Use of Nanocomposite Resin Materials for Dental Restoration in Elderly Patients

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Tooth defects can affect not only periodontal tissue but also the whole body if not restored in good time. Composite resin materials are commonly used filling materials in dental restorations, but they have low material strength and are likely to cause insufficient secondary caries. Improving the ability of composite resin materials to restore defective teeth has thus become the focus of research interest. Nanocomposite materials are widely used in dentistry because of their good design characteristics, wide indications, strong restorative power, and high economic efficiency. However, whether they cause respiratory tract inflammation or tissue damage due to their large specific surface area still needs further investigation. This study compared the effects of nanocomposite resin materials with those of traditional light-curable composite resin materials on the restoration of dental defects in elderly patients and found that nanomaterials could not only reduce the incidence of tooth sensitivity and tooth pain after restoration but also improve the aesthetic outcomes of the tooth. In addition to the restoration effect, the occurrence of adverse reactions in patients who underwent dental restoration using nanomaterials within 2 years after the procedure was significantly lower than that in patients who underwent dental restoration using traditional materials. These results indicate that the nanocomposite resin material improved the restoration effect in elderly patients without increasing their risk for adverse reactions. Therefore, nanocomposite resin materials should be used as the preferred filling material for dental restoration in elderly patients with dental defects.

Keywords: Cohort Study, Elderly Population, Nanocomposite Resin Materials, Tooth Defect

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INTRODUCTION

Tooth defects refer to the appearance and structure of hard tissue in teeth with varying levels of abnormality that specifically manifest as abnormal tooth morphology and decreased occlusal ability [1,2]. Depending on the degree of defect, different symptoms may occur. When the scale of tooth damage is small, there may be no obvious symptoms. When a tooth defect accumulates in the pulp or dentin layer, pulp inflammation due to external stimuli will develop. When a tooth defect involves adjacent teeth, it will destroy the normal abutment dynamics between adjacent teeth, easily causing interdental accumulation of food debris, which in turn could lead to periodontitis [3]. A defect involving adjacent teeth may also cause the primary tooth to tilt, and a severely tilted tooth axis may consequently cause gingivitis [4]. When the site of the defect takes up considerable space, it will significantly affect the occlusal ability of the tooth, resulting in unilateral chewing; notably, prolonged unilateral chewing can cause oral and jaw dysfunction [5]. Furthermore, if a tooth defect occurs in the anterior teeth, it could directly affect the patient's image and mental state [6]. Therefore, timely restoration of dental defects is crucial to patients' physical and psychological health. The main factors that lead to tooth defects include dental caries, dental trauma, as well as severe wear and developmental deformities. Dental caries and dental injuries are primarily caused by poor eating habits and hygiene practices [7-9]. The

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elderly population is more prone to dental defects due to their weaker oral hygiene awareness. Tooth defects in elderly patients mainly manifest as severe tooth wear, thinning of the gums, and tooth loss. These may affect not only the oral health of these elderly patients, due to the residual crown and root, but also their quality of life [10,11].

With the development of modern society, people's living standards continue to improve, as do the requirements of the elderly population for a high quality of life. This has resulted in an increasing number of elderly people becoming more aware of the importance of tooth protection and makes dental defect restoration one of the most common reasons for dental clinic visits. The use of dental restorative materials to fill tooth defects is currently the most commonly used and most effective method of treatment [12]. When using filling materials to restore the shape and function of the tooth, the biocompatibility, durability, and economic efficiency of the restorative material should be thoroughly considered. Restoration of anterior teeth mainly takes into account the aesthetics and bonding characteristics of the restoration, whereas restoration of posterior teeth is more concerned with the strength and wear resistance of the restoration [13]. At present, various types of materials that can be used to restore tooth defects are available. Among them, light-curing composite resin has become widely recognized by patients due to its advantages of easy shaping, vivid color, and minimal trauma [14,15]. However, studies have suggested that traditional composite resin materials trigger a certain degree of pulp irritation and that some patients will have tooth sensitivity after restoration, thereby limiting the use of light-curing composite resin materials [16].

Nanoparticles are primarily characterized by their small particle diameter, high surface energy, and large surface area, which have allowed them to become a research hotspot in such subject areas as light, heat, electricity, and force [17,18]. Nanocomposites are widely used in the fields of biomedicine, industrial catalysis, fine chemicals, as well as national defense and aerospace because of their good design characteristics [19,20]. Nanocomposite resin materials, specifically, are widely used in dentistry for their wide indications, strong restorative power, and high economic efficiency [21]. However, it is precisely because of the large specific surface area of nanoparticles that some patients worry that they may be more easily absorbed by the skin and digestive tract, which may cause adverse reactions, such as respiratory tract inflammation and tissue damage. This study compared the restoration effects of nanocomposite resin materials with those of light-curing composite resin materials on dental defects in elderly patients to determine the application value of the former materials in treating dental defects in this population.

MATERIALS AND METHODS

Research Subjects

A total of 84 patients who received dental defect restoration at College of Stomatology, Qingdao University dental clinic between January 2018 and June 2018 were selected as research subjects for this cohort study. The inclusion criteria were (1) age over 60 years with a tooth defect in the front teeth, (2) normal blood coagulation function, (3) normal function of vital organs, (4) autonomous behavioral ability, and (5) voluntary participation in the study. The exclusion criteria were (1) involuntary participation and (2) failure to cooperate in completing follow-up and testing of relevant indicators during follow-up. The patients were assigned to one of two groups according to dental restorative material: The nano group (n = 42) underwent dental restoration with nanocomposite resin materials (Fig. 1), whereas the control group (n = 42) underwent dental restoration using light-curing composite materials. Differences in sex, age, and causes of dental defects between the two groups were not statistically significant (Table 1), suggesting that all patients had comparable dental sensitivity, pain scores, and restoration effects after restoration.

Fig. 1. Nano restoration material for tooth defect. (A) Nanocomposite resin material. (B) Electron micrograph of the nanocomposite resin material.

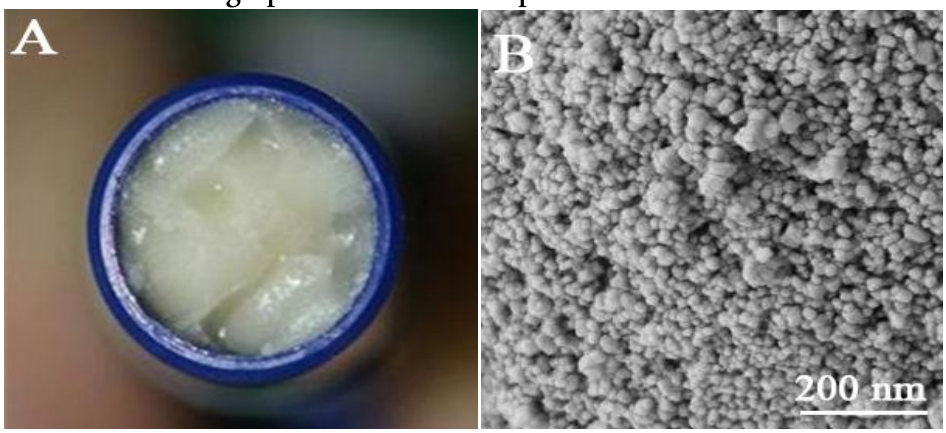


Table 1. Characteristics of the research subjects n(%)

		Nano group	Common group	χ^2/t	*P*
Gender (male/female)		29 (69.05)/13 (30.95)	27 (64.29)/15 (35.71)	0.214	0.643
Age (years)		67.95 ± 3.77	69.13 ± 3.92	1.406	0.163
Number of defect teeth		50	48	0.042	0.837
Cause of tooth defect	Caries	21 (50.00)	23 (54.76)	0.518	0.772
	Trauma	14 (33.33)	11 (26.19)		
	Others	7 (16.67)	8 (19.05)		

Tooth Defect Restoration Method

Both groups were asked to thoroughly clean their teeth before undergoing dental restoration. Their teeth were compared under natural light, and tooth color was recorded using a camera. After placing a rubber dam in a patient's mouth, the carious tissue of the defective tooth was removed and the bonding surface was ground. If the patient's tooth defect was close to the pulp, pulp protection was performed before the filling and restoration to avoid irritation to the pulp during the actual procedures. Acid etching was then conducted, with the etching agent being liquid or jelly phosphoric acid. After acid etching for approximately 30 seconds, the etching agent was rinsed off with running water. Filling using the method of triangular accumulation began after the tooth surface dried up and was evenly rubbed with the adhesive. The dentin and enamel layers were filled with nanocomposite resin material with the support of a silicone rubber partition. The control group was administered the same filling method as that used in the nano group but with light-curing composite resin material applied after filling (30 seconds per layer). Occlusion was adjusted after filling and the shape of the restorative material was fine-tuned using a fine bur. After the polishing process, the rubber dam was removed and the patients' tooth color was recorded using a camera.

Observation Indicators

Comparison of tooth sensitivity and pain score

Both groups were followed up for 2 years, with a monthly follow-up within the first 3 months and once every 6 months after that. According to the Ryge Criteria for Clinical Evaluation of Dental Restorative Materials [22], the patients' tooth sensitivity was evaluated 1, 2, and 3 months after restoration. An air compressor was used to blow air approximately 3 cm away from the patients' restored tooth for approximately 2 seconds. Patients who did not feel pain when stimulated by gas were rated as insensitive (Grade A), those who felt pain when stimulated, with the pain disappearing quickly after the stimulation, were classified as transiently sensitive (Grade B), and those whose pain persisted long after the stimulus ended were categorized as sensitive (Grade C).

A visual analog scale (VAS) was used to evaluate the patients' tooth pain 1, 2, and 3 months after restoration [23]. The VAS used was a 10-cm-long horizontal line labeled with "0" at the start and "10" at the end. The patients were instructed to mark the horizontal line according to their

perceived pain intensity. The higher the value of the mark was, the higher their pain level.

Periodontal alkaline phosphatase level

At the end of follow-up, the dialysis membrane bag method was used to collect gingival crevicular fluid from the patients' restorations, and pyrrole/luminol/gold composite nano-electrochemiluminescence was used to detect the amount of alkaline phosphatase (ALP) in the gingival crevicular fluid. The pocket method does not require the filter paper strip to be inserted into the gingival sulcular epithelium, which can reduce physical stimulation on the gingival sulcus and improve the accuracy of detection. The electrochemiluminescence method using nanomaterials as modified electrodes can also improve the accuracy of ALP detection.

Aesthetic outcomes of restored teeth

The aesthetic outcomes of the patients' teeth at the end of follow-up were compared. The evaluation covered three items: the edge fit between the restorative material and the original tooth, color matching, and surface smoothness. Each item was scored from 0 to 10, with the total score range being 0–30 points, and the degree of tooth aesthetics was proportional to the score. Each patient was evaluated by two clinicians, and the average of their scores served as the patient's dental aesthetic score.

Restorationeffect

The restoration effect on each patient was evaluated at the last follow-up. If the chewing function of the affected tooth was normal, there was no pain during daily brushing and eating, and the tooth exhibited a natural color, then the restoration effect was considered "excellent". If the chewing function of the affected tooth significantly improved, no obvious wear on the surface was noted, and the tooth color was natural, then the restoration effect was rated "good". If the chewing function of the affected tooth improved, the surface was slightly worn, and the tooth color slightly changed, then the restoration effect was classified as "medium". Finally, if the chewing function of the affected tooth did not exhibit any change, the surface was obviously worn, and a difference in color between the restored part and the original tooth was observed, then the restoration effect was graded "poor".

In addition, the occurrence of complications, such as restoration loosening, dental caries, periodontitis, and pulpitis, during the follow-up period was recorded and compared between the groups.

Statistical Analysis

SPSS 25.0 (International Business Machines Corporation, New York, America) and were used to analyze the data. Quantitative data conforming to normal distribution were expressed as mean ± standard deviation. The t-test, and repeated-measures analysis of variancewere used to compare differences between the two groups, and between the groups at different time points, respectively. In addition, the comparison between multiple groups was performed by SNA-Q analysis. Qualitative data were measured using χ^2 analysis and expressed as frequency and percentage. When the theoretical frequency was between 1 and 4, the χ^2 value was corrected. Rank data were assessed using the rank-sum test. All comparisons were $P< 0.05$, indicating that the differences were significant.

RESULTS AND DISCUSSION

Tooth Sensitivity

Evaluation and comparison of tooth sensitivity in the two groups at different time points after filling revealed that the incidence of tooth sensitivity in the nano group was significantly lower than that in the control group at 3 and 24 months after restoration (i.e., end of follow-up; $P< 0.05$) (Fig. 2 and Table 2).

Fig. 2.
Comparison of tooth sensitivity at different time points after dental restoration between the study groups.a: $P< 0.05$.

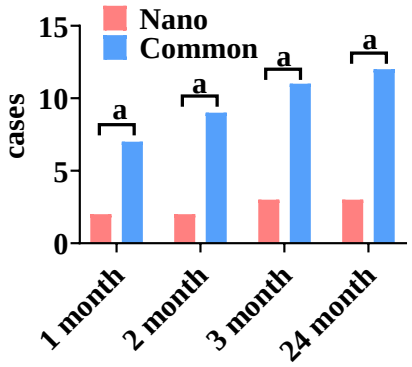


Table 2.
Comparison of tooth sensitivity between the study groups

Item	groups	time			
		1 month	2 month	3 month	24 month
Tooth sensitivity	Nano (42)	2 (4.76)	2 (4.76)	3 (7.14)	3 (7.14)
	Common (42)	7 (16.67)	9 (21.43)	11 (26.19)	12 (28.57)
	χ^2	1.991	3.766	4.200	5.194
	P	0.158	0.052	0.040	0.023

VAS Scores

Analysis of the tooth pain scores of the two groups at four time points after filling showed that the VAS pain scores of the nano group were lower than those of the control group at all time points ($P< 0.05$) (Fig. 3 and Table 3). Combining the results obtained for tooth sensitivity and VAS scores, we determined that nanocomposite resin materials could reduce the incidence of tooth sensitivity and tooth pain after restoration in elderly patients with dental defects.

Fig. 3.
Comparison of tooth pain scores at different time points after dental restoration between the study groups.

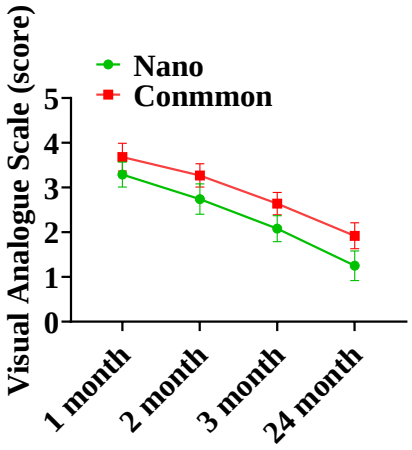


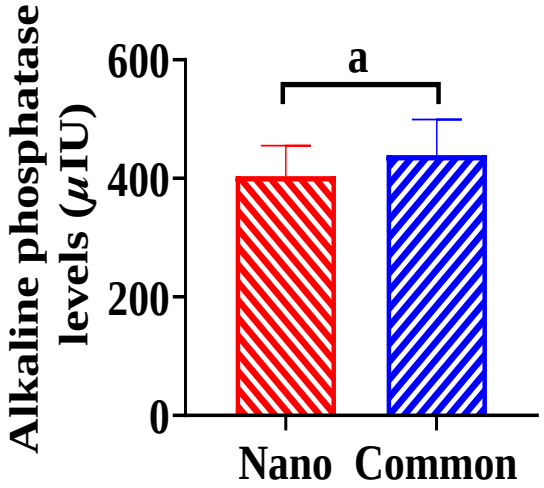
Table 3.
Comparison of tooth pain scores between the study groups

groups	cases	time			
		1 month	2 month	3 month	24 month
Nano	42	3.29 ± 0.28	2.74 ± 0.34	2.08 ± 0.29	1.25 ± 0.33
Common	42	3.68 ± 0.31	3.27 ± 0.26	2.64 ± 0.25	1.92 ± 0.29
$F_{Interaction}$		3.202			
P		0.024			
F_{time}		278.411			
P		< 0.001			
F_{group}		653.614			
P		< 0.001			

Periodontal ALP

The amount of ALP in the gingival crevicular fluid can reflect dental inflammation or immunity of the site. In this study, the ALP content in the gingival crevicular fluid of the nano group was significantly lower than that of the control group (P< 0.05) (Fig. 4). This suggests that nanocomposite resin materials can effectively reduce the risk of dental inflammation in patients.

Fig. 4.
ALP levels detected in the study groups.a: P< 0.05.



Aesthetic Outcomes

The aesthetic outcome of a defective tooth after restoration is an important indicator of the restoration effect. This study evaluated and compared aesthetic outcomes 24 months after restoration and found that the edge fit between the restorative material and the original tooth, color matching, and surface smoothness were significantly better in the nano group compared with the control group (P < 0.05) (Fig. 5 andTable 4).

Fig. 5.
Comparison of aesthetic outcomes after dental restoration between the study groups.a: $P< 0.05$.

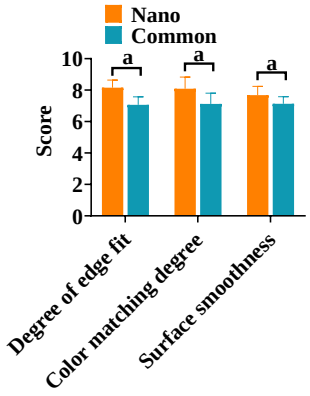


Table 4.
Aesthetic outcomes of restored teeth

groups	Degree of edge fit	Color matching degree	Surface smoothness
Nano (42)	8.15 ± 0.49	8.09 ± 0.74	7.68 ± 0.56
Common (42)	7.06 ± 0.51	7.12 ± 0.68	7.13 ± 0.45
t	9.988	6.255	4.962
P	< 0.001	< 0.001	< 0.001

Restoration Effect

Restoration effect was evaluated in both groups at the end of follow-up, and the results revealed that the difference between them was statistically significant. Notably, a substantial proportion of patients from the nano group were found to have "excellent" and "good" restoration effects (Fig. 6and Table 5).

Fig. 6.
Comparison of dental restoration effects between the study groups.

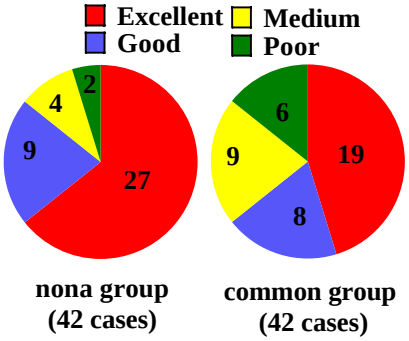


Table 5.
Comparison of restoration effects between the study groups

groups	Excellent	Good	Medium	Poor
Nano (42)	27 (64.29)	9 (21.43)	4 (9.52)	2 (4.76)
Common (42)	19 (45.24)	8 (19.05)	9 (21.43)	6 (14.29)
Z		−2.115		
P		0.034		

Complications

The occurrence of complications within 2 years after restoration was analyzed at the end of follow-up. Only two cases of prosthetic loosening and one case of dental caries occurred in the nano group, yielding a total occurrence rate of 7.14%, which is much lower than that of 26.19% in the control group ($P< 0.05$) (Fig. 7 and Table 6).

Fig. 7.
Comparison of complications after dental restoration between the study groups.

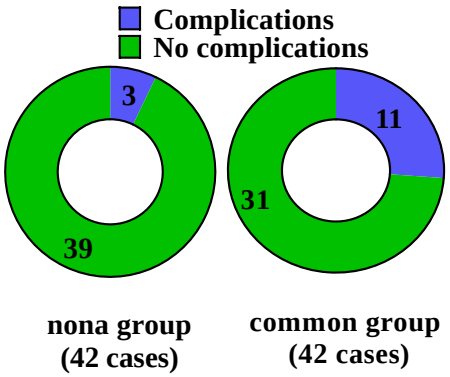


Table 6. Comparison of complications during follow-up between the study groups

groups	Loose	Caries	Periodontitis	Pulpitis	Total incidence
Nano (42)	2 (4.76)	1 (2.38)	0	0	3 (7.14)
Common (42)	5 (11.90)	4 (9.52)	1 (2.38)	1 (2.38)	11 (26.19)
χ^2					4.200
P					0.040

Discussion

Tooth defects can affect not only periodontal tissue but also the whole body if not restored in good time. Composite resin materials are commonly used as filling materials in dental restorations. However, long-term clinical use has revealed that due to their low strength and high polymerization shrinkage, aesthetic retention after restoration is poor and their application can easily cause primary caries. In addition, traditional composite resin materials have poor color stability, which may lead to staining or even discoloration of the filling that is potentially further exacerbated by pigments from the consumption of such foods as tomatoes, carrots, purple cabbage, and other vegetables as well as such beverages as coffee, tea, and red wine, ultimately affecting the aesthetic outcomes of the restoration. Therefore, a reduction in the adhesion of pigments and plaque in the oral cavity on the restorative material, which requires the surface of the restorative material to be as smooth as possible, is essential to maintain the aesthetic of the restored tooth.

In recent years, much work has been committed to developing dental restorative materials with strong performance, strong plasticity, and high aesthetic retention. With the development of nanotechnology and its wide application in the medical field, research into dental restorative materials has progressed. Siddiqui et al. [24] reported that combining nanomaterials with traditional light-curing resin materials can improve the sealing ability of resin materials and reduce the incidence of micropenetration of restorative materials. Wang et al. [25] determined that nano-hydroxyapatite materials can reduce tooth sensitivity. In addition, nano-hydroxyapatite has been proven to reduce the risk of secondary caries in the restoration of teeth [26]. This study found that the incidence of tooth sensitivity and the degree of tooth pain in patients who underwent dental restoration using nanocomposite resin materials were significantly lower than those in patients who underwent dental restoration using traditional composite resin materials. It also found that the degree of edge fit

between the restorative material and the original tooth, color matching, and surface smoothness in the nano group were better than those in the control group at different time points after restoration. These indicate that nanocomposite resin materials are better than traditional composite resin materials in restoring tooth defects in the elderly population.

Furthermore, this study found that the ALP content in the gingival crevicular fluid of patients in the nano group was significantly lower than that of patients in the control group 2 years after restoration. ALP is a group of enzymes produced by the hydrolysis of various phospholipids under alkaline conditions and can exist in multiple tissues of the body [27]. Detecting the amount of ALP in the gingival crevicular fluid can determine tooth inflammation or immunity at the site. Studies have confirmed that the ALP content in gingival crevicular fluid of patients with successful dental restorations is significantly lower than that of patients with failed restorations [28]. The higher ALP content in the gingival crevicular fluid of patients with poor dental restoration may be related to the accumulation of dental bacteria around the restoration. When a patient's original tooth and the filling material have microcracks, bacteria and their metabolites can grow in the oral cavity and enter the teeth through this gap. A large number of bacteria and their antigenic components attached to and repairing the surface of the tooth can trigger the chemotaxis, phagocytosis, and inflammation of leukocytes and subsequently release a substantial amount of ALP, leading to an increase in the ALP content in the gingival crevicular fluid [29]. However, traditional detection methods have poor sensitivity and specificity for the measurement of ALP content in gingival crevicular fluid, which may adversely affect the results of the study. Nano-electrochemiluminescence uses nanomaterials as modified electrodes and has been proven to improve the detection accuracy of electrochemiluminescence [30-38]. Therefore, in this study, electrochemiluminescence with nano-modified electrodes was used to detect ALP in the gingival crevicular fluid of patients. Analysis showed that the ALP content in the nano group was significantly lower than that in the control group, suggesting that nanocomposite resin materials are better than traditional light-cured composite resin materials in restoring dental defects in the elderly population. This can be attributed to the possibility that exponential growth and acid production of bacteria within cracks could lead to more cracks and demineralization of the restored tooth. At the same time, the accumulation of bacteria can easily cause secondary caries and dental pulp infections, thereby leading to restoration failure. However, nanomaterials have high structural stability, are not easily penetrable, and can effectively reduce bacterial adhesion, allowing them to have a better restoration effect on defective teeth. Therefore, the application of nanotechnology has improved the comprehensive performance of composite resin materials, which is beneficial to reducing adverse reactions after dental defect restoration and improving the restoration effect.

CONCLUSIONS

This study compared the incidence of tooth sensitivity, degree of tooth pain, aesthetic outcomes, effects of restoration, and occurrence of complications in patients with dental defects after restoration. The patients who underwent dental restoration using nanocomposite resin materials had a lower incidence of tooth sensitivity and a lower degree of tooth pain after restoration as well as better fit between the restorative material and the original tooth, color matching, and surface smoothness at different time points after restoration compared with the patients who underwent dental restoration using traditional composite resin materials. These results indicate that nanocomposite resin materials are better than traditional light-cured composite resin materials in restoring dental defects in the elderly population.

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