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EXPLORING STUDENT'S KNOWLEDGE AND AWARENESS OF TRANSDERMAL DRUG DELIVERY ROUTES WITH EMPHASIS ON TRANSDERMAL PATCHES: A PROSPECTIVE, OBSERVATIONAL, CROSS-SECTIONAL STUDY IN A TERTIARY CARE TEACHING INSTITUTE

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ABSTRACT

Background: Drug delivery systems form the backbone of rational pharmacotherapy, directly influencing drug efficacy, safety, and patient compliance. Among various novel drug delivery routes, transdermal drug delivery systems (TDDS) have gained prominence due to their ability to provide controlled drug release, bypass first-pass metabolism, and enhance patient adherence. Despite their growing clinical relevance, the extent of knowledge, awareness, and perception regarding transdermal drug delivery among undergraduate medical and dental students remains inadequately explored.

Objectives: To assess and compare the knowledge, awareness, and perception regarding transdermal drug delivery routes with emphasis on transdermal patches among MBBS and BDS students in a tertiary care teaching institute, and to identify educational gaps using a validated scoring system.

Materials and Methods: A prospective, observational, cross-sectional study was conducted among 254 undergraduate students (183 MBBS and 71 BDS). Data were collected using a pre-validated, self-administered questionnaire comprising four sections: demographic details, general knowledge of drug delivery routes, knowledge and awareness of transdermal patches, and perception with educational needs. Knowledge and awareness were assessed using Sections B and C (maximum score: 15), while perception was evaluated using Section D (maximum score: 5). The total score ranged from 0 to 20 and was interpreted as poor, basic, moderate, or good knowledge and awareness. Data were analyzed using descriptive and inferential statistics.

Results: Most participants were familiar with conventional drug delivery routes, while awareness of transdermal drug delivery was comparatively lower. MBBS students demonstrated higher mean knowledge and awareness scores than BDS students. Knowledge of drugs administered via transdermal patches was variable, with better recognition of nitroglycerin and nicotine than hormonal preparations. Perception scores indicated a generally positive attitude toward the clinical relevance of transdermal patches. However, confidence in patient counseling was limited, and a strong demand for additional training and curricular emphasis on TDDS was observed.

Conclusion: The study reveals moderate overall knowledge and awareness of transdermal drug delivery systems among undergraduate students, with significant scope for improvement, particularly in practical and clinical application aspects. Incorporation of targeted educational interventions, hands-on demonstrations, and enhanced curricular focus on TDDS is recommended to better prepare future healthcare professionals.

Keywords: Drug Delivery Routes, Transdermal Drug Delivery Systems, Transdermal Patches, Undergraduate Medical Education, Knowledge, Awareness, MBBS Students, BDS Student.



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INTRODUCTION

The route of drug administration is a critical determinant of therapeutic efficacy, patient safety, and treatment adherence. The most widely used routes in clinical practice still remain the conventional routes such as oral, intravenous, intramuscular, and subcutaneous administration remain; however, each is associated with inherent

limitations. Oral drug delivery, although convenient, is often compromised by first-pass hepatic metabolism, gastrointestinal degradation, variable absorption, and poor compliance in patients with swallowing difficulties. Parenteral routes, while offering rapid and predictable drug action, are invasive, associated with pain, risk of infection, and reduced patient acceptability, particularly during long-term therapy ^[1,2]. These challenges have driven the development of alternative and advanced drug delivery systems aimed at optimizing therapeutic outcomes while improving patient convenience and compliance.

Among the novel drug delivery approaches, Transdermal Drug Delivery Systems (TDDS) have emerged as a promising and patient-friendly method of systemic drug administration. TDDS involve the application of a drug formulation onto the skin, from where the drug permeates through the stratum corneum and enters the systemic circulation at a controlled rate ^[3]. Transdermal patches represent the most commonly utilized form of TDDS and are designed to deliver drugs steadily over prolonged periods, ranging from hours to several days. The success of TDDS lies in their ability to maintain consistent plasma drug concentrations, minimize dosing frequency, and allow rapid termination of drug action by patch removal when necessary ^[4].

Transdermal drug delivery offers several well-established advantages over conventional routes. These include avoidance of first-pass metabolism, reduced gastrointestinal adverse effects, improved bioavailability, enhanced patient compliance, and suitability for chronic disease management ^[5]. Additionally, TDDS are particularly beneficial for special populations such as elderly patients, pediatric patients, and those with dysphagia or poor adherence to oral medications ^[6]. Clinically, transdermal patches are widely used for the delivery of drugs such as nitroglycerin in angina pectoris, nicotine in smoking cessation therapy, fentanyl for chronic pain management, scopolamine for motion sickness, clonidine for hypertension, and estrogen or testosterone for hormone replacement therapy ^[7,8].

Despite these advantages, transdermal drug delivery is not without limitations. The skin acts as a formidable barrier, restricting the permeation of large, hydrophilic, and poorly potent drugs. Local adverse effects such as skin irritation, contact dermatitis, and hypersensitivity reactions may also occur ^[9]. Furthermore, variability in skin permeability due to age, hydration, site of application, and disease conditions can influence drug absorption and therapeutic outcomes ^[10]. A sound understanding of both the advantages and limitations of TDDS is therefore essential for rational prescribing and effective patient counseling.

With rapid advancements in pharmaceutical technology and increasing incorporation of novel drug delivery systems into routine clinical practice, the role of healthcare professionals has expanded beyond prescribing to include patient education, monitoring, and optimization of drug therapy. Undergraduate medical (MBBS) and dental (BDS) students represent future prescribers and healthcare providers who will play a pivotal role in ensuring the safe and effective use of such advanced delivery systems. Adequate knowledge and awareness of TDDS among these students are therefore crucial to promote rational drug use and enhance patient outcomes ^[11].

Pharmacology forms a core component of both medical and dental curricula; however, the extent to which novel drug delivery systems such as transdermal patches are emphasized varies widely across institutions. While MBBS students are exposed to a broader range of systemic pharmacotherapy, BDS students increasingly encounter pharmacological agents in pain management, local anesthesia, and adjunctive systemic therapies, where transdermal delivery may have emerging applications ^[12]. Limited curricular exposure, lack of hands-on demonstrations, and insufficient clinical integration may contribute to gaps in understanding and confidence related to TDDS among undergraduate students.

Previous studies assessing knowledge of drug delivery systems among healthcare students have reported variable levels of awareness, with better familiarity with conventional routes compared to newer modalities such as transdermal, inhalational, and targeted delivery systems ^[13,14]. Several authors have highlighted the need for enhanced educational strategies, including interactive teaching, case-based learning, and practical demonstrations, to improve students' understanding of novel drug delivery technologies ^[15]. However, data specifically comparing the knowledge, awareness, and perception of TDDS between MBBS and BDS students—particularly in the Indian tertiary care teaching institute setting remain limited.

Understanding students' perception of the clinical relevance of transdermal drug delivery is equally important. Positive perception and confidence in explaining transdermal patch use to patients are essential for effective counseling, adherence, and prevention of misuse or adverse effects. Identifying perceived educational needs can guide curriculum planners in strengthening teaching methodologies and ensuring that future healthcare professionals are well equipped to integrate TDDS into clinical practice ^[16].

In this context, the present study was designed to explore the knowledge, awareness, and perception regarding transdermal drug delivery routes, with

special emphasis on transdermal patches, among undergraduate MBBS and BDS students in a tertiary care teaching institute. By employing a structured and validated questionnaire with a defined scoring system, the study aims to quantify levels of understanding, compare differences between disciplines, and identify key educational gaps. The findings of this study are expected to provide valuable insights for curriculum development, targeted educational interventions, and improved integration of novel drug delivery systems into undergraduate medical and dental education.

AIMS AND OBJECTIVES

Primary Objective

- To assess the level of knowledge and awareness regarding transdermal drug delivery systems, with emphasis on transdermal patches, among undergraduate MBBS and BDS students.

Secondary Objectives

- To evaluate students' perception of clinical relevance of transdermal patches.
- To compare knowledge and awareness levels between MBBS and BDS students.
- To identify educational gaps and perceived training needs related to transdermal drug delivery systems.
- To categorize students based on predefined knowledge and perception scores.

MATERIALS AND METHODS

Study Design

This study was designed as a prospective, observational, cross-sectional, questionnaire-based study aimed at assessing the knowledge, awareness, and perception of transdermal drug delivery routes, with special emphasis on transdermal patches, among undergraduate medical and dental students. The cross-sectional design was chosen to capture the existing level of understanding and attitudes of students at a single point in time without any interventional component.

Study Setting

The study was conducted at a tertiary care teaching institute that offers undergraduate programs in Medicine (MBBS) and Dentistry (BDS). The institute provides structured teaching in pharmacology and therapeutics as part of the undergraduate curriculum, making it an appropriate setting to evaluate student's knowledge and awareness of advanced drug delivery systems.

Study Population

The study population consisted of undergraduate students enrolled in MBBS and BDS programs at the institute. A total of 254 students participated in the study, comprising 183 MBBS students and 71 BDS students. Students from all academic years, including first year through internship, were invited

to participate to ensure representation across different levels of academic exposure and clinical training.

Inclusion Criteria

- Undergraduate MBBS and BDS students from first year to internship
- Students who were present at the time of data collection
- Students who provided written informed consent to participate in the study

Exclusion Criteria

- Students who were unwilling to participate
- Questionnaires with incomplete or improperly filled responses

The Participants were subjected to a pre-structured pre-standardized questionnaire consisting of four parts, containing information about: The Demographic profile, general knowledge of drug delivery routes, knowledge and awareness of transdermal patches & perception and educational needs.

The questionnaire comprised of four sections:

Section A: Demographic Information

This section collected baseline information including age, gender, discipline of study (MBBS or BDS), year of study, and prior exposure to formal education or teaching on drug delivery systems.

Section B: General Knowledge of Drug Delivery Routes

This section assessed student's familiarity with commonly used drug delivery routes such as oral, parenteral, inhalational, and transdermal routes, along with their general awareness of transdermal drug delivery systems (TDDS).

Section C: Knowledge and Awareness of Transdermal Patches

This section focused specifically on transdermal patches and included questions related to drugs suitable for transdermal administration, advantages and true statements regarding transdermal patches, limitations of transdermal delivery, and potential clinical applications.

Section D: Perception and Educational Needs

This section evaluated students' perceptions regarding the clinical relevance of transdermal patches, their confidence in explaining patch usage to patients, perceived need for additional training, and opinions on incorporating greater emphasis on transdermal drug delivery systems in the undergraduate curriculum. Suggestions for improving awareness and learning were also explored.

Scoring System

A predefined scoring system was used to quantitatively assess participants' responses:

Knowledge and Awareness Score: Maximum of 15 points (Sections B and C)

Perception Score: Maximum of 5 points (Section D)

Total Score: Maximum of 20 points

Based on the total score, participants were categorized as follows:

16–20: Good knowledge and awareness

11–15: Moderate understanding

6–10: Basic knowledge

0–5: Poor knowledge

Data Collection Procedure

Data collection was carried out after explaining the objectives and purpose of the study to the participants. Written informed consent was obtained before the questionnaire administration. Participation was entirely voluntary, and confidentiality of study participants was maintained.

Statistical Analysis

The responses obtained were recorded, all the relevant data of the enrolled patients was included in the study. The collected data were entered into

Microsoft Excel for analysis. Data was later tabulated, analyzed and expressed in number (n) & (percentage).

RESULTS

Demographic Characteristics of Participants

A total of 254 second-year undergraduate students participated in the study, of which 183 were MBBS students (72.0%) and 71 were BDS students (28.0%). The majority of students (192, 75.6%) belonged to the 20–25 years age group. Students under 20 years were 44 (17.3%), and those above 25 years were 18 (7.1%). The gender distribution was relatively balanced, with 132 males (52.0%) and 122 females (48.0%), reflecting the general composition of the undergraduate cohort.

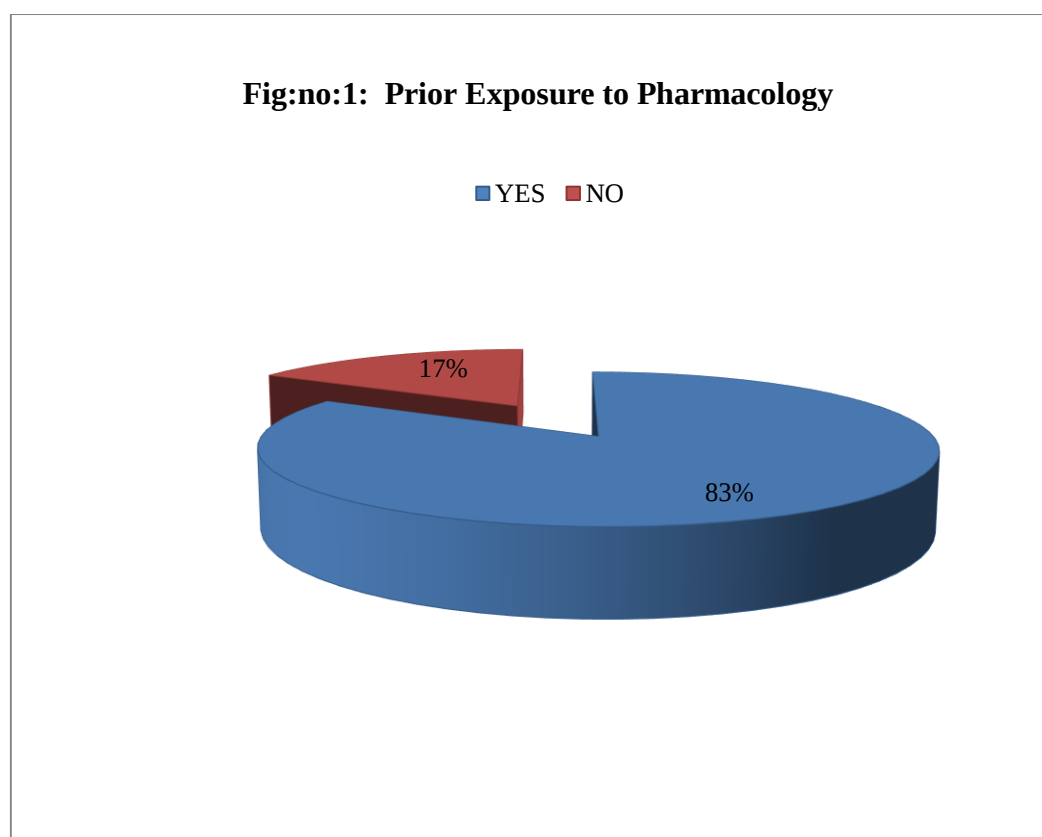


Figure 1. Regarding Prior Exposure to Pharmacology in the Study Population

A total of 212 students (83.5%) reported receiving pharmacology instruction as part of their curriculum whereas, only 98 students (38.6%) recalled specific teaching on drug delivery systems, indicating that detailed instruction on novel delivery systems like transdermal patches is limited in early pharmacology education as shown in fig no:1. Thus, the demographic data suggest that the majority of participants were within the typical age range for second-year students and had foundational

pharmacology knowledge. However, formal exposure to advanced drug delivery systems appears to be lacking, which may influence their knowledge and awareness of transdermal drug delivery.

Knowledge of Drug Delivery Routes

Most participants demonstrated strong familiarity with conventional drug delivery routes, consistent with the pharmacology curriculum as shown in Table no 1.

Table 1. Knowledge of Drug Delivery Routes Among study population

S.no	Route	Number of Students (n=254)	Percentage (%)
1	Oral	245	96.5%
2	Intravenous	230	90.6%
3	Intramuscular	215	84.6%
4	Subcutaneous	198	77.9%

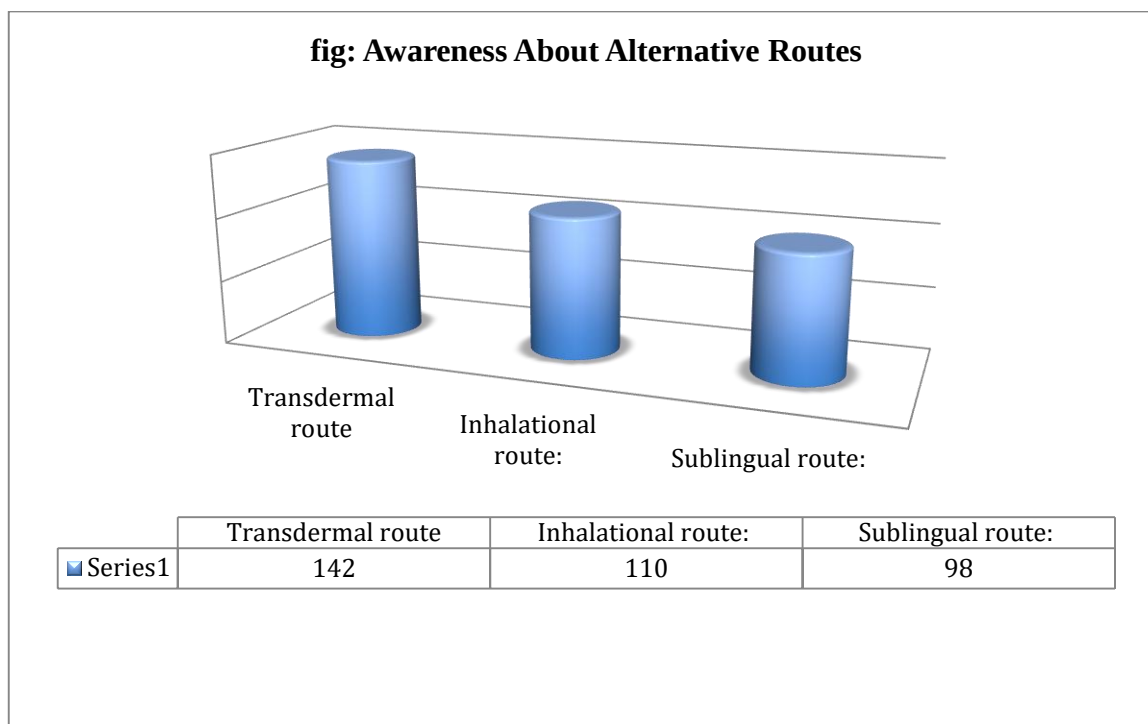


Figure 2: Awareness of Alternative Routes in the Study Population

Awareness of alternative routes was comparatively lower. 142 (55.9%) students showed awareness for Transdermal route, followed by 110 students (43.3%) for Inhalational route & 98 (38.6%) for Sublingual route. (Fig no: 2). Thus, these findings reflects that the curriculum emphasis on traditional routes and pharmacokinetics of oral and parenteral drug administration. Early-year students are typically more exposed to conventional administration methods in lectures and practicals, whereas alternative routes like transdermal delivery are introduced more conceptually, often with limited practical exposure.

Awareness of Transdermal Drug Delivery Systems (TDDS)

Out of total students, 167 students (65.7%) had heard of TDDS whereas, 124 students (48.8%) had seen or handled a transdermal patch during practical sessions or demonstrations.

It was also observed that MBBS students had higher exposure 183, (69.9%) compared to BDS students 71, (54.9%), possibly due to broader coverage of systemic pharmacotherapy in the medical curriculum as shown in **Table no: 2**.

Table 2: Comparison of TDDS exposure between MBBS & BDS students

S.no	COARSE	Total Students (N)	Percentage (%)
1	MBBS	183	69.9%
2	BDS	71	54.9%

So, Awareness of TDDS among second-year students was moderate. While students have theoretical exposure, direct clinical or practical experience with transdermal patches was limited.

This emphasizes the importance of structured demonstrations and early integration of practical examples in pharmacology teaching.

Knowledge of Transdermal Patches

Table 3. Knowledge about the Drugs Suitable for Transdermal Delivery

S.no	Drug	Correct Identification	Number (n)	Percentage (%)
1.	Nitroglycerin	Yes	192	75.6%
2.	Nicotine	Yes	182	71.7%
3.	Fentanyl	Yes	128	50.4%
4.	Hormonal patches	Yes	106	41.7%
5.	Insulin	No	72	28.3%
6.	Paracetamol	No	68	26.8%

Most of the students correctly identified widely taught examples like nitroglycerin and nicotine as the most suitable drugs to be administered for transdermal delivery. Moderate knowledge of fentanyl and hormonal patches indicates partial understanding of transdermal therapy scope was seen, as seen in **Table no: 3**. Misidentification of insulin and paracetamol reflects limited understanding of physicochemical requirements for effective transdermal absorption (e.g., small molecular size, lipophilicity, potency).

Understanding of Advantages

When asked about advantages of transdermal route, Avoidance of first-pass metabolism was selected by 180 students (70.9%) followed by, Controlled, sustained drug release by 165 students (65.0%), incorrect belief like invasive nature by 82 students, (32.3%), & suitable for all drugs by 94 students, (37.0%).

5. Knowledge of Limitations and Clinical Applications

Knowledge of:			Number (N)	Percentage (%)
1) Limitations	Skin Irritation		152	59.8%
	Limited Permeability		138	54.3%
	Misconceptions (rapid absorption/high compliance)		64	25.2%
2) Clinical Applications Correctly Identified:	INDICATIONS		NUMBER (n)	PERCENTAGE (%)
	1	Chronic pain management	145	57.1%
	2	Motion sickness	121	47.6%
	3	Hormone therapy	102	40.2%
	4	Local anesthesia in dentistry	86	33.9%
	5	Incorrect (fever management)	54	21.3%

Students have a general theoretical understanding of the benefits of transdermal patches. Misconceptions about invasiveness or universal applicability highlight the need to reinforce mechanistic and practical aspects of TDDS in the curriculum. Second-year students demonstrated moderate knowledge of limitations and appropriate clinical indications. Some misconceptions (e.g., fever management) may stem from incomplete integration of pharmacological principles with clinical relevance at this stage of learning (**Table no: 5**).

Perception and Educational Needs

The present study revealed that a majority of the participants perceived transdermal patches as clinically relevant in modern therapeutics. Out of the total respondents, 172 students (67.7%) considered transdermal patches to have significant clinical

relevance in patient care. Similarly, 168 students (66.1%) agreed that transdermal patches are particularly useful for patients who experience difficulty in swallowing oral medications, indicating a positive understanding of their practical advantages in specific patient populations.

Regarding confidence in patient counseling and practical application, only 42 students (16.5%) reported being very confident in explaining the correct use of transdermal patches, while 96 students (37.8%) stated that they were somewhat confident. This finding suggests that although students possess basic awareness regarding transdermal drug delivery systems, a considerable proportion still lack adequate confidence in their clinical communication and application skills. The study further demonstrated a substantial demand for additional educational support on transdermal patches. A total

of 218 students (85.8%) expressed the need for further training and educational sessions related to transdermal drug delivery systems. In addition, 200 students (78.7%) supported increasing the emphasis

on this topic within the medical curriculum, highlighting the perceived gap between theoretical knowledge and practical competency.

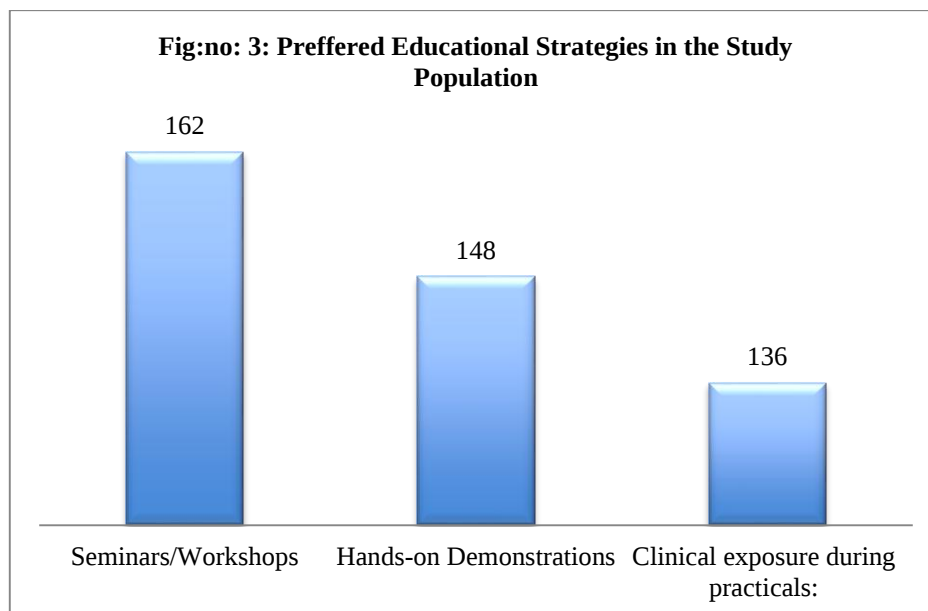


Figure 3. Preferred Educational Strategies in the Study Population

With respect to preferred learning methods, seminars and workshops emerged as the most favored educational strategy, preferred by 162 students (63.8%). Hands-on demonstrations were preferred by 148 students (58.3%), while 136 students (53.5%) favored increased clinical exposure during practical sessions as shown in Fig no:3. These findings indicate that students prefer interactive and clinically oriented teaching

approaches to improve their understanding and practical skills related to transdermal therapeutic systems. While second-year students recognize the importance of TDDS, low confidence in counseling reflects their pre-clinical status and limited patient interaction. Their suggestions for enhanced training indicate a proactive approach to learning and willingness to engage with novel pharmacological concepts.

Overall Score Distribution

Table 4. Understanding of Transdermal Drug Delivery among Study Population

S.no	Knowledge Category	Score (0-20)	Number Of Students (N= 254)	Percentage (%)
1.	Good knowledge & awareness	16–20	48	18.9%
2.	Moderate understanding	11–15	146	57.5%
3.	Basic knowledge	6–10	60	23.6%
4.	Poor knowledge	0–5	00	00%

As we can clearly see in Table no:4, the majority of second-year students demonstrated moderate understanding of transdermal drug delivery, indicating foundational knowledge but gaps in application and confidence. A smaller proportion (18.9%) achieved high proficiency, highlighting the need for targeted educational interventions early in pharmacology teaching.

So, overall second-year pharmacology students show strong familiarity with conventional drug routes, moderate awareness of TDDS, partial

knowledge of transdermal patch drugs and advantages, and low practical confidence. There is a clear demand for enhanced curricular integration, hands-on exposure, and clinical context, which would improve their knowledge, perception, and readiness to use transdermal therapy in future clinical practice

DISCUSSION

Transdermal drug delivery systems (TDDS) represent an important advancement in modern

pharmacotherapy, offering several advantages such as avoidance of first-pass metabolism, sustained drug release, improved patient compliance, and non-invasive administration. Despite their established clinical utility, the extent of knowledge, awareness, and perception of TDDS among undergraduate healthcare students remains variable. The present prospective, observational, cross-sectional study was conducted to evaluate the level of understanding and educational needs related to transdermal drug delivery routes among undergraduate medical and dental students at a tertiary care teaching institute.

Demographic Profile and Educational Exposure

In the present study, the majority of participants belonged to the 20–25-year age group (75.6%), which is consistent with the typical age distribution of undergraduate medical and dental students. The gender distribution was nearly balanced, suggesting minimal gender-related bias in knowledge or perception outcomes. MBBS students constituted a larger proportion of the study population (72%), reflecting higher enrollment in medical courses compared to dental courses in most tertiary care institutes in India.

Although a large proportion of students (83.5%) reported exposure to pharmacology teaching, only 38.6% recalled receiving specific instruction related to drug delivery systems. This finding highlights a critical gap between general pharmacology education and focused teaching on advanced drug delivery technologies. Similar observations have been reported by Gupta R et al., and Vare V et al., who noted that while pharmacology is adequately covered in undergraduate curricula, newer drug delivery systems receive limited structured attention, often restricted to theoretical mentions without clinical correlation^{[13], [17]}.

Knowledge of Drug Delivery Routes

The results demonstrated excellent familiarity with conventional drug delivery routes such as oral (96.5%), intravenous (90.6%), and intramuscular (84.6%) administration. This finding is expected, as these routes are extensively taught and routinely encountered during clinical postings. However, awareness of transdermal drug delivery was comparatively lower, with only 55.9% of students reporting familiarity. Even lower awareness was observed for inhalational and sublingual routes. Similar findings were seen in study done by Bhavasar R P & Sulaxane YD^[18].

This disparity suggests that undergraduate education remains heavily oriented toward traditional routes of administration, with limited emphasis on alternative and patient-friendly delivery systems. Similar trends have been reported in studies like Garg RA et al., conducted among medical students in India and other developing countries, emphasizing the need to diversify teaching beyond conventional routes^[19].

Awareness and Exposure to Transdermal Drug Delivery Systems

A majority of participants had heard of TDDS and had encountered transdermal patches during their academic or clinical exposure. MBBS students demonstrated relatively greater exposure compared to BDS students, likely due to higher clinical exposure in departments such as medicine, cardiology, and anesthesiology where transdermal patches are commonly prescribed.

This observation aligns with previous studies by Prausnitz MR & Langer R showing that clinical exposure significantly influences awareness and retention of knowledge related to drug delivery systems. However, mere exposure does not guarantee adequate conceptual understanding, as reflected by the misconceptions observed in subsequent sections^[20].

Knowledge of Drugs Delivered via Transdermal Patches

Nitroglycerin (75.6%) and nicotine (71.7%) were correctly identified by most participants as drugs administered via transdermal patches. These drugs are commonly cited examples in pharmacology textbooks and lectures, which likely explains the higher recognition rates. Awareness regarding fentanyl (50.4%) and hormonal patches (41.7%) was moderate, indicating partial knowledge. Importantly, a significant proportion of students incorrectly believed that insulin (28.3%) and paracetamol (26.8%) could be administered transdermally. These misconceptions highlight an incomplete understanding of the physicochemical requirements for transdermal drug delivery, such as low molecular weight, lipophilicity, and high potency. Similar misconceptions have been reported in an earlier study by Jain G & Patel R among healthcare students, underscoring the need for focused teaching on drug selection criteria for TDDS^[21].

Understanding of Advantages and Limitations

A majority of students correctly identified key advantages of transdermal patches, including avoidance of first-pass metabolism (70.9%) and sustained drug release (65%). These findings suggest that the basic theoretical benefits of TDDS are reasonably well understood. Similar observations were reported by Trishala A et al., in their study^[22]. However, misconceptions were also evident. Nearly one-third of students believed that transdermal patches are invasive (32.3%), and 37% incorrectly assumed that all drugs can be delivered transdermally. Such misunderstandings indicate superficial learning without adequate conceptual clarity.

Regarding limitations, skin irritation (59.8%) and limited permeability (54.3%) were commonly recognized, reflecting partial awareness of practical

challenges associated with TDDS. These findings are consistent with reports by Singh N et al., who emphasized skin barrier properties as a major limiting factor in transdermal drug delivery [23].

Knowledge of Clinical Applications

Chronic pain management (57.1%) and motion sickness (47.6%) were the most frequently identified clinical applications of transdermal patches. Hormone therapy and dental anesthesia were selected by fewer students, suggesting limited awareness of the expanding scope of TDDS across specialties. A study by Wong W F et al., also observed similar findings as well [24].

Notably, 21.3% of students incorrectly identified fever management as an indication for transdermal patches, further reinforcing the presence of misconceptions regarding appropriate clinical use. These findings highlight the importance of integrating case-based learning and clinical examples into undergraduate teaching.

Perception, Confidence, and Educational Nee

The perception of TDDS among students was generally positive. Approximately two-thirds of participants agreed that transdermal patches are clinically relevant (67.7%) and useful for patients with swallowing difficulties (66.1%). This reflects an appreciation of the patient-centric benefits of TDDS.

Despite this positive perception, confidence levels were low, with only 16.5% reporting that they were very confident in explaining the use of transdermal patches to patients. This gap between knowledge and confidence is clinically significant, as effective patient counseling is a core competency for future healthcare professionals.

Encouragingly, an overwhelming majority of students expressed a desire for additional training (85.8%) and supported increased curricular emphasis on transdermal drug delivery (78.7%). Preferred educational strategies included seminars, hands-on workshops, and enhanced clinical exposure, aligning with modern competency-based medical education principles [25].

Overall Knowledge and Awareness Scores

Based on the predefined scoring system, most students fell into the moderate understanding category (57.5%), followed by basic knowledge (23.6%), while only 18.9% demonstrated good knowledge and awareness. No participant fell into the poor knowledge category.

These findings suggest that while baseline awareness of TDDS exists, in-depth understanding remains inadequate. Similar score distributions have been reported in studies assessing knowledge of novel drug delivery systems among undergraduate students, reinforcing the need for structured educational interventions.

Implications for Curriculum and Practice

The findings of the present study underscore the necessity of strengthening undergraduate pharmacology curricula by incorporating focused teaching on transdermal drug delivery systems. Integrating TDDS into practical sessions, clinical case discussions, and interdisciplinary teaching can bridge the gap between theory and practice. Early exposure to advanced drug delivery systems is likely to improve prescribing competence, patient counseling skills, and rational drug use in future clinical practice.

CONCLUSION

The present prospective, observational, cross-sectional study assessed the knowledge, awareness, and perception regarding transdermal drug delivery systems (TDDS) among undergraduate medical and dental students at a tertiary care teaching institute. The findings reveal that while a majority of students demonstrated familiarity with conventional drug delivery routes, knowledge and understanding of transdermal drug delivery were only moderate.

Most participants correctly identified commonly used transdermal drugs such as nitroglycerin and nicotine and recognized key advantages like avoidance of first-pass metabolism and sustained drug release. However, misconceptions persisted regarding the suitability of transdermal patches for all drugs, their invasive nature, and inappropriate clinical indications such as fever management. These gaps reflect incomplete conceptual understanding and limited integration of TDDS into routine undergraduate teaching.

Despite these limitations, students exhibited a positive attitude toward transdermal drug delivery, acknowledging its clinical relevance and patient-centric benefits, especially for individuals with swallowing difficulties. Importantly, the majority expressed a strong desire for additional training and greater curricular emphasis on TDDS. Overall, the study highlights a clear need to strengthen undergraduate education on advanced drug delivery systems to enhance clinical competence and rational prescribing practices.

Recommendations

Based on the findings of our study, the following recommendations are proposed:

- **Curriculum Enhancement:** Transdermal drug delivery systems should be given greater emphasis within undergraduate pharmacology curricula, with dedicated teaching hours covering principles, advantages, limitations, and clinical applications.
- **Practical and Clinical Integration:** Hands-on demonstrations of transdermal patches during practical sessions and increased exposure during clinical postings can improve

understanding and confidence in patient counseling.

- **Interactive Teaching Methods:** Incorporation of case-based discussions, problem-based learning, and simulation-based teaching related to TDDS can help bridge the gap between theoretical knowledge and clinical application.
- **Faculty Development and Workshops:** Regular seminars, workshops, and guest lectures by clinicians and pharmaceutical experts can enhance both student and faculty awareness of evolving drug delivery technologies.
- **Assessment Reforms:** Including questions on transdermal drug delivery systems in formative and summative assessments may encourage students to develop a deeper understanding of this topic.

Future Scope

The present study opens avenues for further research and educational interventions in the field of drug delivery systems:

- **Interventional Studies:** Future studies can evaluate the impact of structured educational interventions, such as workshops or e-learning modules, on students' knowledge and perception of TDDS.
- **Multicentric Studies:** Conducting similar studies across multiple medical and dental institutions would enhance the generalizability of the findings.
- **Longitudinal Assessment:** Long-term follow-up studies assessing knowledge retention and clinical application of TDDS after curricular modifications would provide valuable insights.
- **Comparative Studies:** Comparative assessments between different years of study, institutions, or healthcare disciplines (nursing, pharmacy) could help identify specific educational gaps.
- **Advanced Scoring Models:** Future research may employ more refined scoring systems, incorporating objective structured clinical examinations (OSCEs) to assess practical competence in transdermal drug delivery and patient counseling.

Limitations of the Study

Despite its strengths, the present study has few limitations as well:

- **Single-Center Design:** The study was conducted at a single tertiary care teaching institute, which may limit the generalizability of the findings to other settings.
- **Cross-Sectional Nature:** As a cross-sectional study, it provides a snapshot of knowledge and perception at a single point in time and cannot assess changes over time or the impact of educational interventions.

- **Self-Reported Data:** Responses were based on self-administered questionnaires and may be subject to response bias or social desirability bias.
- **Limited Clinical Correlation:** Although awareness and perception were assessed, actual prescribing behavior and real-world application of transdermal patches were not evaluated.
- **Exclusion of Other Healthcare Disciplines:** The study focused only on medical and dental students; inclusion of nursing and pharmacy students could have provided a more comprehensive understanding of TDDS awareness among healthcare trainees.

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Declarations

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