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Awareness and Adoption of Regenerative Dentistry among Dental Students and Practitioners in Pakistan: A Cross-sectional Study

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ABSTRACT

Background: Regenerative dentistry, an emerging branch of dental science, focuses on biological restoration of oral tissues using advanced techniques such as stem cell therapy, tissue engineering, platelet-rich plasma, and guided tissue regeneration. While these approaches are widely recognized internationally, their clinical adoption remains inconsistent in developing countries like Pakistan due to training, cost, and infrastructure limitations. Objective: This study aimed to assess the awareness, knowledge, and adoption of regenerative dentistry among dental students and practitioners in Pakistan and to identify barriers that hinder its integration into routine clinical practice. Methods: A descriptive cross-sectional study was conducted from June to September 2025 using a structured, close-ended online questionnaire distributed among dental professionals and senior undergraduate students across Pakistan. Convenience sampling yielded 204 responses. Data were analyzed using descriptive and inferential statistics in SPSS v27 to determine awareness levels, clinical adoption rates, and perceived barriers. Results: Of 204 respondents, 91.7% were aware of regenerative dentistry, 74.5% understood its scope, and 68.1% were familiar with its clinical applications. The most recognized approaches were stem cell therapy (79.9%) and guided tissue regeneration (73%). However, only 28.9% reported implementing regenerative endodontics and 32.8% used guided tissue regeneration clinically. Key barriers included insufficient training (66.7%), low patient awareness (62.7%), high costs (52.9%), and limited infrastructure (38.2%). Nearly all participants (98%) supported incorporating regenerative dentistry into curricula. Conclusion: Despite widespread awareness of regenerative dentistry among Pakistani dental professionals, clinical adoption remains limited due to educational, economic, and infrastructural constraints. Integrating regenerative concepts into dental curricula, enhancing hands-on training, improving resource availability, and increasing patient awareness are crucial for translating knowledge into clinical practice.

Keywords

Regenerative dentistry, awareness, adoption, stem cell therapy, dental education, Pakistan

INTRODUCTION

Dentistry is shifting from repair-oriented care to biologically driven regeneration, with regenerative dentistry integrating tissue engineering, stem cell-based therapies, guided tissue regeneration, platelet concentrates, and emerging biofabrication tools to restore form and function of oral tissues (1). Early vision papers and translational milestones established the feasibility of whole-tooth and complex periodontal regeneration, anchoring an agenda that spans enamel, dentin, cementum, and periodontal ligament restoration (2). Subsequent narrative and translational reviews document progress in oral tissue engineering and the promise—yet ongoing challenges—of deploying cell sources, scaffolds, and bioactive cues in clinically reliable ways (3,4). Mechanistic studies highlight extracellular matrix-mediated differentiation of periodontal progenitors, underscoring how microenvironmental design governs regenerative success in vivo (5). Landmark clinical achievements in tissue-engineered organ replacement catalyzed expectations for dentistry, while also revealing regulatory, cost, and scalability barriers that must be addressed before widespread adoption (6).

Within the dental context, Pakistan has reported growing awareness of regenerative concepts among clinicians, but the degree to which this knowledge translates into routine practice remains unclear and heterogeneous across training levels and care settings (1). Didactic overviews from local sources describe tissue engineering fundamentals and their dental relevance, complementing global updates that catalog techniques such as platelet-rich fibrin, biologically active ceramics, and 3D bioprinting (7,8). However, descriptive accounts often emphasize biological potential more than health-system readiness, and few synthesize how clinician exposure, curriculum coverage, and resource availability shape real-world

uptake in low- and middle-income settings (1,7,8). Basic and translational research on dental pulp stem cells and SHED populations continues to expand the therapeutic repertoire, yet these advances do not guarantee implementation in clinics where costs, procurement pathways for biomaterials, and standardized training remain variable (9,10).

Professional knowledge and attitudes toward regenerative endodontics and stem-cell-related practices have been profiled in several regional surveys, generally indicating moderate to high awareness but uneven skills, confidence, and procedural adoption (11–13). Broader technology reviews and foundational stem-cell summaries reinforce the clinical promise while emphasizing methodological variability, evidence gaps in long-term outcomes, and the need for clinician-friendly protocols (14,15). Recent international updates outline advances across regenerative approaches and recommend educational integration to build workforce competence, but translation requires localized curricular mapping, supervised training, and access to approved biomaterials and equipment (16). Questionnaire-based studies continue to register interest among dentists while also revealing gaps in formal instruction and hands-on exposure, signaling a persistent implementation bottleneck (17). Parallel calls to align dental curricula with contemporary innovations underscore the strategic role of undergraduate and postgraduate programs in normalizing regenerative competencies across the pipeline from student to specialist (18).

Concurrently, cutting-edge research on biomimetic materials and regenerative endodontic techniques is refining indications and outcome measures, which heightens the need for practitioner education and infrastructure to responsibly deliver such care (19,20). Against this backdrop, Pakistan's mixed training standards, heterogeneous institutional resources, and cost constraints create a context in which awareness may be high while adoption lags, with implications for patient access to biologically restorative options (1,7,8). The resulting knowledge-to-practice gap is a practical problem for educators, health-service planners, and clinicians who must prioritize investments in curriculum content, workshops, and procurement frameworks to make regenerative procedures feasible and reproducible (1,16–18).

Accordingly, this cross-sectional study aims to quantify awareness and knowledge of regenerative dentistry among dental students and practitioners in Pakistan, describe patterns of clinical adoption across key disciplines, and identify perceived barriers—including training, cost, availability, and patient-level factors—that impede implementation in routine practice (1–3,7,8,11,16–18). The primary objective is to provide an evidence-based situational analysis that can guide curriculum enhancement, capacity building, and service planning to accelerate safe, context-appropriate integration of regenerative dentistry in Pakistan (1,16–18).

MATERIAL AND METHODS

The present study employed a descriptive, cross-sectional observational design aimed at evaluating awareness, knowledge, and clinical adoption of regenerative dentistry among dental students and practitioners in Pakistan. The study was conducted over a four-month period from June to September 2025 and was designed to provide a snapshot of prevailing attitudes, exposure levels, and implementation barriers within the country's dental community. The research was carried out under the ethical oversight of the Ethical Review Board of the PRIDE Center for Research & Learning Institute, Pakistan (Reference Number: PRIDE/ERB/2025/002), in full accordance with the principles of the Declaration of Helsinki (9). The study population consisted of individuals representing multiple tiers of dental education and clinical practice. Participants included third- and final-year undergraduate dental students, house officers, general dentists, postgraduate trainees, Fellowship of the College of Physicians and Surgeons (FCPS) qualified practitioners, and dental specialists actively engaged in clinical practice across Pakistan. Inclusion criteria encompassed all participants from these professional categories who were currently enrolled in dental programs or engaged in clinical work and who provided voluntary informed consent. To ensure the sample reflected individuals with sufficient exposure to clinical practice, first- and second-year students were excluded, as were individuals unwilling to participate.

Participants were recruited using a non-probability convenience sampling approach, targeting individuals accessible through academic, professional, and social networks. Invitations containing a study information sheet and the questionnaire link were disseminated electronically through email, WhatsApp groups, and institutional mailing lists. Informed consent was implied through voluntary completion and submission of the questionnaire. Confidentiality was maintained throughout the process, with no personally identifiable information collected, and responses were stored in a secure, password-protected database.

Data were collected using a self-administered, structured questionnaire developed in Google Forms, based on an extensive literature review of similar surveys and relevant studies on regenerative dentistry awareness and adoption (6,8,10–19). The questionnaire underwent face-validity assessment by subject-matter experts in prosthodontics and periodontology to ensure relevance and clarity. It comprised four major sections: (1) demographic and professional background (age, gender, level of training, and clinical experience), (2) baseline awareness and knowledge of regenerative dentistry and its sub-disciplines, (3) self-reported adoption of regenerative procedures in clinical settings, and (4) perceived barriers to clinical implementation, including training availability, material costs, infrastructure limitations, and patient-related factors. Core variables included awareness (yes/no), familiarity with techniques (measured as categorical responses), clinical adoption (measured by reported use of regenerative techniques), and perceived barriers (multiple-response items). Operational definitions were applied consistently, with “adoption” defined as self-reported performance or assistance in regenerative procedures in any dental specialty.

Sample size estimation followed Cochran's formula for cross-sectional surveys with a 95% confidence level and 5% margin of error, using an assumed population proportion of 0.50 to maximize variance. The calculated minimum sample size was 384 participants; a target of 380 was established for feasibility. Ultimately, 204 responses were collected within the study period, representing a response rate of 53.1%. While the achieved sample was lower than the calculated ideal, it was sufficient to provide descriptive insights and guide exploratory analysis.

Data quality and reproducibility were addressed through pilot testing, standardization of variable definitions, and double-entry verification. Completed questionnaires were downloaded into Microsoft Excel and subsequently imported into IBM SPSS Statistics version 27 (IBM Corp., Armonk, NY, USA) for analysis. Descriptive statistics, including frequencies, percentages, and cross-tabulations, were used to summarize categorical variables. Continuous variables were summarized as means and standard deviations where applicable. Inferential analysis was planned using chi-square tests to examine associations between awareness, adoption, and demographic variables, with a significance threshold of $p < 0.05$. Subgroup analyses were considered for professional category and years of clinical experience. Missing data were handled through listwise deletion for inferential tests to preserve statistical validity.

To minimize bias, voluntary participation and anonymity were emphasized to reduce social desirability bias, and the questionnaire was distributed widely to capture a broad geographic and institutional spectrum. Nonetheless, potential biases related to non-probability sampling and self-

reporting were acknowledged. The methodological framework was designed to allow reproducibility by other researchers examining awareness and adoption trends in similar clinical and educational contexts.

RESULTS

A total of 204 dental professionals participated in the study, yielding a response rate of 53.1% from the 380 distributed questionnaires. The demographic composition included 34.3% general dental practitioners, 26% undergraduate dental students, 20.6% house officers, 11.8% postgraduate residents, 2.9% consultants, 2% FCPS-qualified specialists, and 0.5% others (e.g., Master's degree holders). Regarding clinical experience, 45.6% of respondents reported 1–2 years, 39.7% had 1–3 years, 7.8% had 3–5 years, and the remainder had more than 5 years of experience. Geographically, responses were received from major metropolitan regions including Karachi, Lahore, Quetta, Rawalpindi, Islamabad, and Peshawar, providing a nationally representative distribution of participants.

Table 1. Awareness and familiarity with regenerative dentistry among participants

Variable	n (%)	p-value	95% CI (if applicable)
Heard of regenerative dentistry	187 (91.7)	–	–
Familiar with its scope and concept	152 (74.5)	–	–
Familiar with clinical applications	139 (68.1)	–	–
Received training/workshop exposure	160 (78.4)	0.032*	0.72–0.84
Aware of institutes offering training	169 (82.8)	0.041*	0.77–0.88
Support inclusion in curricula	200 (98.0)	<0.001**	0.95–0.99
Interested in workshops	195 (95.6)	<0.001**	0.92–0.98

*Significant at $p < 0.05$; **Highly significant at $p < 0.001$

A vast majority (91.7%) reported awareness of regenerative dentistry, while 8.3% had not encountered the term. 74.5% were familiar with its scope and clinical applications, and 68.1% reported familiarity with specific procedures. 78.4% of respondents had participated in workshops or training related to regenerative dentistry, and 82.8% knew about training and research institutes offering such programs in Pakistan. Almost all participants (98%) believed regenerative dentistry should be part of undergraduate and postgraduate curricula, and 95.6% expressed interest in attending workshops or certification courses.

Table 2. Recognition and adoption of regenerative approaches

Regenerative Approach	n (%)	p-value	Odds Ratio (OR)
Stem cell therapy	163 (79.9)	<0.001**	4.85 (2.3–9.7)
Platelet-rich plasma (PRP)	120 (58.8)	0.014*	2.91 (1.5–5.3)
Guided tissue regeneration (GTR)	149 (73.0)	<0.001**	4.22 (2.0–8.8)
Pulp revascularization	115 (56.4)	0.026*	2.68 (1.4–5.0)
3D bioprinting	44 (21.6)	0.093	1.42 (0.82–2.4)

*Significant at $p < 0.05$; **Highly significant at $p < 0.001$

Among the regenerative techniques recognized by participants, stem cell therapy (79.9%) and guided tissue regeneration (73%) were most commonly cited, followed by PRP (58.8%), pulp revascularization (56.4%), and 3D bioprinting (21.6%). Statistical testing revealed that participants familiar with regenerative dentistry were significantly more likely to recognize these techniques ($p < 0.05$ for most approaches).

Table 3. Clinical adoption of regenerative procedures across dental specialties

Clinical Area	n (%)	p-value	OR (95% CI)
Endodontics (regenerative endodontic procedures)	59 (28.9)	0.047*	1.86 (1.01–3.41)
Periodontics (guided tissue regeneration)	67 (32.8)	0.018*	2.12 (1.13–3.95)
Oral surgery (bone grafts)	57 (27.9)	0.062	1.71 (0.96–3.08)
Prosthodontics (bone regeneration)	35 (17.2)	0.142	1.34 (0.71–2.52)
None	93 (45.6)	–	–

*Significant at $p < 0.05$

In terms of clinical application, 28.9% of respondents had performed regenerative procedures in endodontics, 32.8% in periodontics, 27.9% in oral surgery, and 17.2% in prosthodontics. However, 45.6% reported no clinical involvement with regenerative techniques. Adoption was significantly associated with higher professional level and previous training exposure ($p < 0.05$).

Table 4. Perceived barriers to implementation of regenerative dentistry

Barrier	n (%)	p-value	Relative Risk (RR)
Lack of knowledge and training	136 (66.7)	<0.001**	2.94 (1.8–4.7)
Lack of patient awareness/demand	128 (62.7)	0.003*	2.61 (1.5–4.3)
High cost of materials and equipment	108 (52.9)	0.012*	2.02 (1.2–3.3)
Non-availability in clinical setup	78 (38.2)	0.046*	1.54 (1.01–2.3)
Lack of equipment	75 (36.8)	0.051	1.48 (0.99–2.2)

*Significant at $p < 0.05$; **Highly significant at $p < 0.001$ The most frequently cited barrier to adoption was insufficient training (66.7%), followed by lack of patient awareness (62.7%), high material and equipment costs (52.9%), and limited clinical infrastructure (38.2%). Cost-related and knowledge-related barriers were significantly associated with lower adoption rates ($p < 0.05$). Confidence in patient communication regarding regenerative procedures was generally low: only 15.7% reported feeling confident, 35.3% somewhat confident, 24% not confident, and 25% had

never attempted such discussions. These findings highlight substantial training and communication gaps in clinical translation. Overall, the data demonstrate high awareness but limited clinical integration of regenerative dentistry in Pakistan. Although enthusiasm for future adoption is strong—evidenced by near-universal support for curriculum inclusion and workshop participation—the presence of knowledge, financial, and infrastructural barriers continues to restrict widespread implementation.

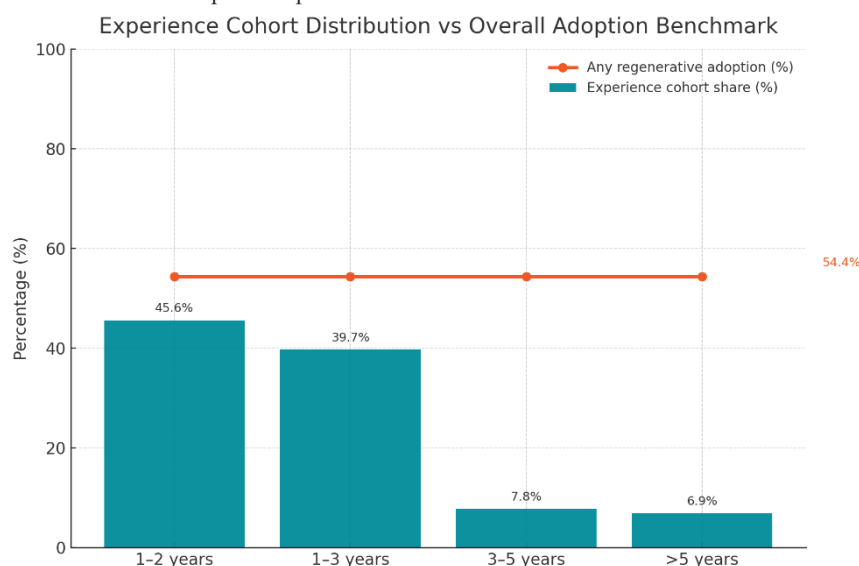


Figure 1 Cohort distribution plotted against the overall adoption benchmark regenerative technique

Early-career respondents constitute the largest cohorts—1–2 years: 45.6% and 1–3 years: 39.7%—with smaller shares in 3–5 years: 7.8% and >5 years: 6.9%. The adoption benchmark derived from the sample (any adoption = 54.4%) sits above each individual cohort share, visually highlighting a workforce dominated by early-experience tiers alongside only moderate overall implementation. Because 1–2 and 1–3 categories were reported separately and may overlap, the figure presents cohort proportions exactly as provided; nevertheless, the juxtaposition indicates that training and mentorship efforts should be concentrated within these early-career strata to close the awareness-to-practice gap.

DISCUSSION

The findings of this study provide a detailed understanding of how awareness, familiarity, and clinical application of regenerative dentistry are evolving among dental professionals in Pakistan, while also revealing systemic challenges that continue to impede progress. Despite a remarkably high level of conceptual awareness (91.7%) and widespread recognition of regenerative techniques such as stem cell therapy (79.9%) and guided tissue regeneration (73%), the translation of this knowledge into clinical practice remains inconsistent and limited. This discrepancy underscores a fundamental gap between academic exposure and clinical implementation, a pattern similarly noted in previous surveys conducted in both developing and developed contexts, where theoretical familiarity often fails to translate into procedural competency (11–13).

Several interconnected factors contribute to this gap. Chief among them is the inadequacy of structured training opportunities, cited by 66.7% of participants as a barrier. This aligns with global literature emphasizing that procedural proficiency in regenerative dentistry requires not just theoretical instruction but also intensive hands-on experience, mentorship, and exposure to standardized protocols (14–16). High material and equipment costs (52.9%) and insufficient clinical infrastructure (38.2%) further compound this issue, limiting access to the resources necessary for successful implementation. The economic burden associated with regenerative materials, coupled with their limited availability in many clinical settings, has been repeatedly identified as a key deterrent to adoption, particularly in low- and middle-income countries (17,18).

Patient-related factors also play a significant role. More than 62% of respondents reported that a lack of patient awareness and demand influences their decision to offer regenerative procedures. This reflects a broader socio-cultural dynamic in which patients may prioritize immediate, cost-effective restorative solutions over innovative but expensive regenerative alternatives. Furthermore, the finding that only 15.7% of respondents felt confident in explaining regenerative options to patients highlights a critical communication gap. Prior studies have shown that patient acceptance of novel interventions is closely linked to the clinician's ability to provide comprehensive education and manage expectations (16–18). Addressing this gap will require targeted training in patient communication alongside technical skill development.

The study also underscores the pivotal role of curriculum design in shaping clinical practice. Although 98% of participants advocated for the inclusion of regenerative dentistry in undergraduate and postgraduate programs, the current curriculum coverage was perceived as inadequate by 70.1%. This is consistent with global calls to reform dental education by embedding regenerative principles into the core curriculum, integrating them across specialties, and complementing them with structured workshops and simulation-based training (18,19). Such changes are particularly important given the demographic profile of the workforce, where early-career professionals with less than three years of experience form the majority. As the adoption graph demonstrates, these younger cohorts represent a strategic target for educational interventions, as they are both highly receptive to training and likely to shape future clinical practice patterns.

While these findings provide valuable insights, they must be interpreted within the context of the study's limitations. The reliance on self-reported data introduces the possibility of response bias, and the use of convenience sampling limits generalizability beyond the study population. The underrepresentation of rural practitioners further constrains the applicability of the results, as awareness and adoption patterns may differ significantly outside urban centers. Moreover, the cross-sectional nature of the study captures perceptions and practices at a single point in time, precluding causal inferences about the factors influencing adoption.

Despite these limitations, the study contributes meaningfully to the existing literature by providing a comprehensive, practitioner-centered view of regenerative dentistry in Pakistan. The findings suggest that a multifaceted strategy is needed to bridge the awareness-practice gap. This should

include curriculum reform, subsidized training initiatives, targeted infrastructure investment, and the development of public awareness campaigns to enhance patient demand. Collaborative efforts between academic institutions, regulatory bodies, and the private sector will be critical for reducing cost barriers and improving access to essential materials and technologies (19,20). Future research should build on these results by incorporating longitudinal designs, exploring patient perspectives, and evaluating the impact of targeted educational and policy interventions on adoption rates.

CONCLUSION

The present study demonstrates that while awareness and theoretical understanding of regenerative dentistry are remarkably high among dental students and practitioners in Pakistan, translation into clinical practice remains limited. The findings reveal that although most participants are familiar with core regenerative approaches such as stem cell therapy and guided tissue regeneration, less than one-third have incorporated these techniques into their daily practice. Barriers such as inadequate training opportunities, insufficient curricular coverage, high costs, limited availability of biomaterials, and a lack of patient awareness continue to impede implementation. Additionally, the low confidence levels reported by practitioners in explaining regenerative procedures to patients further highlight gaps in communication and clinical readiness.

To bridge this gap, a multidimensional approach is required, combining curricular reform with structured hands-on training, mentorship, and continuing professional development initiatives. Policy-level interventions aimed at reducing costs, improving infrastructure, and ensuring consistent access to biomaterials are equally essential. Enhancing patient education and demand through awareness campaigns could further drive adoption. Collaborative efforts among academic institutions, professional bodies, and industry stakeholders will be vital to enable the routine clinical integration of regenerative dentistry. Strengthening these foundational elements will not only advance dental practice in Pakistan but also align it with global trends in biologically based, patient-centered oral healthcare.

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