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Comparative assessment of bioactive core materials and conventional composite cores in supporting full-coverage crowns on endodontically treated teeth

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Abstract:
Endodontically treated teeth require reliable core restorations, but the biological and mechanical performance of bioactive and conventional materials remains unclear. This study compared 120 endodontically treated teeth restored with Biodentine (n = 60) or ParaCore (n = 60), evaluating biological, mechanical and 12-month clinical outcomes. Biodentine showed higher dentinal microhardness ($p < 0.001$), lower microleakage ($p = 0.003$) and greater clinical success (96.7% vs. 88.3%, $p = 0.04$). ParaCore exhibited higher fracture resistance (2214 ± 286 N vs. 1876 ± 241 N, $p < 0.001$) and crown retention force ($p = 0.01$), while overall restoration survival was comparable. Thus, data support individualised material selection based on residual tooth structure and functional demands.

Keywords: Bioactive core material, Bio dentine, composite resin core, endodontically treated teeth, full-coverage crown, fracture resistance, dentinal remineralization and core build-up

Background:
The long-term prognosis of endodontically treated teeth is determined not only by the quality of root canal treatment but critically by the adequacy of the definitive coronal restoration **[1].** Loss of tooth structure from caries, access cavity preparation and previous restorations leaves endodontically treated teeth with reduced dentinal wall thickness and impaired biomechanical resistance, necessitating a reliable core foundation before crown placement **[2].** The core build-up material must satisfy multiple requirements: adequate compressive and flexural strength to withstand occlusal forces, dimensional stability, low water sorption, sufficient adhesion to residual dentine and biocompatibility with surrounding tissues **[3].** Conventional composite resin core materials have been the standard of care for core build-ups for several decades. Dual-cure formulations such as ParaCore (Coltene) offer high compressive strength (250–300 MPa), good workability and predictable adhesion to dentine via adhesive bonding systems. Their principal limitations include polymerisation shrinkage; water sorption induced dimensional change over time and a passive mechanical role that provides no biological benefit to the residual dentine **[4].** Secondary caries at the core–crown margin remains a leading cause of restoration failure, particularly in teeth with large or multi-surface restorations **[5].** Bioactive core materials represent a paradigm shift in core build up philosophy. Biodentine (Septodont), a tricalcium silicate–based cement, offers dentine-like mechanical properties (compressive strength 300 MPa, flexural strength 34 MPa), rapid set, excellent biocompatibility and the capacity to release calcium and hydroxyl ions that promote dentinal remineralisation and apatite formation at the material–dentine interface **[6].** Unlike conventional composites, Biodentine stimulates mineralisation tag formation within dentinal tubules, potentially reinforcing residual dentine and reducing microleakage over time **[7].** Bioactive glass-based core materials have also showed ion-mediated fluoride release and antimicrobial properties beneficial in the context of secondary caries prevention **[8].** Therefore it is of interest to compare the assessment combining *in vitro* mechanical testing with 12-month clinical follow-up data.

Materials and Methods:
Study design, setting and ethical approval:
This was a prospective, randomised, parallel-group study with both *in vitro* laboratory and *in vivo* clinical arms. Written informed consent was obtained from all participants. The *in vitro* arm used extracted human teeth; the *in vivo* arm enrolled consenting patients.

Sample selection and inclusion criteria:
For the *in vitro* arm, 120 extracted human premolars and molars free of caries, cracks and previous restorations were selected and standardised for root canal treatment, access cavity preparation and ferrule height (2 mm circumferential dentine). For the clinical arm, 120 patients aged 20–60 years requiring core build-up and full-coverage crown on a single endodontically treated premolar or molar were enrolled. Exclusion criteria included

severe bruxism, active periodontal disease, teeth with fewer than three remaining axial walls, systemic diseases affecting bone metabolism and patients unable to attend follow-up.

Randomisation and core build-up protocol:
Teeth were randomised 1:1 using computer-generated allocation (block size 4). Group A received Biodentine (Septodont, France) core build-up mixed per manufacturer instructions and inserted incrementally. Group B received ParaCore (Coltene Whaledent) dual-cure composite core, applied with Optibond XTR adhesive system following acid-etch, rinse and light-cure protocol. Full-coverage zirconia crowns were cemented with RelyX Unicem 2 (3M) on both groups following a uniform preparation protocol with standardised taper (6°) and occlusal reduction (1.5 mm).

Outcome measures and testing:
***In vitro* outcomes:** fracture resistance (axial load, Instron 5967, 1 mm/min), crown retention force (tensile pull-off, crosshead speed 0.5 mm/min), microleakage (methylene blue dye penetration after 2,000 thermocycles, scored 0–3) and dentinal microhardness at the core–dentine interface (Vickers hardness, 200 g load, 10 s dwell).

Clinical outcomes at 6 and 12 months:
Restoration survival (absence of fracture, debonding or secondary caries), periodontal health indices and patient-reported satisfaction (5-point Likert scale). Statistical analysis: SPSS v26; t-test or Mann–Whitney U for continuous variables; chi-square for categorical; $p < 0.05$ considered significant.

Results:
All 120 *in vitro* specimens and 120 clinical restorations were included in analysis. One hundred and eleven patients (Group A: 57; Group B: 54) completed 12-month clinical follow-up. Baseline characteristics were comparable between groups **(Table 1).** Results across all outcome parameters are presented in **Tables 2 and 3.** *In vitro* fracture resistance was significantly higher in Group B (2214 ± 286 N vs 1876 ± 241 N; $p < 0.001$). Crown retention force was also significantly higher in Group B (298.4 ± 42.1 N vs 261.7 ± 38.6 N; $p = 0.01$). Microleakage scores were significantly lower in Group A (median 1 vs 2; $p = 0.003$). Dentinal microhardness at the core dentine interface was significantly higher in Group A (62.4 ± 8.2 VHN vs 48.7 ± 7.6 VHN; $p < 0.001$), indicating active remineralization of peri-tubular dentine. Clinically, 12 month restoration success was significantly higher in Group A (96.7% vs 88.3%; $p = 0.04$). The most common failure mode in Group B was secondary caries at the core–crown margin (n = 5); in Group A, one post-cementation failure occurred due to crown debonding. Twelve-month implant survival (absence of any irreversible failure) was 98.2% (Group A) vs 93.3% (Group B; $p = 0.21$, NS). Patient satisfaction scores were comparable between groups at 12 months ($p = 0.38$).

Table 1: Baseline characteristics of study participants

Variable	Group A: Bioactive (n = 60)	Group B: Composite (n = 60)
Age, mean ± SD (years)	36.8 ± 8.4	37.2 ± 9.1
Female, n (%)	31 (51.7)	30 (50.0)
Tooth type: molar, n (%)	38 (63.3)	37 (61.7)
No. of remaining axial walls, mean ± SD	2.8 ± 0.4	2.7 ± 0.4
Ferrule height, mean ± SD (mm)	2.1 ± 0.3	2.0 ± 0.3
Crown material: zirconia, n (%)	60 (100.0)	60 (100.0)

Table 2: *In vitro* outcomes: fracture resistance, retention force, microleakage and dentinal microhardness

Parameter	Group A: Bioactive	Group B: Composite	p-value
Fracture resistance (N)	1876 ± 241	2214 ± 286	<0.001*
Crown retention force (N)	261.7 ± 38.6	298.4 ± 42.1	0.01*
Microleakage score (median)	1	2	0.003*
Dentinal microhardness (VHN)	62.4 ± 8.2	48.7 ± 7.6	<0.001*

**Statistically significant ($p < 0.05$)*

Table 3: Clinical outcomes at 12 months

Outcome	Group A: Bioactive	Group B: Composite	p-value
12-month success rate (%)	96.7	88.3	0.04*
Secondary caries, n (%)	0 (0.0)	5 (9.3)	0.02*
Crown debonding, n (%)	1 (1.8)	2 (3.7)	0.55 (NS)
Restoration survival (%)	98.2	93.3	0.21 (NS)
Patient satisfaction (mean score)	4.5 ± 0.5	4.4 ± 0.6	0.38 (NS)

**Statistically significant ($p < 0.05$); NS = not significant*

Discussion:
This study showed a clinically and statistically significant difference in the performance profile of bioactive and composite resin core materials across both mechanical and biological outcome parameters. The higher fracture resistance and crown retention force of composite resin cores aligns with the superior flexural and compressive strength of dual cure composite resin compared with tricalcium silicate cement, a difference well-documented in the materials literature **[9]**. The mean fracture resistance of both groups (1876 N and 2214 N) substantially exceeds the maximum molar biting force in adults (700–900 N), suggesting both materials provide adequate fracture protection under physiological loading**.** The significantly higher dentinal micro hardness at the core dentine interface in Group A (62.4 vs 48.7 VHN) provides direct *in vitro* evidence of bioactive mineralisation at the material dentine boundary. Calcium silicate hydrate formation and apatite precipitation induced by Biodentine's ion release increase peri-tubular dentine mineralisation, reinforcing the residual dentine and potentially reducing the risk of micro-crack propagation under cyclic fatigue loading **[10, 11].** This biological reinforcement mechanism is unique to bioactive materials and represents a fundamental advantage in teeth with compromised dentinal walls. The superior micro leakage resistance of bioactive cores is attributable both to their expansive setting behaviour (providing marginal sealing through volumetric compensation) and to the formation of mineralisation tags within dentinal tubules that physically occlude micro gaps at the material dentine interface **[12, 13].** The absence of secondary caries in the bioactive group versus 9.3% in the composite group at 12 months clinically validates this advantage and reflects the antimicrobial alkaline pH of tricalcium silicate materials **[14, 15].** This finding carries

significant clinical weight, as secondary caries at the crown margin remains a principal cause of restoration failure in endodontically treated teeth**.** The 12-month clinical success rate of 96.7% for bioactive cores versus 88.3% for composite cores, while statistically significant, should be interpreted cautiously given the relatively short follow-up and sample size. Longer observation periods are needed to determine whether the biological advantages of bioactive cores translate into durably superior restoration longevity, particularly given the lower fracture resistance and retention force compared with composites **[16, 17].** A hybrid strategy incorporating a thin bioactive base liner at the pulpal floor and axial walls followed by a composite resin bulk-fill layer may combine the biological benefits of ion-releasing materials with the mechanical strength of composite, a concept supported by recent *in vitro* evidence **[18, 19].** Limitations include the single-Centre *in vitro* component, the 12-month follow-up period, restriction to zirconia crowns (limiting generalisability to lithium disilicate or metal-ceramic restorations) and the inability to simulate intraoral fatigue in the *in vitro* fracture resistance test. Future multi-Centre RCTs with 3-5 year follow-up, incorporating standardised fatigue loading protocols and radiographic bone density assessment, are required to fully characterise the long-term clinical performance differential between these two core systems**.**

Conclusion:

Biodentine showed superior dentinal remineralisation, lower microleakage, absence of secondary caries and higher 12-month clinical success than ParaCore. Conversely, ParaCore exhibited greater fracture resistance and crown retention, with both materials showing clinically acceptable survival. Material selection should consider residual tooth structure and functional demands, while layered approaches warrant further investigation.

Conflict of interest: The authors declare no conflict of interest

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