

Original Article

Effects of different restorative materials on incisor root canal and crown restoration outcomes along with patient functional recovery

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Abstract: Aims: To compare the clinical outcomes of incisor residual root and crown restorations using precious metal porcelain crowns (PMPC) versus zirconia all-ceramic crowns (ZACC), with a focus on gingival health, dental aesthetics, functional recovery, and oral health-related quality of life (OHRQoL). Methods: This retrospective cohort study included 218 adult patients who underwent incisor restoration with at least 1 year of follow-up (91 PMPC, 127 ZACC). Gingival health was evaluated by plaque, gingival, and bleeding indices, as well as probing depth, and gingival fluid volume. Dental aesthetics were assessed by color matching, gloss, and patient satisfaction. Functional recovery was examined by bite force, and OHRQoL was measured using the Oral Health Impact Profile-14. Restoration quality and integrity were evaluated during follow-up. Results: Both groups showed significant improvement in gingival health, with ZACC demonstrating superior reductions in plaque, gingival, and bleeding indices, and gingival fluid volume. ZACC also achieved better color matching, gloss consistency, and higher patient satisfaction with aesthetics. Bite force recovery was consistently greater in the ZACC group. OHRQoL improved in both groups, but gains were more pronounced with ZACC. At six months, ZACC showed a higher rate of excellent restorations and fewer poor outcomes. At one year, no significant differences were observed between groups in crown durability, loss, or secondary caries. Conclusion: Compared with PMPC, ZACC offer provides greater benefits in gingival health, aesthetics, functional recovery, and OHRQoL compared, while both materials show comparable long-term durability and complication rates.

Keywords: Zirconia all-ceramic crowns, precious metal porcelain crowns, incisor restoration, gingival health, dental aesthetics, oral health-related quality of life

Introduction

The restoration of incisors following endodontic treatment and coronal structure loss remains a significant challenge in contemporary dental practice, with considerable implications for oral function, aesthetics, and patient quality of life [1]. Positioned at the forefront of the dental arch, incisors are essential not only for mastication and phonation but also for facial harmony and self-esteem. However, trauma, caries, and recurrent restorative failure often compromise incisor integrity, necessitating comprehensive interventions that address both the residual root and the coronal portion of the

tooth [2]. Given the high aesthetic and functional demands of incisor restoration, the selection of suitable restorative materials is therefore critical [3].

Crowns are widely used to restore both structural strength and esthetics in teeth with extensive incisal damage [4]. For decades, clinicians have relied on precious metal porcelain crowns (PMPC) because of their durability, favorable mechanical properties, and proven clinical success [5]. However, PMPC, which consist of a noble metal substructure veneered with feldspathic porcelain, present inherent limitations - most notably suboptimal translucency, risk of marginal discoloration, and gingival darkening

due to metal ion migration, particularly in esthetically demanding anterior regions [6].

With advances in dental materials science, zirconia all-ceramic crowns (ZACC) have emerged as an alternative that more closely replicates the properties of natural tooth [7]. Zirconia-based ceramics demonstrate high flexural strength, superior fracture resistance, and excellent biocompatibility [8]. Developments in digital dentistry and computer-aided design/computer-aided manufacturing now enable highly customized crowns with precise marginal adaptation and refined color matching [8]. Notably, zirconia restorations are reported to promote periodontal health, reduce plaque accumulation, and provide long-term color stability without the risks of metal show-through or allergic reactions [9].

Despite growing evidence in favor of all-ceramic systems for anterior teeth, the clinical superiority of zirconia over PMPC in root canal - treated incisor restoration remains debated [10]. Many comparative studies emphasize laboratory-based properties or focus mainly on posterior teeth, whereas fewer rigorous clinical investigations evaluate patient-centered outcomes such as functional recovery, restoration longevity, and oral health-related quality of life (OHRQoL) in anterior restorations [10]. Systematic reviews have also underscored the lack of large-scale, long-term, real-world data to guide material selection for incisor crowns following endodontic therapy [11].

Accordingly, this retrospective cohort study was conducted to evaluate the effects of PMPC and ZACC on clinical and patient-reported outcomes in incisor root canal and crown restoration. Using data from patients treated in the 964th Hospital of the Joint Logistics Support Force, we compared gingival health, restoration success, aesthetic outcomes, patient satisfaction, functional recovery, and OHRQoL between the two restorative modalities. This study aims to provide evidence-based guidance to assist clinicians in selecting materials that optimize both biological and psychosocial outcomes in incisor reconstruction.

Methods

Study design and participants

This retrospective cohort study evaluated the impact of different restorative materials on in-

cisor residual root and crown restoration outcomes and patient functional recovery. Data were collected from patients treated at the 964th Hospital of the Joint Logistics Support Force between January 2020 and December 2023. Eligible patients had undergone restoration for incisor residual roots or crowns and were followed for at least one year post-treatment. In total, 218 patients were included: in the analysis, 91 treated with PMPC and 127 with ZACC. All clinical information was retrieved from the hospital's electronic medical record system.

Ethical considerations

This retrospective study used de-identified patient data and involved no direct patient contact. It was conducted in accordance with the ethical standards of the Declaration of Helsinki and approved by the Ethics Review Committee of the 964th Hospital of the Joint Logistics Support Force, which granted an exemption from informed consent. The study was designed to provide evidence-based insights into restorative material selection in clinical dentistry, with the goal of improving therapeutic efficacy and patient quality of life.

Inclusion criteria

Patients were eligible if they met all of the following conditions: they were undergoing first-time restoration of incisor residual roots or crowns, were aged over 18 years, had completed the full conventional restoration process at the 964th Hospital of the Joint Logistics Support Force, and had complete electronic medical records.

Exclusion criteria

Patients were excluded if they had a history of previous restorations; recent myocardial infarction, organ dysfunction, bleeding disorders, autoimmune diseases (e.g., rheumatoid arthritis), hyperparathyroidism, uncontrolled diabetes, severe osteoporosis, or malignancy; recent organ transplantation, long-term corticosteroid use, or radiation therapy; mental health conditions causing non-compliance or cognitive impairment; heavy smoking, poor oral hygiene, or detrimental functional habits such as bruxism or biting hard objects; infectious diseases, coagulation disorders, pregnancy or breast-

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feeding; or documented allergies to restorative materials or anesthetics.

Baseline data at initial diagnosis

Baseline data were collected from patient medical records at the initial consultation. Lesion location and residual tooth structure were assessed using radiographs obtained with the Sirona Orthophos SL 3D system (Dentsply Sirona, Germany).

Restoration outcomes

At baseline and at the six-month follow-up, patients chewed GC Tri Plaque ID Gel (GC Corporation, Japan) tablets to visualize plaque, which was scored from 0 to 4 based on surface coverage (0 = no plaque; 4 = plaque covering > one-third of the surface).

Gingival status was evaluated using oral mirrors and probes to assess color, texture, and bleeding tendency. Scores ranged from 0 (healthy, pink, firm, no bleeding) to 3 (severe inflammation, dark red/purple, very soft, spontaneous bleeding or pus). Each of the four tooth surfaces (buccal/labial, lingual/palatal, mesial, and distal) was scored, and average values was calculated.

Bleeding on probing was assessed with periodontal probes inserted 2-3 mm into the gingival sulcus and held for several seconds. Scores ranged from 0 (no bleeding) to 3 (immediate bleeding or pus). Again, four surfaces were scored per tooth, and the mean was calculated. Probing depth was recorded in millimeters when the probe reached the alveolar bone.

Gingival crevicular fluid (GCF) was collected using PerioPaper™ and measured with Periotron® 6000 (Oraflow Inc., USA). Strips were inserted into the gingival sulcus for 30 seconds and then quantified. Measurements were recorded for all four surfaces of each tooth.

Aesthetic evaluation

At six months post-restoration, color matching was assessed using a ColorEye XTH colorimeter (X-Rite Incorporated, USA). Measurements were taken at defined points on both the restoration and adjacent natural teeth, and color differences (ΔE values) were calculated. A ΔE

value < 1.0 was considered indicative of good color matching.

Gloss was evaluated with a Konica Minolta Gloss Checker IG-331 (Konica Minolta Sensing Americas, Inc., USA). Restoration margins and adjacent tooth surfaces were cleaned before measurement. Readings were obtained from multiple points, including three at the margin, three at the center of the restoration, and corresponding points on the adjacent tooth. Gloss unit values were recorded, and mean values were calculated.

Patient satisfaction was assessed using a questionnaire that included ratings of color, translucency, gloss, and overall aesthetic satisfaction. Responses were recorded on a five-point Likert scale (1 = very dissatisfied to 5 = very satisfied). To minimize bias, evaluators responsible for aesthetic assessments and satisfaction scoring were blinded to the type of restoration.

Bite force and cutting efficiency

Bite force was evaluated using the T-Scan III system (Tekscan, Inc., USA). A thin T-Scan sensor was positioned intraorally over the maxillary and mandibular incisors. Patients were instructed to perform natural occlusal movements, including maximum intercuspation, lateral excursions, and protrusion. Occlusal force distribution and temporal sequence data were recorded in real-time, and bite force values were automatically generated by the system.

Cutting efficiency was assessed using medical-grade silicone food simulants (MedSil-50, SimuTech Medical Supplies, Germany) with a hardness of Shore A 50±5 and dimensions of 50 × 7 × 7 mm. The midpoint of each simulant was aligned with the incisal edge of the tested tooth. Patients were instructed to incise the simulant with natural force in a single stroke. The time from initial tooth contact to complete cutting was recorded. Each test was repeated three times, and mean values were calculated.

Oral Health Impact Profile (OHIP-14)

OHIP-14 was used to assess the impact of oral health on quality of life before treatment and three months post-treatment [12]. The OHIP-14 consists of 14 items across seven domains,

evaluating the influence of oral conditions on daily functioning. Each item was scored on a 5-point Likert scale: 0 = never, 1 = hardly ever, 2 = occasionally, 3 = fairly often, and 4 = very often. Higher average scores indicate a greater negative impact on OHRQoL.

Evaluation of restoration outcomes at long time follow-up

At the six-month follow-up, the restoration outcomes were evaluated by a dentist based on clinical and functional criteria. Excellent outcome: The restoration demonstrated harmonious color, shape, and translucency with adjacent teeth; full recovery of chewing function without discomfort; normal bite force; healthy gingival tissues characterized by pink color, firm texture and no bleeding on probing; and optimal marginal adaptation with no noticeable gaps between the restoration and the prepared tooth. Good outcome: The restoration closely matched adjacent teeth in color, shape, and translucency, with only minor differences that did not compromise aesthetics. Chewing function was partially restored with slight discomfort or mildly reduced bite force. Minor marginal gaps within clinically acceptable limits, mild gingival redness, slight softness, and pinpoint bleeding on probing could be observed. Poor outcome: The restoration was associated with incomplete recovery of chewing function, significant discomfort or notably reduced bite force. Gingival tissues appeared deep red or dark purple with very soft texture, accompanied by spontaneous bleeding or pus discharge on probing. Noticeable marginal gaps, risk of secondary caries, or restoration instability were also present.

At the 12-month follow-up, restorations were further assessed for long-term integrity. Clinical evaluation included inspection for wear, fractures, marginal gaps, secondary caries, dislodgement, or complete restoration failure. All findings were documented to guide timely interventions and ensure appropriate management.

Data analysis

In this study, statistical analyses were performed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA). Psychological state, hope lev-

els, resilience, stigma, self-care, quality of life, and fatigue dimensions were expressed as means $\pm$ standard deviations and compared between groups using two-tailed t-tests. Adherence to functional exercises was presented as ratios and percentages, and group differences were analyzed using chi-square tests (χ^2) or rank-sum tests as appropriate. A p value < 0.05 was considered statistically significant.

Results

Baseline data at initial diagnosis

Table 1 presents the baseline characteristics of patients in the PMPC group and the ZACC group. No statistically significant differences were observed between the two groups in terms of age, sex distribution, or body mass index. Similarly, the groups were comparable with respect to education level, smoking status, drinking status, affected incisor position, affected side, and underlying dental condition. These findings suggest that the baseline characteristics were well balanced between the two groups (all $P > 0.05$), thereby minimizing the likelihood that subsequent analyses of treatment outcomes would be confounded by demographic or clinical factors.

Assessment of gingival health status

Table 2 summarizes the comparisons between the PMPC and ZACC groups. At baseline, no statistically significant differences were observed in plaque index, gingival index, bleeding index, probing depth, or GCF volume, indicating comparable gingival health status between the two groups prior to treatment (all $P > 0.05$). Six months after treatment, both groups demonstrated significant improvements; however, the ZACC group exhibited statistically superior outcomes in several indices. Specifically, compared with the PMPC group, the ZACC group showed lower plaque index, lower gingival index, lower bleeding index, and reduced GCF volume (all $P < 0.05$). No significant intergroup difference was noted in probing depth at six months ($P > 0.05$). These results suggest that although both restorative modalities improved gingival health, the ZACC group achieved more favorable outcomes in plaque control, gingival condition, bleeding, and gingival fluid parameters at the six-month follow-up.

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Table 1. Baseline characteristics of the PMPC and ZACC groups

Variable	PMPC group (n = 91)	ZACC group (n = 127)	t/ χ^2	P
Age	35.73±5.63	36.28±5.85	0.701	0.484
Sex			0.066	0.798
Female	41 (45.05%)	55 (43.31%)		
Male	50 (54.95%)	72 (56.69%)		
BMI	21.95±2.16	22.14±2.39	0.590	0.556
Education level			1.041	0.594
Junior high school and below	14 (15.38%)	26 (20.47%)		
High school	27 (29.67%)	38 (29.92%)		
College and above	50 (54.95%)	63 (49.61%)		
Current smoker	42 (46.15%)	60 (47.24%)	0.025	0.874
Current drinker	55 (60.44%)	79 (62.20%)	0.070	0.792
Position			0.249	0.969
Maxillary Central Incisors	37 (40.66%)	52 (40.94%)		
Maxillary Lateral Incisors	22 (24.18%)	32 (25.20%)		
Mandibular Central Incisors	20 (21.98%)	29 (22.83%)		
Mandibular Lateral Incisors	12 (13.19%)	14 (11.02%)		
Affected Side			0.075	0.784
Left	49 (53.85%)	66 (51.97%)		
Right	42 (46.15%)	61 (48.03%)		
Dental condition			0.040	0.980
Dental Caries	42 (46.15%)	57 (44.88%)		
Trauma	15 (16.48%)	21 (16.54%)		
Attrition	34 (37.36%)	49 (38.58%)		

Note: PMPC: precious metal porcelain crowns; ZACC: zirconia all-ceramic crowns; BMI: body mass index.

Table 2. Gingival health status of the PMPC and ZACC groups before treatment and at six months after treatment

Variable	PMPC group (n = 91)	ZACC group (n = 127)	t	P
Before treatment				
Plaque Index	2.61±0.43	2.58±0.41	0.594	0.553
Gingival Index	1.89±0.39	1.86±0.42	0.475	0.635
Bleeding Index	2.09±0.24	2.08±0.23	0.020	0.984
Probing Depth (mm)	2.71±0.57	2.69±0.56	0.225	0.822
Gingival Crevicular Fluid Volume (μ L/30 s)	3.24±0.68	3.13±0.65	1.197	0.232
Six months after treatment				
Plaque Index	1.05±0.41	0.94±0.31	2.185	0.030
Gingival Index	1.18±0.32	1.09±0.29	2.016	0.045
Bleeding Index	2.19±0.47	2.05±0.51	2.041	0.042
Probing Depth (mm)	2.91±0.65	2.83±0.62	0.946	0.345
Gingival Crevicular Fluid Volume (μ L/30 s)	0.96±0.22	0.88±0.17	2.858	0.005

Note: PMPC: precious metal porcelain crowns; ZACC: zirconia all-ceramic crowns.

Aesthetic restoration outcomes

As shown in **Figure 1**, significant differences in dental aesthetic outcomes were observed

between the PMPC and ZACC groups at follow-up. The ZACC group demonstrated superior performance across all evaluated dimensions, including lower color difference scores, smaller

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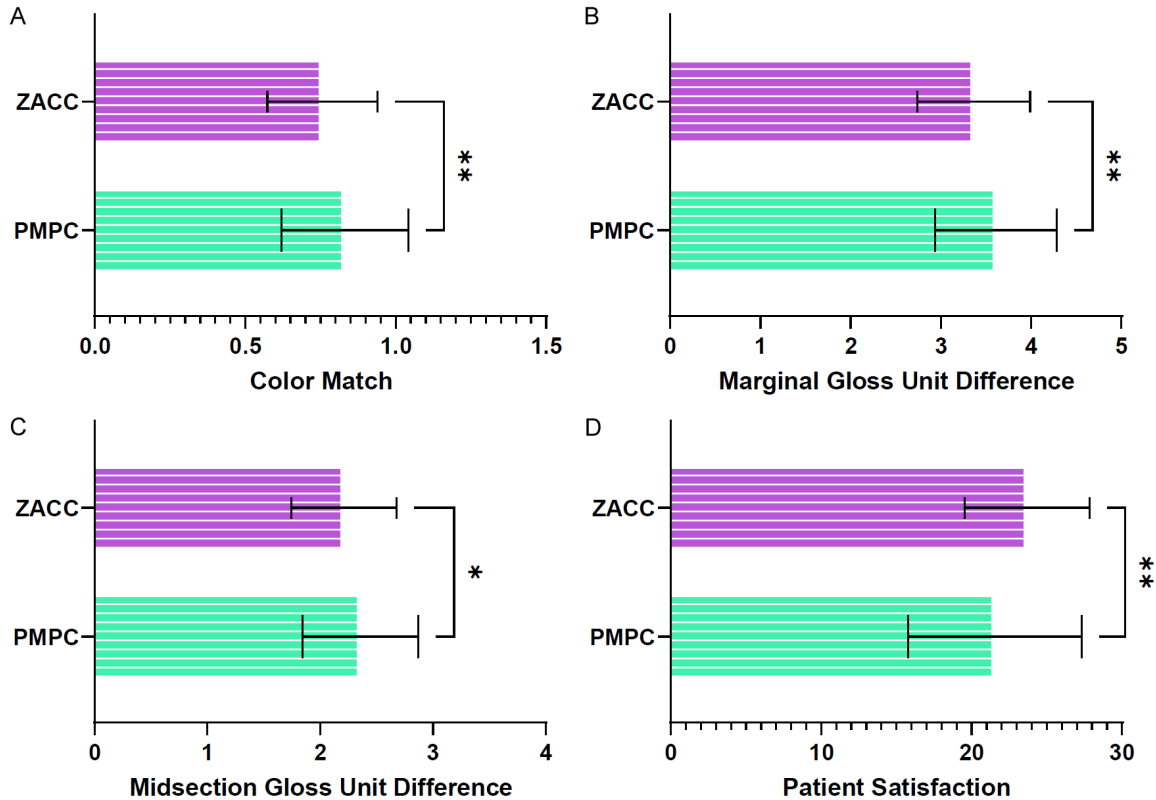


Figure 1. Comparative evaluation of dental aesthetics between the PMPC and ZACC groups. Note: PMPC: precious metal porcelain crowns; ZACC: zirconia all-ceramic crowns. A: Color Match; B: Marginal Gloss Unit Difference; C: Midsection Gloss Unit Difference; D: Patient Satisfaction. *: $P < 0.05$; **: $P < 0.01$.

marginal gloss unit differences, and reduced midsection gloss unit differences compared with the PMPC group. In addition, patient satisfaction scores were significantly higher in the ZACC group. These findings suggest that ZACC restorations offer distinct advantages over PMPC restorations in terms of color matching, gloss consistency, and patient-perceived aesthetic satisfaction (all $P < 0.05$).

Functional recovery outcomes

As shown in **Figure 2**, baseline incisor bite force was comparable between the PMPC and ZACC groups, with no significant difference detected. Following restoration, however, the ZACC group exhibited significantly greater bite force than the PMPC group at all subsequent time points (all $P < 0.05$). At one month post-treatment, bite force in the ZACC group was already higher than in the PMPC group. This difference persisted at three months, with mean values of 135.58 ± 8.84 in the ZACC group versus 131.71 ± 8.78 in the PMPC group.

Similarly, at six months, the ZACC group continued to demonstrate significantly higher bite force. These findings suggest that ZACC restorations provide superior functional recovery, as evidenced by greater incisor bite force across multiple follow-up intervals.

Prior to treatment, cutting efficiency did not differ significantly between groups ($P = 0.851$) (**Table 3**). One month after treatment, cutting efficiency improved in both groups, but the difference remained non-significant ($P = 0.134$). At later time points, however, significant between-group differences emerged. At three months, the ZACC group required significantly less time to complete cutting, reflecting higher cutting efficiency compared with the PMPC group ($P = 0.011$). This advantage persisted at six months ($P = 0.008$), with the ZACC group consistently demonstrating shorter cutting times, maintaining superior cutting efficiency compared to the PMPC group. These results indicate that although both groups benefited from improved cutting efficiency after incisor

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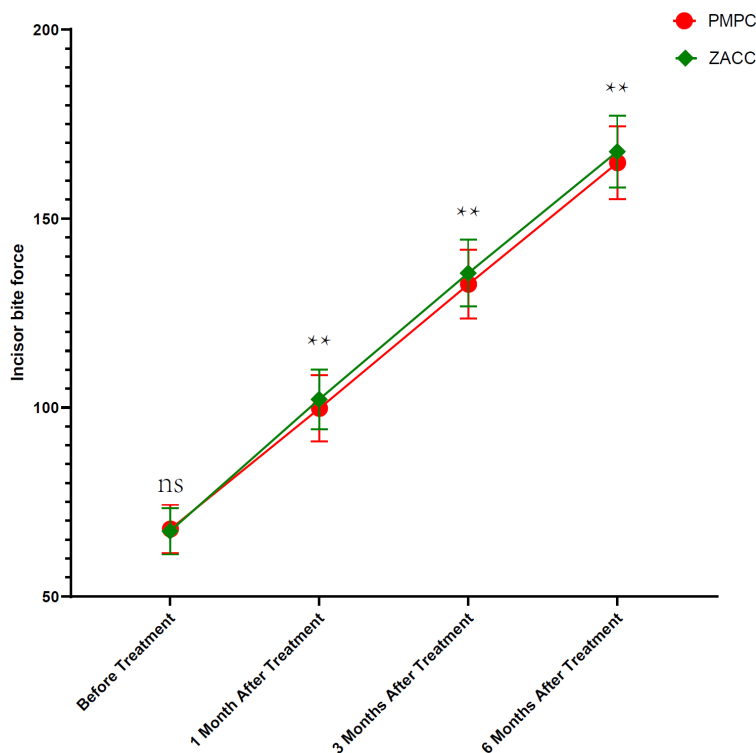


Figure 2. Changes in incisor bite force before and after treatment in the PMPC and ZACC groups. Note: PMPC: precious metal porcelain crowns; ZACC: zirconia all-ceramic crowns; ns: no significant; **: $P < 0.01$.

Table 3. Cutting efficiency of the PMPC and ZACC groups before and after incisor restoration

Variable	PMPC group (n = 91)	ZACC group (n = 127)	t	P
Before treatment	14.12±1.34	14.09±1.45	0.188	0.851
1 months after treatment	9.37±1.17	9.12±1.23	1.503	0.134
3 months after treatment	8.05±1.09	7.68±1.02	2.578	0.011
6 months after treatment	6.19±0.86	5.86±0.94	2.673	0.008

Note: PMPC: precious metal porcelain crowns; ZACC: zirconia all-ceramic crowns.

restoration, the ZACC group achieved superior outcomes at three and six months post-treatment.

Quality of life

At baseline, no statistically significant differences were observed between the PMPC and ZACC groups across any of the seven OHIP-14 domains, including functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap, indicating comparable pre-treatment OHRQoL between groups (all $P >$

0.05, **Table 4**). Three months after treatment, both groups showed marked improvements across all domains. Notably, the ZACC group achieved significantly lower scores in functional limitation, physical pain, psychological discomfort, physical disability, and social disability compared with the PMPC group (all $P < 0.05$). No significant differences were detected between groups for the psychological disability or handicap domains at this time point (both $P > 0.05$). These findings suggest that while both restorative materials significantly enhanced OHRQoL, the ZACC provided more pronounced benefits in functional, physical, psychological, and social domains at three months post-treatment.

Restoration quality

Assessment of restoration quality, as presented in **Figure 3**, demonstrated a significantly higher rate of excellent restorations in the ZACC group compared with the PMPC group (116 vs 70, $\chi^2 = 8.796$, $P = 0.003$). Although the proportions of restorations rated as good did not differ significantly between groups (8 vs 11, $\chi^2 = 2.233$, $P = 0.135$), the rate of poor restorations was significantly lower in the ZACC group than in the PMPC group (3 vs 10, $\chi^2 = 7.036$, $P = 0.008$).

Long-term outcomes

Long-term follow-up demonstrated no statistically significant differences between the PMPC and ZACC groups with respect to the proportion of crowns maintaining continuity with the original anatomic form, incidence of partial crown loss, complete crown loss, or occurrence of secondary caries (all $P > 0.05$, **Table 5**). These findings suggest that while ZACC provide superior immediate restoration quality com-

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Table 4. OHIP-14 domain scores in the PMPC and ZACC groups at baseline and 3 months after treatment

Variable	PMPC group (n = 91)	ZACC group (n = 127)	t	P
At baseline				
Functional limitation	4.57±0.91	4.65±0.94	0.634	0.527
Physical pain	4.78±0.82	4.67±0.83	0.988	0.324
Psychological discomfort	4.37±0.68	4.41±0.71	0.353	0.725
Physical disability	2.17±0.49	2.23±0.43	0.920	0.359
Psychological disability	2.06±0.35	2.09±0.37	0.754	0.452
Social disability	1.62±0.38	1.65±0.35	0.699	0.485
Handicap	1.95±0.21	1.98±0.26	0.928	0.355
3 months after treatment				
Functional limitation	0.84±0.24	0.74±0.21	3.168	0.002
Physical pain	1.74±0.52	1.57±0.48	2.562	0.011
Psychological discomfort	2.04±0.69	1.82±0.57	2.507	0.013
Physical disability	1.82±0.54	1.63±0.49	2.662	0.008
Psychological disability	0.73±0.19	0.68±0.18	1.810	0.072
Social disability	1.02±0.25	0.94±0.22	2.552	0.011
Handicap	1.24±0.38	1.16±0.36	1.524	0.129

Note: OHIP-14: Oral Health Impact Profile-14; PMPC: precious metal porcelain crowns; ZACC: zirconia all-ceramic crowns.

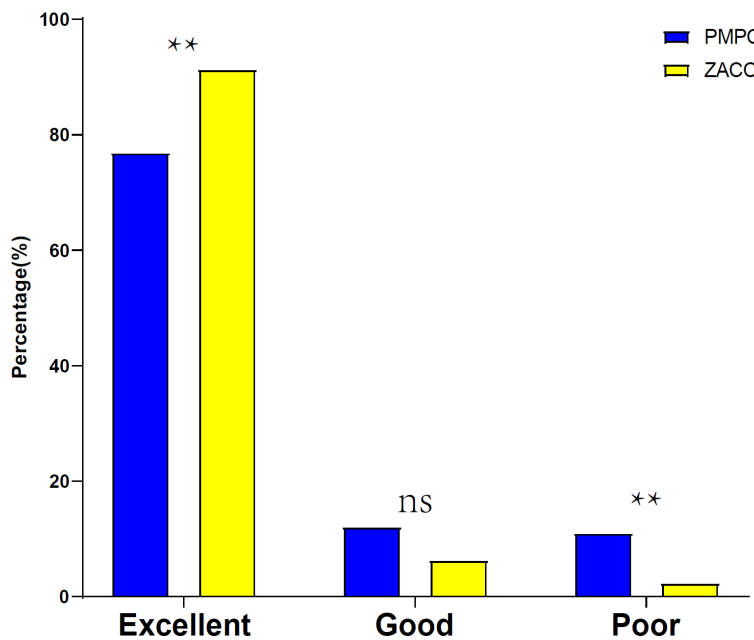


Figure 3. Clinical assessment of restoration quality in the PMPC and ZACC groups. Note: PMPC: precious metal porcelain crowns; ZACC: zirconia all-ceramic crowns; ns: no significant; **: P < 0.01.

Discussion

The present study evaluated the effects of two commonly used restorative materials - PMPC and ZACC - on both clinical and patient-centered outcomes following incisor root canal and crown restoration. The findings indicate that ZACC offers distinct advantages over PMPC in terms of gingival health, dental aesthetics, patient satisfaction, functional recovery, and several domains of OHRQoL. To interpret these findings, it is essential to consider the underlying material properties and mechanisms that may account for the observed differences, while integrating relevant prior research and their potential clinical implications.

pared with PMPC, both restorative materials exhibit comparable long-term durability and risk of complications.

A primary consideration in restorative dentistry is the interaction between restorative materials and the surrounding periodontal tis-

Table 5. Long-term clinical evaluation of restorations in the PMPC and ZACC groups

Variable	PMPC group (n = 91)	ZACC group (n = 127)	χ^2	P
Restoration Damage				
Crown was continuous with the existing anatomic form	80 (87.91%)	116 (91.34%)	0.686	0.408
Missing part of the crown	7 (7.69%)	6 (4.72%)	0.833	0.361
Complete loss of crown	4 (4.40%)	5 (3.94%)	0	1.000
Secondary Caries	9 (9.89%)	8 (6.30%)	0.951	0.330

Note: PMPC: precious metal porcelain crowns; ZACC: zirconia all-ceramic crowns.

sues [13]. In this study, the ZACC group demonstrated superior outcomes in plaque control, gingival index, bleeding index, and GCF compared with the PMPC group. These differences are likely attributable to the distinct physical and chemical properties of zirconia versus precious metal porcelain materials [14]. Zirconia is widely recognized for its high biocompatibility, low surface roughness, and minimal plaque accumulation relative to metal-ceramic systems [15]. The absence of a metal substructure eliminates the risk of galvanic interactions, local ion release, or corrosion-related cytotoxicity, which have been implicated in adverse soft tissue responses surrounding metal-based restorations [16]. Moreover, the glassy matrix of all-ceramic crowns, combined with their highly polished surfaces, provides an unfavorable substrate for bacterial adhesion and colonization, thus contributing to improved gingival health [17]. Previous studies have also shown that zirconia elicits a relatively benign inflammatory profile in gingival epithelial tissues compared with metals, likely owing to its chemical inertness and lack of allergenic potential [18]. The absence of metallic ions further mitigates the risk of hypersensitivity reactions that could otherwise promote chronic inflammation or impair tissue healing [19].

In contrast, despite the widespread clinical utility and established durability of PMPC, the underlying metallic framework - typically composed of high-noble alloys such as gold, platinum, or palladium - can adversely affect peri-restorative tissue health [20]. Even high-noble alloys are susceptible to surface oxidation, which may result in microgaps at the metal-ceramic interface and increased surface roughness, thereby promoting plaque accumulation [21]. Furthermore, interactions between metal ions and oral fluids can gradually alter the local microenvironment, leading to increased

inflammatory cell infiltration, elevated GCF production, and higher bleeding and gingival index scores [22]. These factors likely contribute to the comparatively less favorable periodontal status observed in the PMPC group. Notably, both groups demonstrated improvements in periodontal indices following restoration, which may reflect the removal of previously diseased tissue and restoration of oral function; however, the intrinsic properties of zirconia appear to confer a more pronounced periodontal benefit.

An equal determinant of restorative success is aesthetic integration, particularly in the anterior dentition, where color, translucency, and gloss critically influence patient satisfaction [23]. ZACC, owing to their translucent glass-ceramic microstructure, closely replicate the light transmission properties of natural enamel [24]. Advances in computer-aided design/computer-aided manufacturing and coloring technologies have further enabled individualized color characterization, allowing zirconia crowns to achieve superior color matching and gloss consistency compared with metal-based restorations [25]. In contrast, porcelain-fused-to-metal crowns are limited by the optical opacity of the underlying alloy, which necessitates the application of opaque porcelain layers to mask the metal [26]. This requirement inherently constrains the depth and natural gradient of achievable color, often resulting in suboptimal aesthetics, such as grayish discoloration at the cervical margins or reduced vitality under specific lighting conditions [27]. The present findings show that ZACC outperformed PMPC in color match, gloss, and midsection gloss unit differences, which aligns with these material-dependent limitations.

From a patient-centered perspective, the high satisfaction scores observed in the ZACC group likely reflect not only enhanced clinical aesthet-

ics but also subjective perceptions of naturalness and comfort. Features inherent to zirconia-based prostheses - such as nearly invisible restoration margins, improved translucency, and the absence of metallic shine - have been demonstrated to positively influence patients' psychological and social well-being [28]. Moreover, the overall enhancement of oral function and aesthetics can have downstream benefits on self-esteem and quality of life, addressing psychosocial domains that are increasingly recognized as integral components of successful dental therapy.

Functional recovery, as evaluated by bite force, also demonstrated a sustained advantage for zirconia crowns. The superior mechanical properties of zirconia - particularly its high fracture toughness, flexural strength, and resistance to deformation - enable it to withstand occlusal forces more effectively than porcelain-fused-to-metal restorations [29]. Furthermore, the modulus of elasticity of zirconia more closely approximates that of natural dentin compared with precious metals, potentially facilitating more uniform stress distribution across the restoration-tooth complex and thereby reducing the risk of adhesive failure, microleakage, and secondary caries formation [30]. These biomechanical characteristics likely underlie the higher and more sustained bite force measurements observed in the ZACC group. Additionally, restorations that more accurately replicate the functional properties of native tooth structure may support rehabilitative neuromuscular adaptations - such as enhanced masticatory efficiency and increased patient confidence during chewing - further contributing to overall functional recovery [31].

Regarding the impact on OHRQoL, both groups demonstrated substantial improvements across all OHIP-14 domains, consistent with the general benefits of successful incisor restoration on mastication, phonetics, and aesthetic appearance. Notably, the ZACC group exhibited more pronounced gains in physical, psychological, and social functioning. The superior color matching, gloss, and overall comfort provided by zirconia crowns likely reduce patients' self-consciousness or embarrassment in social and professional contexts, thereby diminishing psychological discomfort and social disability. Moreover, the absence of visible metallic mar-

gins and the long-term color stability of zirconia restorations contribute to higher patient satisfaction and enhanced quality of life over time.

Long-term durability and complication rates - including restoration retention, secondary caries, and maintenance of anatomic form - were comparable between the two groups over the follow-up period. This finding highlights the high performance and reliability of both materials when applied under appropriate clinical conditions and with careful case selection. Although ZACC demonstrated pronounced short- to medium-term advantages in clinical and patient-centered outcomes, the comparable longevity and biological safety of PMPC support their continued use in specific scenarios, particularly when certain occlusal or anatomical considerations limit the applicability of ceramic restorations.

Although our study provides valuable insights, its retrospective design introduces potential biases, including selection bias and unmeasured confounding factors. Unlike prospective studies, retrospective designs cannot balance known and unknown confounders through randomization, and therefore, the influence of such factors on the results cannot be entirely excluded. For instance, patients' oral hygiene practices, dietary habits, and other unrecorded behavioral variables may have affected the outcomes. Additionally, the skill level and experience of the clinicians performing the restorations could significantly impact success rates. In this study, restorations were performed by multiple operators, potentially introducing variability that may have affected the consistency and internal validity of the results. Future studies should consider standardizing operator techniques or controlling for operator variability to enhance internal validity. Although baseline characteristics were carefully matched between groups, the inherent limitations of a retrospective design necessitate cautious interpretation of the findings. Prospective studies incorporating comprehensive control of relevant variables are warranted to provide a more robust evidence base. Furthermore, while our 12-month follow-up captured key early and intermediate outcomes, it is insufficient to fully assess the long-term durability and clinical performance of the restorative materials. Future investigations should extend the follow-up peri-

od to 24 months or longer to generate reliable long-term data on critical outcomes, including complication rates, marginal adaptation, and patient-reported measures. Such data are essential for a comprehensive evaluation of the clinical longevity and performance of restorative materials, particularly in the context of potential degradation and wear over time.

In summary, the distinct advantages of ZACC in terms of biocompatibility, aesthetic integration, patient satisfaction, and functional recovery are closely associated with their favorable material properties, including low surface roughness, high translucency, superior mechanical strength, and chemical inertness. These characteristics contribute to enhanced periodontal health, a more natural dental appearance, and improved restoration of incisal function. While PMPC remains a viable restorative option, particularly in clinical scenarios requiring specific mechanical or structural attributes, ZACC offers notable benefits for anterior tooth restoration. Future research should continue to assess advances in dental ceramic technologies, examine patient-specific factors influencing restorative outcomes, and monitor long-term clinical performance to inform personalized restorative strategies that optimize both biological and psychosocial outcomes.

Disclosure of conflict of interest

None.

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References

- [1] Bekes K, Steffen R and Krämer N. Update of the molar incisor hypomineralization: Würzburg concept. *Eur Arch Paediatr Dent* 2023; 24: 807-813.
- [2] Vaid N, Venugopal A, Gandedkar N, Farella M, Darendeliler MA, Adel SM and Nucci L. Molar incisor hypomineralization (MIH): The "Why, What and How" of decision making for orthodontists. *J World Fed Orthod* 2024; 13: 240-249.
- [3] Çakmak G, Donmez MB, Yılmaz D, Yoon HI, Kahveci Ç, Abou-Ayash S and Yılmaz B. Fabrication trueness and marginal quality of additively manufactured resin-based definitive laminate veneers with different restoration thicknesses. *J Dent* 2024; 144: 104941.
- [4] Zaninovich M, da Rosa JCM and Drago C. Immediate dentoalveolar restoration (IDR) of central maxillary incisor using sinus lateral wall block graft to regenerate loss of facial and palatal bone: literature review and 1 year follow-up. *J Prosthodont* 2024; 33: 619-625.
- [5] Jayanti CNR and Riyanti E. Treatment alternative of molar incisor hypomineralisation for young permanent teeth: a scoping review. *Clin Cosmet Investig Dent* 2024; 16: 337-348.
- [6] Xue P, Luo Q, Huang Y, Xu M, Qiu L, Wang J, He H and Chen F. Retreatment and aesthetic restoration of maxillary incisor with calcified root canal using a dynamic navigation system: a case report. *BMC Oral Health* 2024; 24: 1358.
- [7] Mendonça FL, Grizzo IC, Alencar CRB and Rios D. Restorative therapy of MIH-affected molars. *Monogr Oral Sci* 2024; 32: 236-260.
- [8] Djemal S and Shah M. Avulsion injuries: assessment and management. *Prim Dent J* 2023; 12: 57-63.
- [9] Lassmann L, Calamita MA and Blatz MB. The "smile design and space" concept for altering vertical dimension of occlusion and esthetic restorative material selection. *J Esthet Restor Dent* 2025; 37: 56-67.
- [10] Martins FV, Mattos de Santana CM, Magno MB, Maia LC, Fonseca EM and Barcellos de Santana R. Gingival zenith level, position, and symmetry: a systematic review and meta-analysis. *J Prosthet Dent* 2024; [Epub ahead of print].
- [11] Fraser J and MacInnes A. Which caries removal method to select? *Evid Based Dent* 2024; 25: 29-30.
- [12] Slade GD and Spencer AJ. Development and evaluation of the oral health impact profile. *Community Dent Health* 1994; 11: 3-11.
- [13] Voinot J and Bedez M. Pretreatments to bonding on enamel and dentin disorders: a systematic review. *Evid Based Dent* 2024; 25: 215.
- [14] Patel S, Abella F, Patel K, Lambrechts P and Al-Nuaimi N. Clinical and radiographic features of external cervical resorption - an observational study. *Int Endod J* 2023; 56: 1475-1487.
- [15] Broutin A, Delrieu J, Blanc C, Esclassan R, Nasr K, Marty M, Canceill T and Noirrit E. Description and durability of the various indirect restoration techniques in molar-incisor hypomineralisation: a systematic review. *Eur J Prosthodont Restor Dent* 2024; 32: 91-101.
- [16] Alshali S, Asali R and Almarghani AA. Prosthetically driven computer-guided 1-piece zirconia

- implant placement and restoration replacing missing central incisor: a case report. *J Oral Implantol* 2023; 49: 8-12.
- [17] Rathod P, Patel A, Mankar N, Chandak M and Ikhar A. Enhancing aesthetics and functionality of the teeth using injectable composite resin technique. *Cureus* 2024; 16: e59974.
- [18] D'Arcangelo C, Buonvivero M and De Angelis F. Anterior esthetic restorations with the stratified stamp technique: a case report. *Biomimetics (Basel)* 2024; 9: 299.
- [19] Sultanoğlu EG, Eliaçık BBK, Eroğlu BK and Tez B. Evaluation of stress distributions in endodontically treated anterior incisors under occlusal and trauma-induced forces following various restoration treatments: a finite element analysis. *Dent Traumatol* 2024; 40: 688-701.
- [20] Chen D, Yu MQ, Li QJ, He X, Liu F and Shen JF. Precise tooth design using deep learning-based templates. *J Dent* 2024; 144: 104971.
- [21] Muslimah DF, Hasegawa Y, Antonin T, Richard F and Hosaka K. Composite injection technique with a digital workflow: a pragmatic approach for a protruding central incisor restoration. *Cureus* 2024; 16: e58712.
- [22] Denis R, Marty M, Esclassan R, Noirrit-Esclassan E and Canceill T. Description and durability of the various direct restoration techniques in molar-incisor hypomineralization: a systematic review. *Eur J Prosthodont Restor Dent* 2025; 33: 113-122.
- [23] Watanabe K, Tanaka E, Kamoi K, Tichy A, Shiba T, Yonerakura K, Nakajima M, Han R and Hosaka K. A dual composite resin injection molding technique with 3D-printed flexible indices for biomimetic replacement of a missing mandibular lateral incisor. *J Prosthodont Res* 2024; 68: 667-671.
- [24] Liu J, Maihemaiti M, Ren L, Maimaiti M, Yang N, Wang Y, Wang M, Wang X, Fu Y and Wang Z. A comparative study of the use of digital technology in the anterior smile experience. *BMC Oral Health* 2024; 24: 492.
- [25] Sara Mistry N and Muwaquet Rodriguez S. Comparison of aesthetic treatments for molar-incisor hypomineralisation: systematic review and meta-analysis. *Saudi Dent J* 2024; 36: 222-227.
- [26] Abella Sans F, Suresh N, Dummer PMH, Garcia-Font M, Gómez-Rojas A and Nagendrababu V. Guided autotransplantation of an immature premolar to the maxillary incisor region with immediate restoration of esthetics: a case report. *J Endod* 2024; 50: 252-257.
- [27] Xu H, Chen X, Wang J, Zou Q, Qi F and Ma X. Clinical evaluation of resorbable polylactic acid (PLA) intracanal posts for primary incisor restoration. Randomized controlled clinical trial. *J Clin Pediatr Dent* 2024; 48: 102-110.
- [28] Kurundkar S, Patel A, Ikhar A, Chandak M, Urkande NK, Rathod P and Bhojwani PR. Restoration of a peg lateral incisor using the putty index technique: a case report. *Cureus* 2024; 16: e68964.
- [29] Robbins JW. A case against the implant. *Int J Periodontics Restorative Dent* 2024; 44: 250-251.
- [30] Geduk N, Ozdemir M, Erbas Unverdi G, Ballikaya E and Cehreli ZC. Clinical and radiographic performance of preformed zirconia crowns and stainless-steel crowns in permanent first molars: 18-month results of a prospective, randomized trial. *BMC Oral Health* 2023; 23: 828.
- [31] Vignon M, Bensaidani T, Soliveres S and Bousquet P. Interdisciplinary management of bilateral congenital lateral incisor agenesis. *Case Rep Dent* 2023; 2023: 5576050.