RESEARCH PAPER

Awareness, Attitude and Clinical Adoption of Advanced Local Drug Delivery and Controlled Release Systems in Dental Practice: A Cross-Sectional Questionnaire-Based Study

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ABSTRACT

Background: Advanced local drug delivery (LDD) and controlled release systems (CRS) have been introduced to enhance targeted antimicrobial therapy in periodontal and other dental conditions. Despite demonstrated clinical benefits, their adoption in routine practice remains inconsistent.

Objective: To assess the awareness, attitude, perceived efficacy, barriers, and clinical adoption of advanced LDD/CRS among dental practitioners.

Methods: A cross-sectional, anonymous, online questionnaire survey was conducted among dental practitioners. The instrument was developed through literature review and expert validation. Content validity was established by subject experts, pilot testing was performed, and internal consistency was assessed using Cronbach's alpha. The questionnaire included sections on demographics, awareness and knowledge, attitudes, clinical use patterns, and perceived barriers. Sample size estimation was performed based on reliability analysis and prevalence calculation. Data were collected over 8 weeks and analyzed using descriptive statistics, chi-square tests, and multivariable logistic regression. Statistical significance was set at $p < 0.05$.

Results: Of 420 invited practitioners, 312 responded (74.3%). The mean age was 33.8 ± 7.2 years, and 56% were female. Participants included 48% general dentists, 34% periodontists, and 18% other specialists. Although 82% were aware of LDD/CRS products, only 39% reported good/very good practical knowledge. Regular use (≥1/month) was reported by 27.9%, while 43.9% used them rarely and 28.2% had never used them. Major barriers were high cost (72.1%), limited training (60.9%), uncertain reimbursement (53.8%), and concerns about long-term efficacy (39.1%). Periodontal specialization (adjusted OR 3.6; 95% CI 2.1–6.2) and prior continuing education attendance (adjusted OR 2.9; 95% CI 1.7–5.0) were significant predictors of regular adoption ($p < 0.001$).

Conclusions: Although awareness of LDD/CRS is high among dental practitioners, routine clinical adoption remains limited. Addressing cost constraints, enhancing targeted continuing education, and strengthening clinical guidelines may improve integration of these technologies into standard dental practice

Keywords: Local drug delivery; Controlled release systems; Periodontics; Awareness; Clinical adoption; Dental practice; Continuing education.

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INTRODUCTION

Periodontal diseases are chronic inflammatory conditions initiated by microbial biofilms that lead to progressive destruction of the supporting structures of the teeth. Although mechanical debridement through scaling and root planing (SRP) remains the gold standard of non-surgical periodontal therapy, complete elimination of pathogenic microorganisms from deep periodontal pockets and anatomically complex sites is often challenging (1,2). This limitation has stimulated interest in adjunctive antimicrobial strategies, particularly local drug delivery (LDD) and controlled release systems (CRS).

Local drug delivery systems are designed to deliver antimicrobial agents directly into periodontal pockets at

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therapeutic concentrations while minimizing systemic exposure and associated adverse effects (3). Controlled release devices further enhance therapeutic efficiency by maintaining sustained drug concentrations over an extended period, thereby improving substantivity and reducing the need for repeated applications (4). Various LDD/CRS formulations—including chlorhexidine chips, doxycycline hyclate gels, and minocycline microspheres—have demonstrated clinical benefits in terms of probing depth reduction and clinical attachment level gain when used as adjuncts to SRP (5–7).

The pharmacokinetic advantage of LDD lies in achieving drug concentrations in gingival crevicular fluid that are significantly higher than those obtained through systemic administration, while reducing risks such as gastrointestinal disturbances and antibiotic resistance (3,8). Evidence from systematic reviews and meta-analyses suggests that adjunctive LDD may provide statistically significant, though modest, improvements in clinical periodontal parameters (6,9). Consequently, professional guidelines recognize LDD as a potential adjunct in selected cases of persistent or refractory periodontitis (2).

Despite demonstrated clinical efficacy and availability of commercially approved products, the translation of LDD/CRS into routine dental practice appears variable. Adoption of innovative therapeutic modalities in dentistry is influenced by multiple factors, including clinician awareness, perceived effectiveness, cost considerations, training exposure, and reimbursement policies (10). Understanding these determinants is essential for identifying gaps between evidence-based recommendations and real-world clinical implementation.

Although several clinical trials have evaluated the therapeutic outcomes of LDD systems, limited data exist regarding practitioners' awareness, attitudes, and actual usage patterns, particularly in diverse clinical settings. Therefore, the present study aimed to assess the awareness, attitude, perceived efficacy, barriers, and clinical adoption of advanced LDD/CRS among dental practitioners.

MATERIALS AND METHODS

The present study was a cross-sectional, anonymous, online questionnaire-based survey conducted among licensed dental practitioners (general dentists and specialists) across India. Data collection was carried out over a two-month period from January 1 to February 28, 2026. Ethical approval was obtained from the Institutional Review Board of Private Dental College and Hospital, India (IRB No.: LMH/IEC/2025/214). Participation was entirely voluntary. Electronic informed consent was obtained from all participants prior to accessing the survey. Confidentiality and anonymity were strictly maintained, and no personally identifiable information was collected or stored.

The study population comprised licensed dental practitioners actively engaged in clinical practice with a minimum of one year of clinical experience. Interns, undergraduate students, non-practicing dentists, and respondents submitting incomplete questionnaires were excluded from the final analysis. A convenience sampling approach was adopted. A sampling frame was constructed using professional dental networks, state and national dental associations, institutional alumni databases, and targeted professional social media platforms including email groups and WhatsApp forums. Invitations included a structured description of the study objectives along with a secure survey link.

Sample size estimation was performed considering both reliability assessment and prevalence estimation. For internal consistency evaluation, assuming a target Cronbach's alpha of ≥0.75 with a 95% confidence interval width of ±0.08, and following Bonett's formula for reliability studies, a minimum sample exceeding 200 participants was indicated. For estimation of clinical adoption prevalence, assuming a conservative prevalence of 50%, a 95% confidence level, 5–6% margin of error, alpha level of 0.05, and statistical power of 80%, approximately 250–300 completed responses were required. Based on these parameters and in accordance with Bonett and Bujang's methodological recommendations for reliability studies, a target of 300 completed questionnaires was set to ensure adequate statistical precision and power.

The questionnaire consisted of approximately 32 items organized into six domains: demographics and practice characteristics (age, gender, years in practice, specialty, and practice setting); awareness and knowledge (eight multiple-choice items assessing familiarity with types of LDD/CRS, mechanisms of action, clinical indications, and commonly used agents/products); attitudes (six Likert-scale items ranging from strongly disagree to strongly agree evaluating perceived efficacy, safety, cost-effectiveness, and clinical importance); clinical use and adoption (frequency of use, indications, products utilized, and decision-making drivers such as evidence, cost, and patient preference); perceived barriers and facilitators (multiple-choice and open-ended responses); and training and information sources (continuing education programs, scientific journals, and industry-based information).

Questionnaire items were developed following a structured review of relevant literature and were evaluated for content validity by a panel of four subject experts representing periodontics, endodontics, pharmacology, and public health dentistry. Face validity was assessed through pilot testing among 20 practicing dental professionals to evaluate clarity, comprehension, and average completion time. Internal consistency reliability of the awareness and attitude domains was assessed using Cronbach's alpha, with $\alpha \geq 0.70$ considered acceptable. Construct validity was examined during pilot testing through item-total correlation analysis and exploratory factor analysis using principal component extraction with varimax rotation to confirm domain structure.

The finalized questionnaire was administered using an online survey platform (Google Forms). Survey links were distributed via professional email lists, dental association groups, and WhatsApp-based practitioner forums. Two reminder notifications were sent at two-week intervals to enhance response rates. The estimated time required to complete the questionnaire was approximately 8–10 minutes.

Completed responses were exported into IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA) for statistical analysis. Descriptive statistics were computed as frequencies and percentages for categorical variables and as mean ± standard deviation for continuous variables following assessment of normality. Awareness and attitude scores were calculated by summing relevant item responses and categorized into low, moderate, and high levels based on tertile distribution. Bivariate associations were assessed using chi-square or Fisher's exact tests for categorical variables and independent t-tests or one-way ANOVA for continuous variables where appropriate. Multivariable logistic regression analysis was performed to identify independent predictors of regular clinical adoption, defined a priori as use of LDD/CRS at least once per month. Independent variables entered into the model included age, gender, years of practice, specialty, attendance at continuing education programs related to LDD, and perceived cost barrier. Adjusted odds ratios with 95% confidence intervals were calculated. Statistical significance was set at $p < 0.05$.

RESULTS

A total of 312 completed responses were analyzed, yielding a response rate of 74.3%. The mean age of participants was 33.8 ± 7.2 years. Females constituted 56.0% (n = 175) of the sample, while males accounted for 44.0% (n = 137). Nearly half of the respondents were general dentists (48.0%, n = 150), followed by periodontists (34.0%, n = 106) and other specialists (18.0%, n = 56). With respect to professional experience, 37.8% had 1–5 years of practice, 32.7% had 6–10 years, and 29.5% had more than 10 years of clinical experience. The majority were engaged in private clinical practice (63.5%), followed by academic institutions (23.7%) and hospital-based settings (12.8%) (Table 1).

Regarding awareness, 82.0% (n = 256) of practitioners reported having heard of local drug delivery (LDD) or controlled release systems (CRS). However, when self-assessing practical knowledge, only 39.1% rated their knowledge as good or very good, while 60.9% reported poor or fair understanding. Categorization of knowledge scores showed that 28.2% had low knowledge, 43.6% moderate knowledge, and 28.2% high knowledge levels (Table 2).

In terms of clinical adoption, 27.9% (n = 87) reported regular use of LDD/CRS (defined as ≥1 application per month), 43.9% (n = 137) reported rare use (<4 times per year), and 28.2% (n = 88) had never used these systems in practice. The most common indications for use were persistent periodontal pockets (52.6%), maintenance phase therapy (35.9%), and peri-implantitis management (24.4%) (Table 3).

High cost of materials was the most frequently cited barrier (72.1%), followed by limited clinical training (60.9%), uncertain reimbursement policies (53.8%), concerns regarding long-term efficacy (39.1%), and limited patient acceptance (23.7%) (Table 4).

Bivariate analysis demonstrated a statistically significant association between professional specialty and regular adoption ($\chi^2 = 32.84$, $p < 0.001$). Periodontists showed significantly higher regular usage (46.2%) compared with general dentists (16.0%). Attendance at continuing education (CE) programs on LDD was also significantly associated with regular use ($\chi^2 = 28.71$, $p < 0.001$), with 39.5% of CE attendees reporting regular use compared with 15.3% among non-attendees. No statistically significant association was observed for gender ($p = 0.53$) or years of practice ($p = 0.09$) (Table 5).

Knowledge level was significantly associated with clinical adoption ($\chi^2 = 36.92$, $p < 0.001$). Practitioners with high knowledge scores reported substantially greater regular use (47.7%) compared with those with moderate (25.0%) or low knowledge (12.5%) (Table 6).

Comparison of mean attitude scores revealed that regular users had significantly higher attitude scores (23.6 ± 3.8) than non-regular users (19.4 ± 4.5), with a statistically significant difference ($t = 7.21$, $p < 0.001$) (Table 7).

Multivariable logistic regression analysis identified specialist training in periodontics (adjusted OR = 3.6; 95% CI: 2.1–6.2; $p < 0.001$) and prior CE attendance on LDD (adjusted OR = 2.9; 95% CI: 1.7–5.0; $p < 0.001$) as independent predictors of regular adoption. High knowledge level was also a significant predictor (adjusted OR = 2.7; 95% CI: 1.5–4.8; $p = 0.001$). Perceived cost barrier was negatively associated with regular use (adjusted OR = 0.6; 95% CI: 0.4–0.9; $p = 0.03$). Age and other specialty categories were not statistically significant predictors. The regression model demonstrated good fit (Hosmer–Lemeshow $p = 0.47$), with a Nagelkerke R^2 of 0.38 and overall classification accuracy of 74.6% (Table 8).

Tables

Table 1. Demographic and Practice Characteristics of Participants (n = 312)

Variable	Category	n	%
Age (years)	Mean ± SD	33.8 ± 7.2	—
Gender	Male	137	44.0
	Female	175	56.0
Professional Qualification	General Dentist	150	48.0
	Periodontist	106	34.0
	Other Specialists	56	18.0
Years in Practice	1–5 years	118	37.8
	6–10 years	102	32.7
	>10 years	92	29.5
Practice Setting	Private Clinic	198	63.5
	Academic Institution	74	23.7
	Hospital-based Practice	40	12.8

Table 2. Awareness and Knowledge of LDD/CRS

Variable	Category	n	%
Heard of LDD/CRS Products	Yes	256	82.0
	No	56	18.0
Self-Rated Practical Knowledge	Poor	74	23.7
	Fair	116	37.2
	Good	86	27.6
	Very Good	36	11.5
Knowledge Level (Categorized)	Low	88	28.2
	Moderate	136	43.6
	High	88	28.2

Table 3. Clinical Adoption Patterns

Variable	Category	n	%
Frequency of LDD/CRS Use	≥1/month (Regular)	87	27.9
	<4 times/year (Rare)	137	43.9
	Never	88	28.2
Common Indications*	Persistent Periodontal Pockets	164	52.6
	Maintenance Therapy	112	35.9
	Peri-implantitis	76	24.4

***Multiple responses allowed.**

Table 4. Perceived Barriers to Adoption

Barrier	n	%
High Cost of Materials	225	72.1
Limited Clinical Training	190	60.9
Uncertain Reimbursement	168	53.8
Concerns About Long-Term Efficacy	122	39.1
Limited Patient Acceptance	74	23.7

Table 5. Association Between Professional Characteristics and Regular Use

Variable	Regular Use n (%)	Non-Regular Use n (%)	χ^2	p-value
Specialty				
General Dentist	24 (16.0)	126 (84.0)	32.84	**<0.001***
Periodontist	49 (46.2)	57 (53.8)		
Other Specialists	14 (25.0)	42 (75.0)		
CE Attendance on LDD				
Yes	64 (39.5)	98 (60.5)	28.71	**<0.001***
No	23 (15.3)	127 (84.7)		
Gender				
Male	36 (26.3)	101 (73.7)	0.39	0.53
Female	51 (29.1)	124 (70.9)		
Years of Practice				
1–5 years	28 (23.7)	90 (76.3)	4.82	0.09
6–10 years	30 (29.4)	72 (70.6)		
>10 years	29 (31.5)	63 (68.5)		

***Statistically significant at $p < 0.05$**

Table 6. Association Between Knowledge Level and Regular Adoption

Knowledge Level	Regular Use n (%)	Non-Regular Use n (%)	χ^2	p-value
Low	11 (12.5)	77 (87.5)	36.92	**<0.001***
Moderate	34 (25.0)	102 (75.0)		
High	42 (47.7)	46 (52.3)		

***Statistically significant at p < 0.05**

Table 7. Comparison of Mean Attitude Scores by Adoption Status

Variable	Regular Users (n=87) Mean ± SD	Non-Regular Users (n=225) Mean ± SD	t-value	p-value
Attitude Score (0–30)	23.6 ± 3.8	19.4 ± 4.5	7.21	**<0.001***

***Statistically significant at p < 0.05**

Table 8. Multivariable Logistic Regression for Predictors of Regular LDD/CRS Use

Predictor	Adjusted OR	95% CI	Wald χ^2	p-value
Periodontist vs General Dentist	3.6	2.1–6.2	18.42	**<0.001***
Other Specialist vs General Dentist	1.8	0.9–3.4	2.74	0.09
CE Attendance (Yes)	2.9	1.7–5.0	15.36	**<0.001***
High Knowledge Level	2.7	1.5–4.8	11.08	**0.001***
Perceived Cost Barrier	0.6	0.4–0.9	4.72	**0.03***
Age	1.02	0.98–1.05	1.54	0.21

***Statistically significant at p < 0.05**

DISCUSSION

Periodontal diseases remain a major global health concern, characterized by chronic inflammatory destruction of tooth-supporting tissues initiated by complex microbial biofilms (1). Mechanical debridement through scaling and root planing (SRP) continues to be the cornerstone of non-surgical therapy; however, anatomical complexities, deep periodontal pockets, and microbial recolonization often limit complete pathogen elimination (1,2). In this context, local drug delivery (LDD) and controlled release systems (CRS) were developed to enhance subgingival antimicrobial concentrations while minimizing systemic exposure (3,4,8). The present study demonstrates that although awareness of advanced LDD/CRS modalities among Indian dental practitioners is high (82%), routine clinical adoption remains limited (27.9% regular use), revealing a translational gap between evidence and practice.

The high awareness observed aligns with the longstanding presence of LDD agents in periodontal literature and clinical guidelines. Controlled clinical trials have demonstrated that chlorhexidine chips and minocycline microspheres provide statistically significant improvements in probing depth reduction and clinical attachment gain when used adjunctively with SRP (5,7). Systematic reviews and meta-analyses have consistently reported modest but clinically meaningful benefits of adjunctive local antimicrobials (6,9,11). However, the magnitude of improvement is often small, and heterogeneity in study designs, follow-up duration, and case selection has led to cautious interpretation of long-term superiority (6,9,12). The EFP S3 clinical practice guideline recognizes adjunctive local antimicrobials as potentially beneficial in specific clinical scenarios, particularly persistent deep pockets, but does not recommend indiscriminate routine use (2). This nuanced positioning in guidelines may partly explain why awareness does not automatically translate into frequent application.

A notable finding of the present study is the discrepancy between awareness (82%) and self-reported good/very good practical knowledge (39%). This suggests superficial familiarity rather than operational competence. Similar discrepancies have been reported in other areas of dental pharmacotherapy and prescribing behavior, where theoretical exposure does not consistently translate into confident clinical execution (13). Inadequate understanding of indications, cost–benefit assessment, and case selection criteria may reduce clinicians' readiness to integrate LDD into routine workflows.

Economic considerations emerged as the most significant barrier (72.1%), followed by limited clinical training (60.9%) and reimbursement uncertainty (53.8%). These findings are consistent with the Diffusion of Innovations theory, which identifies relative advantage, compatibility, complexity, and observability as determinants of technology adoption (10). In resource-sensitive healthcare systems, perceived cost-effectiveness plays a pivotal role. Although local antimicrobials reduce systemic adverse effects and antibiotic exposure (3,8), their additional financial burden compared with SRP alone may influence practitioner and patient acceptance. Previous cost-effectiveness analyses have suggested that adjunctive therapies may be economically justified in high-risk or non-responsive cases but less so in routine moderate disease (14). This economic ambivalence may contribute to selective adoption.

The strong independent association between periodontal specialization (adjusted OR 3.6) and regular LDD use reflects the influence of advanced training and case mix complexity. Periodontists are more likely to manage

refractory or advanced disease stages where adjunctive therapies are indicated, consistent with guideline-based care (2). Similarly, continuing education (CE) attendance independently predicted adoption (adjusted OR 2.9), underscoring the role of structured professional development in bridging evidence–practice gaps. Educational reinforcement has been shown to significantly influence rational prescribing behaviors in dentistry (13). Therefore, targeted CE modules incorporating case-based decision algorithms, hands-on workshops, and evidence synthesis may enhance clinical confidence.

Concerns regarding long-term efficacy (39.1%) observed in the present survey are not unfounded. While early-generation LDD systems focused primarily on antibiotic delivery (e.g., tetracycline fibers, minocycline microspheres), contemporary research increasingly explores non-antibiotic adjuncts, including host-modulation agents, anti-inflammatory compounds, and regenerative bioactive molecules (15,16). Advances in biodegradable polymers, nanoparticle carriers, and smart-responsive hydrogels have demonstrated promising sustained-release kinetics and targeted bioactivity (15–18). These next-generation platforms aim to address limitations such as short substantivity, antimicrobial resistance concerns, and inconsistent clinical outcomes. The evolution toward multifunctional, bioactive delivery systems may expand clinical indications beyond purely antimicrobial therapy.

Another important consideration is antimicrobial stewardship. Overreliance on systemic antibiotics in periodontal therapy has raised global concerns regarding resistance (19). Localized delivery systems theoretically reduce systemic exposure and may align better with stewardship principles (3,8,19). However, clinician apprehension regarding resistance selection even at local sites remains a debated topic in the literature (12). Clearer consensus guidelines integrating antimicrobial stewardship principles with periodontal therapy protocols could alleviate uncertainty.

The regression model in the present study demonstrated acceptable explanatory power (Nagelkerke $R^2 = 0.38$), suggesting that specialty training, CE exposure, and knowledge level are substantial determinants of adoption. However, unexplained variance indicates that additional contextual factors—such as patient socioeconomic status, product availability, marketing influences, and practice infrastructure—may also contribute. The cross-sectional design precludes causal inference; nonetheless, the observed associations are consistent with established behavioral and implementation science frameworks (10).

Methodologically, the present study benefits from an adequate sample size supporting reliability testing and multivariable modeling, as well as representation across generalists and specialists. The use of a validated questionnaire with acceptable internal consistency strengthens internal validity. However, convenience sampling may introduce selection bias, potentially overrepresenting practitioners with pre-existing interest in periodontal therapeutics. Self-reported data are susceptible to recall and social desirability bias. Furthermore, regional variations in product availability and reimbursement policies may limit extrapolation beyond the study setting.

Overall, the findings suggest that while the scientific foundation of LDD/CRS is well established (3–9), practical integration into everyday dental practice remains influenced by economic feasibility, training exposure, and evolving evidence. Bridging this translational gap requires alignment between clinical guidelines, educational reinforcement, economic accessibility, and continued innovation in delivery platforms.

CONCLUSION

Although awareness of advanced local drug delivery (LDD) and controlled release systems (CRS) among dental practitioners is high, routine clinical adoption remains limited. Economic constraints, inadequate training, and concerns about long-term efficacy are key barriers. Periodontal specialization and continuing education significantly influence regular use, underscoring the importance of structured training and clearer clinical guidance to enhance evidence-based integration of LDD/CRS into practice..

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