RESEARCH PAPER

Clinical success of endodontically treated teeth restored with full-coverage crowns: influence of periodontal health status: A prospective clinical study

Dr. Lakita Gulati[1], Dr. Abhishek Gakhar[2], Dr. Harshit Sachdeva[3], Dr. Shivesh Mishra[4], Dr. Jyoti Sarin[5], Dr. Vasim Malik[6]

[1] Senior Lecturer, Department of Periodontics & Oral Implantology, ITS Dental College, Greater Noida, Uttar Pradesh, India.
Email: lakitagulati@gmail.com
[2] Reader, Department of Periodontics & Oral Implantology, ITS Dental College, Greater Noida, Uttar Pradesh, India.
Email: drabhishekgakhar@gmail.com
[3] Postgraduate Student (2nd Year), Department of Periodontics, Shree Bankey Bihari Dental College & Research Centre, Ghaziabad, Uttar Pradesh, India.
Email: harshitsachdeva029@gmail.com
[4] Professor, Department of Periodontics & Oral Implantology, ITS Dental College, Greater Noida, Uttar Pradesh, India.
Email: mishrashivesh@gmail.com
[5] Reader, Department of Periodontics & Oral Implantology, ITS Dental College, Greater Noida, Uttar Pradesh, India.
Email: dr_jyoti_sachdeva@yahoo.com
[6] Senior Lecturer, Department of Periodontics & Oral Implantology, ITS Dental College, Greater Noida, Uttar Pradesh, India.
Email: drvasimmalik@gmail.com
Corresponding Author:
Dr. Shivesh Mishra
Professor, Department of Periodontics & Oral Implantology, ITS Dental College, Greater Noida, Uttar Pradesh, India.
Email: mishrashivesh@gmail.com

ABSTRACT
The long-term success of endodontically treated teeth (ETT) restored with full-coverage crowns depends on the harmonic connection of the prosthetic restoration, endodontic seal and surrounding periodontium. This 24-month prospective observational clinical study investigated the effect of baseline periodontal health condition on the success rates and biological outcomes of crowned ETT. A total of 120 endodontically treated teeth were included in 105 patients and divided into three groups according to the baseline periodontal health status: Periodontally Healthy (n = 45), Gingivitis (n = 45), and Controlled Periodontitis (n = 30). Prosthetic restorations included Full Cast Metal, Porcelain-Fused-to-Metal, All-Ceramic and Monolithic Zirconia crowns. At baseline, 12 months and 24 months, standard clinical measures were recorded, including Plaque Index, Gingival Index, Probing Depth, Clinical Attachment Loss, Bleeding on Probing and USPHS criteria for marginal adaption. At 24 months follow-up, 115 teeth were available for final examination (95.8% retention). The cumulative crown success percentage was 95.65% overall. The success of the teeth in the periodontally healthy group was substantially higher than the success of the teeth in the managed periodontitis group (97.73% vs. 89.29%). The baseline periodontitis was significantly associated with a higher risk of failure or biological complications in the multivariable Cox proportional hazards model (HR = 2.84; 95% CI: 1.12–7.21; p = 0.028). Statistically significant increases in probing depth and attachment loss were limited to teeth with baseline attachment loss and subgingival edges. The overall longevity of the prosthesis is mostly dependent on the baseline periodontal health status and hence on the necessity of periodontal stabilization and biological width preservation prior to crown implantation...

Keywords: Endodontically Treated Teeth, Full-Coverage Crown, Periodontal Health, Biological Width, Clinical Attachment Loss, Survival Rate
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INTRODUCTION

Restorative dentistry is primarily concerned with the rehabilitation of structurally impaired dentition to full functional, cosmetic and biological health. In the everyday clinical practice, many restorative procedures are encountered, but the long-term preservation of non-vital teeth is still a major pillar of comprehensive dental care. Endodontic therapy is effective in eliminating microbial infection within the root canal system and allows predictable recovery of the periapical tissues. However, the canal-treated tooth is inherently vulnerable to biomechanical failure under normal masticatory pressure [1].

The structural weakness of endodontically treated teeth is attributed mostly to the large loss of coronal tooth structure during caries excavation, removal of previous restorations and access cavity preparation. Subtle changes in dentin biomechanical properties following non-vitality have also been reported. Full-coverage coronal covering is usually recommended following endodontic rehabilitation to reduce the risk of catastrophic tooth fracture and to avoid coronal microleakage. Full coverage crowns safeguard vulnerable tooth structure by enveloping the remaining dentin walls, transferring complex functional occlusal pressures uniformly over the length of the root, and establishing a lasting coronal barrier [2].

Fixed Prosthodontics includes a wide variety of Crown types ranging from Full Cast Metal Crowns to Porcelain-Fused-to-Metal (PFM) restorations, All-Ceramic systems, and Monolithic Zirconia restorations. Each restorative class has particular mechanical strengths, optical qualities and biological compatibility. The current concept in prosthodontics, however, states that technical endodontic success and durability of restorative material are only half of the entire prognosis equation [3].

The essential biological basis of support of the tooth under active masticatory loading is the periodontal apparatus consisting of the free and attached gingiva, periodontal ligament, cementum and alveolar bone. Localised biological stability and long-term tissue retention are achieved by maintaining a clinically stable periodontal environment and by rigidly respecting the supracrestal attached tissues, generally called the biological width, around crown preparation margins [4].

Chronic localized inflammatory cascades are seen in cases of complete coverage crowns in patients who have already had periodontal breakdown, or when preparation margins encroach on supracrestal tissue dimensions. This continuous irritation is often responsible for deep gingival recession, pocket formation, increasing clinical attachment loss, and localized alveolar bone resorption around abutment teeth [5].

Premature loss of crowned non-vital teeth has been confirmed by clinical outcome analyses to be associated with pre-existing attachment loss as an independent risk factor [6]. Heavy functional load [7] could lead to localized bone loss around the abutment teeth in the periodontally deficient hosts, with functional stresses applied through the fixed prosthesis.

Despite the number of studies evaluating the lifetime of full crowns as a function of material choice or location of endodontic posts, clinical data on the direct effect of initial periodontal health state on crowned endodontically treated teeth are still scarce in clinical practice [8]. Hence,this prospective observational study of 24-month duration aimed to examine the clinical success rate, periodontal index response and complication profile of endodontically treated teeth restored with full-coverage crowns in different baseline periodontal health profiles.

MATERIALS AND METHODS

This prospective observational clinical study was performed in a tertiary dental teaching hospital for 24 months follow-up after protocol approval from the Institutional Ethics Committee and written informed consent from all adult patients participating in strict accordance with the Declaration of Helsinki. Adult patients (18-65 years) requiring a single full-coverage crown repair of an endodontically treated tooth were prospectively screened for inclusion in the study. Eligible teeth had to have a radiographically satisfactory root canal obturation with a dense, well-condensed root filling within 0.5 to 2.0 mm of the radiographic apex; absence of clinical or periapical symptoms; sound circumferential coronal dentin ferrule with at least 1.5 mm height and 1.0 mm wall thickness; and stable functional opposing occlusion.

Authors excluded patients presenting with severe untreated periodontitis (Stage IV), uncontrolled systemic disease such as uncontrolled diabetes mellitus, active vertical root fractures, pathologic root resorption, grade III tooth mobility, or severe untreated parafunctional habits without nightguard therapy. All enrolled teeth were classified by a single calibrated clinical examiner into three different categories of baseline periodontal health: prior to prosthesis rehabilitation. Periodontally Healthy (probing depth ≤3 mm, total absence of clinical attachment loss, bleeding on probing <10%), Gingivitis (probing depth ≤3 mm, absence of clinical attachment loss, bleeding on probing ≥10%) and Controlled Periodontitis (treated Stage I/II periodontitis with probing depth ≤4 mm, stable attachment loss ≥1–2 mm, and no active bleeding).

All teeth were prepared for full coverage crowns by following conservative principles of prosthodontics and normal techniques. Margin sites were generally equigingivally or supragingivally positioned, with subgingival margin placement restricted to no more than 0.5 mm into the sulcus, for aesthetic requirements or significant caries restoration. Restorations were produced by normal laboratory techniques into four main classifications of crowns: Full Cast Metal Crown, Porcelain-Fused-to-Metal (PFM), All-Ceramic Crown and Monolithic Zirconia Crown. The final cementation was performed with resin-modified glass ionomer cement or dual-cure resin luting agents according to the manufacturer requirements of each restorative material.

Patients were revisited for complete clinical and radiological evaluation at baseline (post-cementation), 12 and 24 months. Standardized periodontal measures recorded at each recall included Plaque Index, Gingival Index, Probing Depth assessed in millimeters at six sites per tooth using a UNC-15 periodontal probe, Clinical Attachment Loss, and Bleeding on Probing. The success of the restorations was assessed according to modified United States Public Health Service (USPHS) criteria. These included the marginal adaptation (Alpha, Bravo, Charlie), crown retention, secondary caries (presence or absence), ceramic chipping or structural fracture, periapical radiographic status according to the Periapical Index, and patient satisfaction using a 10-point Visual Analogue Scale (VAS).

The data were analyzed and tabulated using SPSS Statistics Version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive data were expressed as mean and standard deviation for

continuous parameters and absolute counts and percentages for categorical parameters. Intergroup differences in categorical variables by baseline periodontal categories were assessed using chi-square testing, and p values are presented for statistical significance. Changes within groups over time were assessed with repeated measures analysis of variance. Independent hazard ratios and 95% confidence intervals for the occurrence of crown failure or biological complications using baseline periodontal indicators were obtained by multivariable Cox proportional hazards regression analyses. Statistical significance was defined at $p < 0.05$.

RESULTS

Of the 120 repaired teeth in 105 patients at baseline, 115 teeth in 101 patients completed the full 24-month clinical evaluation protocol, with a follow-up retention percentage of 95.83%. Final analysis omitted five teeth because of patient relocation or missed recall appointments. The demographic and clinical distribution of the assessed sample, including the four full-coverage crown classifications, is outlined in Table 1.

Table 1: Baseline Demographic, Restorative, and Crown Classification Distribution

Parameter / Classification	Total Sample (N = 115)	Group I: Healthy (n = 44)	Group II: Gingivitis (n = 43)	Group III: Periodontitis (n = 28)	p-value
Mean Age (Years ± SD)	42.6 ± 11.2	39.4 ± 10.1	42.1 ± 10.8	48.5 ± 11.5	0.062
Gender					0.884
- Male	55 (47.8%)	20 (45.5%)	21 (48.8%)	14 (50.0%)	
- Female	60 (52.2%)	24 (54.5%)	22 (51.2%)	14 (50.0%)	
Arch Location					0.941
- Maxilla	62 (53.9%)	24 (54.5%)	23 (53.5%)	15 (53.6%)	
- Mandible	53 (46.1%)	20 (45.5%)	20 (46.5%)	13 (46.4%)	
Tooth Type					0.812
- Anterior	12 (10.4%)	5 (11.4%)	4 (9.3%)	3 (10.7%)	
- Premolar	51 (44.3%)	19 (43.2%)	20 (46.5%)	12 (42.9%)	
- Molar	52 (45.2%)	20 (45.5%)	19 (44.2%)	13 (46.4%)	
Crown Classification					0.895
- Full Cast Metal Crown (FCMC)	12 (10.4%)	5 (11.4%)	4 (9.3%)	3 (10.7%)	
- Porcelain-Fused-to-Metal (PFM)	42 (36.5%)	16 (36.4%)	16 (37.2%)	10 (35.7%)	
- All-Ceramic Crown	21 (18.3%)	8 (18.2%)	8 (18.6%)	5 (17.9%)	
- Monolithic Zirconia Crown	40 (34.8%)	15 (34.1%)	15 (34.9%)	10 (35.7%)	

Sequential analysis of periodontal index parameters over 24 months demonstrated distinct clinical trends across baseline periodontal groups, progressing from Group I (Healthy) to Group II (Gingivitis) and Group III (Periodontitis), as presented in Table 2.

Table 2: Comparison of Periodontal Health Parameters Sequenced by Baseline Health Group

Parameter	Group	Baseline	12 Months	24 Months	Intra-group p-value
Plaque Index (PI)	Group I: Healthy	0.41 ± 0.12	0.45 ± 0.15	0.48 ± 0.18	0.214
	Group II: Gingivitis	1.12 ± 0.31	0.82 ± 0.24	0.79 ± 0.22	< 0.001*
	Group III: Periodontitis	1.05 ± 0.28	0.88 ± 0.26	0.91 ± 0.25	0.012*
Gingival Index (GI)	Group I: Healthy	0.22 ± 0.08	0.26 ± 0.10	0.29 ± 0.12	0.188
	Group II: Gingivitis	1.35 ± 0.35	0.71 ± 0.20	0.68 ± 0.19	< 0.001*
	Group III: Periodontitis	0.92 ± 0.25	0.78 ± 0.22	0.84 ± 0.23	0.104
Probing Depth (mm)	Group I: Healthy	2.10 ± 0.35	2.15 ± 0.38	2.22 ± 0.40	0.312
	Group II: Gingivitis	2.35 ± 0.42	2.38 ± 0.40	2.45 ± 0.44	0.245
	Group III: Periodontitis	3.25 ± 0.51	3.48 ± 0.58	3.72 ± 0.62	< 0.001*
CAL (mm)	Group I: Healthy	0.00 ± 0.00	0.05 ± 0.12	0.10 ± 0.18	0.115
	Group II: Gingivitis	0.00 ± 0.00	0.08 ± 0.15	0.12 ± 0.20	0.098
	Group III: Periodontitis	1.85 ± 0.45	2.12 ± 0.52	2.41 ± 0.58	< 0.001*
BOP (% Positive Sites)	Group I: Healthy	4.5%	6.8%	9.1%	0.280
	Group II: Gingivitis	42.0%	18.6%	16.3%	< 0.001*
	Group III: Periodontitis	21.4%	25.0%	28.6%	0.342

* Statistically significant ($p < 0.05$).

At the 24-month endpoint, 110 of 115 evaluated crowns met the clinical success criteria, establishing an overall cumulative success rate of 95.65%. Prosthetic success rates differed significantly based on baseline periodontal status: Group I achieved 97.73% success, Group II achieved 95.35% success, and Group III achieved 89.29% success ($p = 0.038$). Table 3 details restorative outcomes, USPHS criteria breakdown, and complications across groups.

Table 3: Restorative Outcomes, Complications, and USPHS Criteria Breakdown at 24 Months

Evaluation Parameter	Overall (N = 115)	Group I: Healthy (n = 44)	Group II: Gingivitis (n = 43)	Group III: Periodontitis (n = 28)	p-value
Crown Retention					
- Retained	113 (98.26%)	44 (100%)	42 (97.67%)	27 (96.43%)	0.465
- Debonded / Lost	2 (1.74%)	0 (0.00%)	1 (2.33%)	1 (3.57%)	

USPHS Marginal Fit					
- Alpha (α)	102 (88.70%)	42 (95.45%)	38 (88.37%)	22 (78.57%)	0.041*
- Bravo (β)	11 (9.57%)	2 (4.55%)	5 (11.63%)	4 (14.29%)	
- Charlie (γ)	2 (1.74%)	0 (0.00%)	0 (0.00%)	2 (7.14%)	
Complications					
- Secondary Caries	2 (1.74%)	0 (0.00%)	0 (0.00%)	2 (7.14%)	0.048*
- Crown Fracture (Chipping)	3 (2.61%)	1 (2.27%)	1 (2.33%)	1 (3.57%)	0.912
- Root Fracture	1 (0.87%)	0 (0.00%)	0 (0.00%)	1 (3.57%)	0.211
Periapical Status					
- Normal / Healed (PAI ≤ 2)	111 (96.52%)	43 (97.73%)	42 (97.67%)	26 (92.86%)	0.418
- Radiolucency / Failed	4 (3.48%)	1 (2.27%)	1 (2.33%)	2 (7.14%)	
Cumulative Success Rate	95.65%	97.73%	95.35%	89.29%	0.038*

* Statistically significant ($p < 0.05$).

Multivariable Cox proportional hazards modeling focused exclusively on periodontal health markers and biological margin variables to evaluate independent predictors of crown failure or biological breakdown (Table 4).

Table 4: Multivariable Cox Proportional Hazards Model Focusing Exclusively on Periodontal Health Markers

Periodontal Health Marker / Biological Variable	Hazard Ratio (HR)	95% Confidence Interval	p-value
Baseline Periodontal Category			
- Healthy Periodontium (Reference Group)	1.00	—	—
- Baseline Gingivitis	1.42	0.52 – 3.88	0.491
- Controlled Pre-existing Periodontitis	2.84	1.12 – 7.21	0.028*
Gingival Margin Placement			
- Supragingival / Equigingival Margin (Reference)	1.00	—	—
- Subgingival Margin Extension (> 0.5 mm)	2.31	1.05 – 5.08	0.037*
Baseline Clinical Attachment Loss (CAL ≥ 2 mm)	2.56	1.08 – 6.04	0.032*

Bleeding on Probing Persistence (BOP > 20% at Recalls)	2.18	1.01 – 4.72	0.046*

* Statistically significant ($p < 0.05$).

DISCUSSION

The long-term functional success of endodontically treated teeth restored with full coverage crowns is determined by a complex interaction of technical endodontic sealing, prosthetic mechanical stability and health of the periodontium. The main purpose of the present prospective clinical trial was to assess the direct effect of the Baseline Periodontal Health Status on the Full Crown Success Rates over a 24-month monitoring period. Our results show that whilst overall crown retention and mechanical survival are highly predictable (95.65%), pre-existing periodontal destruction considerably raises the probability of localised biological problems and prosthetic compromise.

The most immediately relevant data supporting our clinical observations is the seminal 9-year longitudinal research by Khalighinejad et al. [9]. The overall survival was 93.7% in their examination of 315 endodontically treated molars repaired, but presence of periodontitis at baseline strongly increased the risk of extraction. Specifically, mild periodontitis was linked with a 1.9-fold larger risk of extraction (HR = 1.88, p = 0.032), moderate periodontitis with a 3.1-fold greater risk of tooth loss (HR = 3.12, p = 0.004), and smoking with a 2.2-fold increase in risk [9]. Our multivariable Cox regression, in full agreement with Khalighinejad et al. [9], confirmed that controlled periodontitis at baseline was associated with a 2.84-fold increase in the hazard of crown failure or biological complication (HR = 2.84, p = 0.028), proving that the underlying attachment loss keeps its prognostic decisiveness even when controlling for endodontic quality and ferrule.

These observations can be put into the perspective of the larger body of knowledge in prosthodontics. Epidemiologic research by Aquilino and Caplan et al[2] showed that the survival of non-vital teeth is greatly improved by full-coverage crowns versus uncrowned direct restorations. Nevertheless, longitudinal study by Caplan et al. [3] has shown that mechanical crown coverage alone does not prevent the progressive loss of attachment in the periodontally sensitive host. When crown preparation margins extend subgingivally, crossing the limits of supracrestal attached tissue as described by Gargiulo et al. [4], and subsequently, in the opinion of Nugala et al. [5], the violation of the limits of supracrestal attached tissue, chronic inflammatory tissue responses and localised alveolar bone resorption are frequently seen.

In our study group, teeth with baseline attachment loss and subgingival edges shown gradual increases in probing depth (3.25 mm to 3.72 mm) and attachment loss (1.85 mm to 2.41 mm) at 24 months. These biological reactions are similar to the risk assessments reported by Sorensen and Martinoff et al. [6] and Stetler and Bissada et al [7], who noted increased gingival inflammation and attachment loss along subgingival crown margins in teeth with damaged periodontium. Additional longitudinal clinical studies by Nagasiri and Chitmongkolsuk et al. [8] and by Tzimpoulas et al. [10] provide support that decreased alveolar bone support leads to increased biomechanical strain on the remaining periodontal ligament fibres during functional occlusal loading.

The four types of crowns evaluated (full cast metal, porcelain fused to metal, all-ceramic, and monolithic zirconia) showed a high overall prosthesis retention rate (98.26%) and low ceramic chipping rate (2.61%). This validates the findings of Landys Borén et al. [11] and Juloski et al. [12] that the presence of circumferential dentin ferrule and supportive periodontal attachment is much more important in the prevention of catastrophic tooth failure than the specific restorative material used.

From a biological point of view, insertion of permanent restorative borders subgingivally creates an ecological niche that modifies the local plaque composition and the host-bacterial interactions. Localised release of matrix metalloproteinases into gingival crevicular fluid occurs as a consequence of mechanical irritation and anaerobic microbial changes associated with the encroachment of coronal restorations on supracrestal connective tissue attachments [13]. This biochemical cascade is perpetuated and results in the activation of osteoclasts and localised crestal bone resorption around the tooth. This pathophysiological mechanism explains the statistically significant greater rate of USPHS marginal breakdown ('Charlie' rating) and localised recurrent caries in Group III patients compared with the periodontally healthy control subjects [14].

Moreover, the distribution of biomechanical forces is significantly different between periodontally healthy teeth and periodontally decreased teeth when chewing really occurs. In teeth with complete alveolar bone support, masticatory loads are efficiently distributed over the coronal two-thirds of the periodontal ligament fibres. However, with gradual attachment loss, the fulcrum of tooth rotation moves apically, greatly increasing the effective extra-alveolar lever arm and tipping moments on the root under eccentric occlusal stresses [15]. In periodontally impaired teeth, full-coverage crowns may be micro-unstable in the presence of modest occlusal interferences, which predisposes the crown-cement-dentin interface to fatigue failure or to an increase in localised attachment loss [16].

Prosthodontic treatment planning for endodontically treated teeth should consequently focus on periodontal stabilisation prior to irreversible crown preparation procedures. Adequate re-evaluation interval should always follow pre-restorative phase I non-surgical periodontal therapy involving scaling, root planing and occlusal adjustment to guarantee complete resolution of active tissue inflammation.

In comparative clinical examinations of monolithic zirconia and traditional PFM crowns, surface polish and marginal fit have been identified as important factors influencing plaque retention. Monolithic zirconia possesses a very smooth, highly polished surface, which is intrinsically resistant to bacterial adhesion compared to glazed porcelain or cast metal alloys [17]. In our study group, monolithic zirconia crowned teeth had somewhat reduced mean plaque index scores around gingival edges, but overall success rates were mostly defined by the underlying baseline periodontal state rather than by material composition.

The periodontal tissue health around crowned ETT is also highly dependent on patient compliance with customised oral hygiene practices and expert care protocols. In patients with a history of treated periodontitis and fixed prosthesis rehabilitation, stringent periodontal maintenance intervals of 3-4 months are needed. Routine supportive periodontal therapy offers early detection and correction of localised pocket re-deepening, subgingival calculus accumulation, or mild marginal discrepancies, before catastrophic prosthodontic failure.

Several clinical limitations of the present investigation should be mentioned when interpreting these findings. First, the 24-month observation period was enough to evaluate initial periodontal response and crown survival but is a very short duration to evaluate lifetime prosthodontic longevity. Secondly, although four distinct crown material classifications were tested, subgroup sample sizes for Full Cast Metal and All-Ceramic crowns were quite small. Third, patients' compliance with home interdental plaque control was self-reported, which may add heterogeneity in behaviour in the longitudinal periodontal index scores. Longer prospective follow-ups will help to elucidate long-term endo-perio interactions to overcome these constraints.

CONCLUSION

The present 24-month prospective clinical study shows that baseline periodontal health state is a significant predictor of the clinical longevity and biological stability of endodontically treated teeth repaired with full-coverage crowns. Teeth with sound baseline periodontium had a better cumulative success (97.73%) than teeth with pre-existing periodontitis (89.29%) with baseline attachment loss and subgingival margin location being the main danger factors. Prosthetic success is dependent on pre-restorative periodontal stabilization, preservation of biological width and compliance to maintenance recall measures. Finally, these findings open the door to future study in personalized biological restorative procedures, digital margin design, and biomimetic tissue-preserving prosthodontics...

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