	0.7603 (0.3181, 1.229)*	C	2.197 (1.122, 3.356)
-0.2986 (-1.673, 1.094)	-1.432 (-2.486, -0.4591)*	-2.197 (-3.356, -1.122)*	D

A: NanoRBCMs; B: RBCMs; C: Ceramic; D: Cement

Table 2. Relative effects.



NanoRB: NanoRBCMs; RB: RBCMs

Figure 4. Cumulative probability ranking chart.

3.3.4. Publication bias test

The inverted funnel plot was drawn with the total effective rate as the indicator using RevMan5.4.0 software. The results showed that the distribution on both sides was more on the right side, indicating that there was a certain risk of publication bias in this study, and the interpretation of the research results needed to be cautious, as shown in Figure 5.

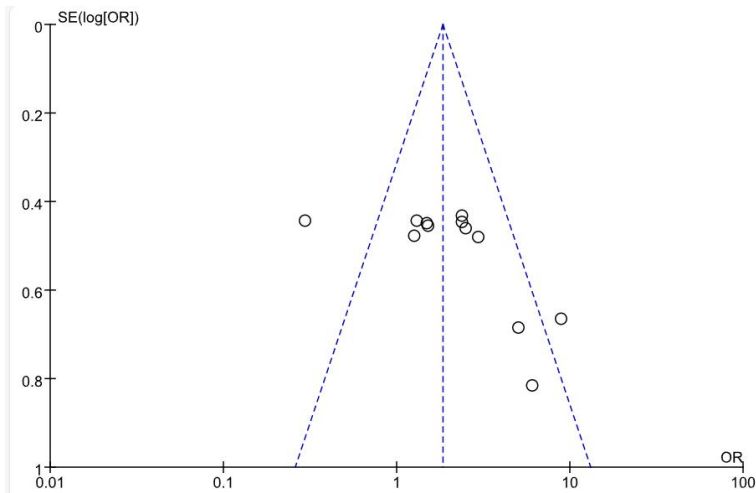


Figure 5. Funnel plot.

4. Discussion

In terms of oral function, the posterior teeth bear most of the bite force during chewing. However, when the posterior teeth are defective, the stress cannot be dispersed normally, which can easily lead to stress concentration [30]. In the repair of wedge-shaped defects in posterior teeth, different materials are used to repair and fill the defects, resulting in different levels of stress concentration. Studies have shown that the stress concentration near the wedge-shaped defect is obvious, and the stress concentration near the defect is significantly improved after using glass ionomer cement and RBCMs to simulate filling the wedge-shaped defect. Among them, RBCMs have better stress improvement. The maximum principal stress value at the deepest part of the defect after repair is reduced to 36.2MPa, which is very close to the stress value of normal teeth. However, the maximum principal stress value at the deepest part of the defect after repair with glass ionomer cement has an improved effect. Weaker, 42.5MPa [31]. Research results show that RBCMs have an excellent stress dispersion effect [32], but at the same time, the frequency of curing shrinkage, edge microleakage, wear, pulp symptoms, and other phenomena after direct filling with RBCMs is significantly higher than that of other materials. [33]. NanoRBCMs are a relatively new type of resin, which is made by adding 5-75nm inorganic fillers including nano-silica, nanodiamond, nano zirconia, nano silica nitride, nanohydroxyapatite, nano titanium oxide, nanometer Aluminum trioxide, etc. [34], this improvement can effectively reduce the polymerization shrinkage of dental RBCMs, improve the fineness of filler particles, and improve the wear resistance and other significant properties of the material. It plays an important role in the optical, mechanical, and optical properties of resin materials.

The chemical properties have also been improved and basically have the advantage of not irritating the dental pulp [35]. The biochemical environment of the oral cavity is complex. When RBCMs undergo hot and cold cycles, polymerization shrinkage or corrosion will inevitably occur. However, ceramic materials are resistant to chemical corrosion, and high heat and light will not affect the performance of ceramic materials. Causes problems such as local shrinkage and deformation [36]. In addition, if nano-resin pays too much attention to performance and adds a large amount of nano-inorganic fillers, it will affect its light transmittance and affect its appearance to a certain extent. However, ceramics are closer to the color of human gums, which can achieve ideal aesthetic effects and help improve patient health. Clinical repair satisfaction, and has the advantages of wear resistance, non-toxic, and harmless [37]. The results obtained in this study are similar to previous studies. During the follow-up period of posterior tooth restoration, ceramics have the highest success rate, followed by nano-resin, followed by RBCMs. The success rate of glass ionomer cement is lower. This is to a certain extent. Clinical material selection for posterior tooth restoration provides a data basis. However, since the studies included in this study are only Chinese literature and the product brands and models used are different, the results of this study need to be interpreted with caution.

5. Conclusions

In terms of clinical efficacy for posterior tooth restoration, machined ceramics lead in performance followed closely by Nano RBCMs. Standard RBCMs also show commendable efficacy but are outperformed by their nano counterparts. Glass ionomer cement, however, lags in efficacy evaluation. These findings highlight the

continuous evolution and diverse efficacy of RBCMs in dental restorations, providing valuable insights for clinical decision-making.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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