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Assessing Knowledge, Adherence, and Barriers to Cross-Infection Control Measures Among Dental Students: A Mixed-Methods Study

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ABSTRACT

Objective: Cross-infection control is critical in dental settings due to routine exposure to blood, aerosols, and sharp instruments. Despite curricular emphasis, adherence to infection control protocols among dental students in low-resource settings remains inconsistent. This study aimed to assess knowledge, compliance, and barriers to infection control among Pakistani dental students using a mixed-methods approach.
Methods: A convergent mixed-methods study was conducted among 91 third- and final-year clinical dental students at HITEC Institute of Medical Sciences, Taxila. Quantitative data were collected through a validated questionnaire assessing knowledge (10 items), adherence (10 items), and barriers (8 items). Open-ended questions explored perceived challenges. Quantitative data were analyzed using SPSS, while thematic analysis was applied to qualitative responses. Triangulation and inter-coder reliability ensured analytical rigor.
Results: The mean knowledge score was 7.13 ± 1.45, with 73.6% of students demonstrating good-to-excellent knowledge. High adherence was reported for glove use (97.8%), hand hygiene (97.8%), mask use (95.6%), and sharps disposal (97.8%). However, gaps included incomplete hepatitis B vaccination (18.7%), glove misuse (22%), and low adherence to eye protection (73.6%). Final-year students demonstrated significantly higher adherence compared to third-year students ($p = 0.048$). Thematic analysis revealed six key barriers: resource scarcity, time constraints, PPE discomfort, training gaps, supervision lapses, and systemic deficiencies.
Conclusion: While dental students exhibited strong knowledge and reported adherence, systemic and behavioral obstacles undermine consistent compliance. Institutions must invest in structured training, consistent supervision, and adequate resources to ensure the sustainability of infection control practices.

Keywords: Cross-infection; Dental students; Infection control; Personal protective equipment; Surveys and questionnaires

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Introduction

Clinical dentistry involves blood, saliva, and aerosolized pathogens, making infection prevention essential. Dental students are especially vulnerable because they perform clinical procedures under training and may not know how to follow protocols. Healthcare-associated infections (HAIs) affect millions of patients and put healthcare workers at risk, according to the World

Health Organization (WHO). High-speed handpieces, ultrasonic scalers, and sharp instruments increase cross-infection risks in dentistry. [1, 2] On a global scale, infection prevention and control are essential for both patient safety in clinical training settings and the safety of healthcare personnel.[3] According to the Centers for Disease Control and Prevention (CDC), following universal precautions significantly lowers the risk of HIV, hepatitis B, hepatitis C, and other infectious agent transmission. However, there are significant regional differences in dental students' adherence, especially in low- and middle-income nations, where common barriers include a lack of infrastructure, inadequate monitoring, and limited resources.[4]

In addition to structural difficulties, behavioral and perceptual elements are also important. According to studies, dental students may undervalue their vulnerability to infection, find wearing protective gear uncomfortable, or follow the habits of peers and supervisors who may not always follow through on their own. The need for educational strategies that address both behavioral reinforcement and cognitive knowledge is highlighted by these psychosocial factors.[5] Therefore, it is just as crucial to establish an institutional culture that places a high priority on infection control as it is to teach protocols.

Previous studies show that dental students have moderate-to-high theoretical knowledge of infection control, but adherence is variable.[2] It was found that Saudi dental students had adequate knowledge but poor PPE use. Similar patterns were seen in India and Pakistan, indicating a knowledge-practice gap.[6] Despite increased awareness, there are still gaps in dental students' understanding and application of infection control across the globe.[7] Research from South Asia, the Middle East, and Europe consistently shows that although students are aware of the risks of cross-infection, systemic obstacles like a lack of personal protective equipment, poor supervision, and weak institutional enforcement frequently hinder compliance. [8]

Additionally, adherence patterns are significantly shaped by behavioral and perceptual factors, such as perceived invulnerability, discomfort related to personal protective equipment, and peer influence.[2] These difficulties underline the necessity of context-specific research that combines qualitative investigation of barriers and lived experiences with quantitative evaluation of knowledge. In low- and middle-income nations, where cultural beliefs and infrastructure constraints may increase the likelihood of infection control failures, such a mixed-methods approach is especially beneficial.

In Pakistan, where hepatitis B, C, and tuberculosis are common, infection control is crucial. Despite curriculum emphasis, anecdotal and research evidence show students skip precautions due to resource constraints, discomfort, or perceived low risk.[9] Most previous studies used quantitative surveys, which may not fully explain non-adherence.

Using mixed methods, this study fills this gap. It seeks to understand Pakistani dental students' infection control behavior through quantitative knowledge and adherence assessments and qualitative barriers exploration.

Materials and Methods

Study Design and Setting

This study employed a convergent mixed-methods design to explore adherence to infection control protocols among undergraduate dental students. This approach was chosen to integrate numerical trends with contextual explanations, providing a comprehensive understanding of behavior, barriers, and perceptions. Data were collected at HITEC Institute of Medical Sciences (HITEC-IMS), Dental College, Taxila, a tertiary academic institution in Pakistan serving a high patient load across multiple dental specialties. The institution follows national infection control protocols and provides access to basic personal protective equipment (PPE), though constraints in supply and compliance have been observed.

Sample Size and Power Justification

Sample size was initially calculated using Cochran's formula for finite populations, assuming a 95% confidence level, 5% margin of error, and maximum variability ($p = 0.5$), yielding a required sample size of 169 from an estimated eligible pool of 300 students. Due to institutional and logistical constraints, 91 students completed the survey, resulting in a 100% usable response rate. While this reduced sample may lower statistical power, high participation and response completeness enabled

meaningful analysis. A post-hoc power analysis, assuming an effect size of 0.3 and alpha = 0.05, indicated power above 0.80 for major outcomes.

Participant Selection

Participants included third- and final-year undergraduate dental students actively engaged in clinical training. Students in preclinical years, on academic leave, or those who had received recent targeted infection control training outside the curriculum were excluded. Students were approached in person during scheduled academic sessions and provided with a written consent form outlining the study's aims, voluntary nature, and confidentiality assurances.

Questionnaire Instrument

A structured questionnaire was developed by adapting items from validated instruments. Content validity was confirmed through expert review by three infection control specialists. The instrument consisted of four sections:

1. **Knowledge**: 10 items on sterilization, standard precautions, post-exposure protocols, and PPE use (true/false and MCQs).

2. **Adherence**: 10 items using a 3-point Likert scale (Always = 3, Sometimes = 2, Never = 1).

3. **Barriers**: 8 items assessing resource availability, time pressure, and supervision using a 5-point Likert scale.

4. **Open-Ended Questions**: Three qualitative prompts exploring barriers, improvements, and real-life challenges in infection control.

Pilot testing was conducted with 10 students not included in the final sample. Minor revisions improved clarity and contextual relevance. Internal consistency was high, with Cronbach's alpha = 0.78 for knowledge and 0.83 for adherence scales. Open-ended responses were completed anonymously on paper at the end of the structured questionnaire.

Qualitative Data Collection and Analysis

Open-ended responses were analyzed using Braun and Clarke's six-phase thematic analysis framework. Two independent coders conducted open coding, followed by axial coding to identify patterns and develop themes. Thematic saturation was achieved by the 75th response. Inter-coder reliability was assessed using Cohen's kappa (κ = 0.82), indicating substantial agreement. Coding discrepancies were resolved through discussion with a third researcher.

Data Analysis

Quantitative data were analyzed using SPSS v26. Descriptive statistics (frequencies, percentages, means ± SD) summarized demographic and response variables. Chi-square and Fisher's exact tests were used to assess associations between categorical variables. Pearson correlation was used to examine associations between knowledge and adherence scores. Assumptions of normality and variance homogeneity were tested before applying parametric tests. Qualitative and quantitative findings were integrated during the interpretation phase using a contiguous approach, allowing triangulation of themes and statistical outcomes.

Ethical Considerations and Reporting Standards

Ethical approval was obtained from the Institutional Review Board of HITEC-IMS Dental College, Taxila (Ref: Dental/HITEC/IRB/108). All participants provided written informed consent. Participation was voluntary, and anonymity and confidentiality were strictly maintained. The study adhered to international reporting guidelines, including STROBE (for quantitative components), COREQ (for qualitative reporting), and GRAMMS (for mixed-methods studies).

Methodological Limitations

This study's single-institution scope may limit the generalizability of findings to other contexts. Additionally, reliance on self-reported adherence data introduces potential for social desirability bias. However, triangulation with qualitative data, high internal consistency of instruments, and the use of validated tools mitigate some of these concerns.

Results

Quantitative Findings

The final sample comprised 91 clinical dental students, with a 100% response rate. The

overall mean knowledge score was 7.13 ± 1.45 (out of 10), with 73.6% (n = 67) demonstrating good to excellent knowledge and only 2.2% (n = 2) falling into the poor knowledge category. Regarding adherence, high self-reported compliance rates were observed for core practices: glove use (97.8%, n = 89), hand hygiene (97.8%, n = 89), mask use (95.6%, n = 87), gown use (93.4%, n = 85), and sharps disposal (97.8%, n = 89).

Despite these encouraging figures, notable gaps emerged. Glove misuse was reported by 22% (n = 20) of students who admitted to walking around the clinic without changing gloves. Incomplete hepatitis B vaccination was noted in 18.7% (n = 17) of respondents. Eye protection adherence was particularly low, with only 73.6% (n = 67) reporting routine use, leaving 26.4% (n = 24) non-compliant (Table 1).

Table 1: Quantitative results showing knowledge, adherence, and gaps in infection control practices among dental students.

Domain	Key Findings	Notable Gaps
Knowledge	Mean score 7.13/10; 73.6% good-to-excellent	2.2% poor knowledge
Glove Use	97.8% always/change gloves	22% walked around with gloves
Hand Hygiene	97.8% compliance	Minimal gaps
Masks	95.6% new mask per session	Few reuse masks
Eye Protection	73.6% adherence	26.4% non-use
Gowns	93.4% compliance	Minority non-compliance
Vaccination	97.8% vaccinated	18.7% incomplete doses
Sharps Disposal	97.8% compliance	Excellent adherence

Comparative Analyses

Subgroup analyses revealed no statistically significant differences in knowledge or adherence by gender ($p > 0.05$). However, comparison by academic year showed that final-year students exhibited significantly higher adherence to personal protective equipment (PPE) and hand hygiene protocols (mean adherence score: 2.91 ± 0.39 vs. 2.72 ± 0.46, $t = 2.01$, $p = 0.048$), suggesting a positive correlation between clinical exposure and compliance behavior.

Qualitative Findings

Thematic saturation was achieved after coding all open-ended responses from the 91 participants. Three researchers independently coded the data, and inter-coder reliability was verified through consensus discussion. Triangulation was accomplished using cross-validation between survey comments, field observations, and open responses.

Six major themes were identified as barriers to infection control adherence (Table 2):

1. **Resource Scarcity** – A majority cited frequent shortages of PPE and disinfectants:
   "Sometimes masks and gloves are not available in every clinic, which makes it impossible to follow protocols."

2. **Time Constraints** – High patient loads and multitasking were repeatedly cited:
   "During crowded clinics, it becomes hard to wash hands properly after each patient."

3. **PPE Discomfort** – Physical discomfort, especially in summer, limited consistent PPE use:
   "Wearing protective eyewear in hot weather makes it very difficult to work."

4. **Training Gaps** – Respondents highlighted insufficient practical training and refreshers:
   "We are taught in theory but need more practical demonstrations."

5. **Supervision Issues** – Weak enforcement and peer behavior influenced poor compliance:
   "Some supervisors don't insist on strict protocol use, so students also become careless."

6. **Systemic Constraints** – Broader institutional challenges included waste segregation and infrastructure gaps:
   "Disposal bins sometimes overflow or are

missing."

Table 2: Themes and illustrative quotes from qualitative analysis depicting perceived barriers and challenges to infection control adherence.

Theme	Sub-Themes	Representative Quotes
Resource Scarcity	PPE shortages, disinfectant shortages	"Masks and gloves are not always available."
Time Constraints	Patient flow, workload fatigue	"Busy clinics make it hard to follow all steps."
PPE Discomfort	Heat, sweating, eyewear fogging	"Wearing protective eyewear is difficult in summer."
Training Gaps	Inexperience, forgetfulness	"We need more hands-on training sessions."
Supervision	Weak enforcement, peer influence	"Some supervisors don't insist on protocol use."
Systemic Issues	Poor waste systems, infrastructure gaps	"Disposal bins sometimes overflow or are missing."

Integration of Quantitative and Qualitative Data

The mixed-methods design revealed key disconnects between reported adherence and observed or described barriers. While 97.8% reported glove use, the 22% glove misuse rate and qualitative comments indicate superficial adherence driven by environmental constraints rather than behavioral conviction. Similarly, the low eye protection rate (73.6%) aligned with discomfort-related non-compliance from open responses. These integrated findings underscore that knowledge alone does not guarantee adherence, particularly in the face of structural and supervisory gaps (Figure 1).

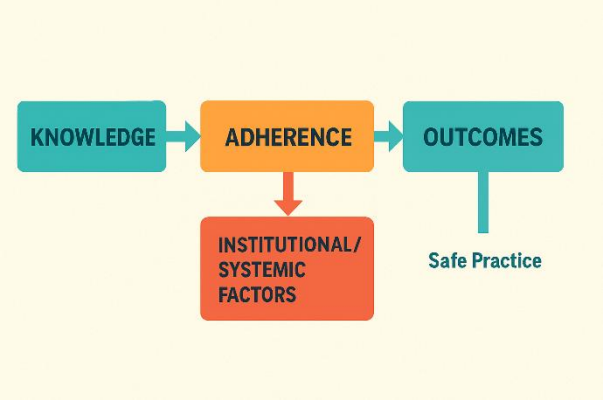

Figure 1: Conceptual framework illustrating the relationship between knowledge, adherence, and perceived barriers to infection control among dental students.

Limitations in Self-Reported Data

The use of self-report questionnaires may introduce social desirability bias, potentially inflating adherence rates. No independent observational audit was conducted to validate responses. Additionally, missing data were minimal (<2%) and did not materially affect the analysis.

Discussion

This mixed-methods study reveals a paradox: systemic and behavioral barriers impede complete compliance, even though dental students show sufficient knowledge and generally strong adherence. The findings in Saudi Arabia and India, where knowledge was adequate but practices varied, are in line with knowledge scores (mean=7.13/10).[7,8] Eye protection is still the most neglected PPE item, according to international reports, which is reflected in the relatively low adherence rate of 73.6%. [3] Similarly, the 18.7% incomplete hepatitis B vaccination rate is similar to trends seen in Nigeria and India, where barriers were related to availability, cost, and awareness.[10]

This depiction is enhanced by qualitative findings, which highlight significant obstacles such as a lack of resources, discomfort, time constraints, and insufficient supervision.[11] These concur with those who highlighted supervision and institutional support as crucial factors influencing adherence.[12] The frequent occurrence of needle stick injuries emphasizes the critical need for uniform post-exposure procedures, which are not always followed in dental schools around the world.[5] The

results of this study are in line with global research that has repeatedly shown a discrepancy between infection control knowledge and adherence. Studies conducted in the US and the UK, for instance, have shown that practical compliance frequently fails because of time constraints and perceived inconvenience, even in cases where dental professionals and students are well-informed. [13] Conversely, studies conducted in Scandinavia have revealed greater adherence, which is probably due to improved institutional support and resource accessibility. [3] This implies that adherence is context-dependent and influenced by systemic infrastructure and cultural emphasis on safety, whereas knowledge is comparatively universal.[14] The results are consistent with behavioral models like the Health Belief Model, which holds that institutional reinforcement and perceived susceptibility are important factors in determining preventive behavior.[7] Although curricula emphasize universal precautions, systemic flaws such as inadequate enforcement, a lack of resources, and infrastructure constraints make it difficult to put these precautions into practice.

The importance of supervision and training is a recurrent theme in both the quantitative and qualitative results. Students stressed the need for ongoing reinforcement and real-world examples, even though theoretical instruction is incorporated into the curriculum. Similar findings were noted in India, where lapses were caused in part by a lack of practical workshops.[8] This gap might be filled by incorporating frequent refresher courses and simulation-based infection control training.[15] Furthermore, faculty enforcement is crucial because students are more likely to follow rules when their supervisors set an example of rigorous adherence. Accountability may be further improved by incorporating infection control competencies into clinical evaluation. Several suggestions can be made in light of the study's findings: Frequent refresher training sessions, simulation-based instruction, and infection control curriculum integration.[13]Assure continuous PPE supplies, state-of-the-art sterilization facilities, and enhanced waste disposal. Increased oversight, frequent audits, sanctions for non-adherence, and peer accountability frameworks. Hepatitis B vaccination completion requirements, uniform post-exposure care, and transparent reporting procedures.[16] Establish a safety-focused atmosphere where faculty and students are held accountable and rewarded for compliance.[9] Adherence among Pakistani dentistry students (overall >90%) is comparable to findings from Saudi Arabia[1] and greater than reports from India.[3] However, because of more resources and stronger institutional enforcement, Western research indicates even higher compliance.[6,8] This disparity underscores the necessity of institutional investment in infection control infrastructure in underdeveloped contexts by highlighting the influence of contextual and infrastructure factors on adherence behaviors.

This study also emphasizes how crucial it is to look at infection control from a perspective that goes beyond personal behavior and knowledge. The qualitative themes demonstrated how supply availability, peer culture, and institutional policies all have a direct impact on compliance. Frameworks for comprehending these dynamics are offered by the Health Belief Model and the Theory of Planned Behavior, which highlight perceived vulnerability, institutional norms, and enabling circumstances as factors that influence preventive measures.[17] Therefore, to address systemic barriers, guarantee sufficient resources, and promote a culture of safety, interventions must go beyond knowledge improvement. Recent WHO guidelines have promoted this strategy, emphasizing institutional accountability just as much as individual compliance.[18]

The findings of this study can be meaningfully interpreted through behavior change theories such as the Health Belief Model (HBM) and the Theory of Planned Behavior (TPB), which explain how perceived barriers (e.g., resource scarcity, time constraints), perceived susceptibility (fear of infection), and subjective norms (peer behavior, supervision) influence infection control adherence. While high reported adherence scores suggest good knowledge, qualitative findings reveal a divergence, highlighting lapses due to PPE discomfort, inadequate training, and inconsistent oversight, underscoring the importance of context-specific barriers often masked in surveys. This convergence of methods validates the mixed-methods approach and emphasizes the need for curricular models that integrate both theoretical instruction and hands-on reinforcement. Compared to intervention-based studies globally, such as those in Saudi Arabia and India, where structured infection control workshops significantly improved compliance, our results highlight the absence of regular, monitored reinforcement strategies within the local institutional framework. Moreover,

current dental curricula and institutional policies in Pakistan appear misaligned with WHO and CDC guidelines, particularly regarding PPE use and waste management protocols, which were frequently reported as deficient. Additionally, equity considerations such as gendered access to resources or supervision, and psychological stressors like fear of exposure or moral fatigue, warrant deeper exploration, especially in post-pandemic academic environments. Future research should include longitudinal studies to assess behavior change over time, implementation trials of low-cost infection control interventions, and multicenter audits to validate self-reported practices. Embedding behavioral science into infection control education, paired with systemic reforms, can offer a sustainable path forward.

Conclusion

Despite high self-reported adherence and knowledge levels among Pakistani dental students, this mixed-methods study reveals persistent systemic and behavioral barriers, most notably resource constraints, inadequate supervision, and discomfort with PPE, that undermine consistent infection control practices. The disconnect between theoretical understanding and clinical implementation highlights the need for a multifaceted approach integrating structured training, institutional accountability, and behavioral reinforcement. Embedding simulation-based modules, regular audits, and stronger policy alignment with global standards such as those from the WHO and CDC can address these gaps. Moving beyond awareness to sustained behavior change requires institutional investment, longitudinal evaluation, and equity-focused policies to ensure safe clinical environments for both patients and providers.

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Author Contribution

F.S. conceptualized and designed the study, supervised data collection, interpreted findings, and led the drafting of the manuscript. M.K. was responsible for quantitative data collection, statistical analysis, and preparation of the results section. M. conducted the literature review and contributed to the writing of the introduction and discussion sections. S.S. managed data entry, performed qualitative analysis, and prepared tables. M.F. contributed to formatting, proofreading, and reference management. All authors reviewed and approved the final version of the manuscript.

Data Availability Statement

All relevant data are within the manuscript. Additional data supporting this study are available from the corresponding author upon reasonable request.

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Conflict of Interest

The author has no conflicts of interest to disclose.

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