The Review of DIABETIC STUDIES

Reprint from The Review of DIABETIC STUDIES

The Review Of
DIABETIC
STUDIES
OPEN ACCESS

Strengthening Institutional Infection Prevention And Control (IPC): A Cross-Specialty Analysis Of Epidemiological Compliance Among Nursing, Dentistry, And Operation Technician Teams

Aedah Ahmad A. Alhaithy[1], Sanad Mobarak Aqeel Alharbi[2], Buthaynah Mahdali Aljehani[3], Reema Khalid Abdullah Aldulayqan[4], Rusha Abdulrahman Abdullah Alfriah[5], Abrar Hamad Ali Alnasser[6], Salma Mohammed Buhays Alkinani[7], Nawal Abdullah Aldfire[8], Majed Saleh Abdullah Al-Anzi[9], Ahmed Nasser Mohammed Khayrat[10], Abdulrahman Ali Mohammed Hawaz[11], Musleh Hussein Al Harithi[12]

[1]*Dental Technology Technician, Maysan Primary Health Care Center, Taif Health Cluster, Maysan, Saudi Arabia*
[2]*Nursing Technician, Uyun Aljawa General Hospital, Qassim Health Cluster, Qassim, Saudi Arabia*
[3]*Operations Room Technician, Al-Barak General Hospital, Saudi Arabia.*
[4]*Dentist, North of Riyadh Dental Center, Riyadh Second Health Cluster, Riyadh, Saudi Arabia*
[5]*Dental Hygienist, North of Riyadh Dental Center, Riyadh Second Health Cluster, Riyadh, Saudi Arabia*
[6]*Dental Hygienist, North of Riyadh Dental Center, Riyadh Second Health Cluster, Riyadh, Saudi Arabia*
[7]*Dental Hygienist, School Health Unit, Riyadh Second Health Cluster, Riyadh, Saudi Arabia*
[8]*Nurse, Al-Janadriyah West Center, Riyadh Second Health Cluster, Riyadh, Saudi Arabia*
[9]*Nursing Technician, Al-Ashash Health Center, Madinah Health Cluster, Khaybar, Saudi Arabia*
[10]*Epidemiologist, Musliyah Primary Health Care Center, Jazan Health Cluster, Jazan, Saudi Arabia*
[11]*Epidemiologist, Bish Al Shamali Primary Health Care Center, Jazan Health Cluster, Jazan, Saudi Arabia*
[12]*Epidemiology Technician, Al-Sur Primary Health Care Center, Taif Health Cluster, Maysan, Saudi Arabia*

Abstract

Background
Healthcare-associated infections (HAIs) represent a pervasive and escalating challenge to global health security, affecting between 3.6% and 8.0% of hospitalized patients worldwide. While the etiology of HAIs is multifactorial, the intersection of human behavior, institutional policy, and environmental infrastructure remains the primary determinant of transmission. Historically, infection prevention and control (IPC) surveillance has predominantly focused on nursing and medical staff, leaving the compliance behaviors of allied technical teams—specifically dentistry personnel and operation technicians (surgical technologists and sterile processing staff)—under-represented in the epidemiological literature. This gap is critical, as these groups manage high-risk vectors including aerosolized pathogens and invasive surgical instrumentation.

Objective
This systematic review aims to synthesize epidemiological data regarding IPC compliance across three distinct healthcare cadres: Nursing, Dentistry, and Operation Technician teams. The primary objectives are to: (1) compare quantitative compliance rates across these specialties; (2) identify specialty-specific failure modes, distinguishing between behavioral, cognitive, and systemic barriers; and (3) evaluate the efficacy of the World Health Organization (WHO) Multimodal Improvement Strategy versus standard educational interventions in these diverse operational contexts.

Methods
A comprehensive systematic review was conducted adhering to the PRISMA 2020 guidelines. Data sources included PubMed, EMBASE, Cochrane Library, and WHO/CDC technical reports published between 2000 and 2024. The review included randomized controlled trials, observational cohort studies, and cross-sectional surveys. Quality assessment was rigorous, utilizing the Newcastle-Ottawa Scale (NOS) for observational studies and the Cochrane Risk of Bias 2.0 (RoB 2) tool for interventional studies. Data synthesis focused on extracting compliance percentages, odds ratios for adherence, and qualitative themes related to psychosocial and environmental barriers.

Results

The analysis of 124 distinct data sources reveals significant variance in compliance drivers and failure mechanisms. Nursing compliance with hand hygiene varies widely (45-65%) and is strongly negatively correlated with burnout and "effort-reward imbalance." In contrast, dental teams demonstrate high theoretical knowledge (93% conceptual accuracy) but suffer from "process-driven non-compliance," particularly regarding environmental disinfection and instrument turnover times. Operation technicians exhibit a distinct risk profile: while surgical technologists in the operating room maintain high vigilance for sterile field breaches, sterile processing technicians in decontamination units face a "visualization crisis," with 88% of instrument defects attributed to visual inspection failures under high production pressure. The cumulative risk of error in sterile processing was quantified at 4.8 defects per instrument set.

Conclusion

Institutional IPC is not a monolithic challenge solvable by generic education. Compliance is highly role-specific: nursing requires psychosocial support to combat fatigue; dentistry requires process engineering to manage turnover pressure; and operation technicians require advanced visualization technology to overcome human cognitive limitations. The WHO Multimodal Strategy is superior to single-mode interventions but must be adapted to address the specific "epidemiology of work" within each specialty. Strengthening IPC requires a shift from blaming individuals to engineering resilient systems that account for the unique stressors of each healthcare domain.

---

1. Introduction

1.1 The Global Burden and the Imperative for IPC

The modern healthcare environment is a paradox of advanced therapeutic capability and persistent biological risk. Healthcare-associated infections (HAIs) constitute one of the most significant burdens on global health systems, representing a failure of patient safety that transcends economic and geographic boundaries. Recent comprehensive systematic reviews and meta-analyses indicate that the pooled global point prevalence of HAIs is approximately 3.6% in long-term care facilities, with acute care settings reporting rates as high as 7% in high-income countries and 15% in low- and middle-income countries (LMICs) [1]. The trajectory of this burden is alarming; data suggests the rate of HAIs is increasing by approximately 0.06% annually, a trend exacerbated by the proliferation of multidrug-resistant organisms (MDROs) and the increasing complexity of invasive medical procedures [2].

The economic and human cost of these infections is staggering. On average, one in every ten affected patients will die from their HAI, and in adult intensive care units (ICUs), almost half of all cases of sepsis with organ dysfunction are healthcare-associated. Beyond mortality, the financial strain on healthcare systems is immense, driven by prolonged hospital stays, expensive antimicrobial regimens, and the need for isolation protocols. The World Health Organization (WHO) posits that effective Infection Prevention and Control (IPC) measures—specifically the rigorous application of hand hygiene, environmental cleaning, and sterilization protocols—can prevent up to 70% of these infections [3]. However, the translation of these theoretical protocols into consistent clinical practice remains one of the most intractable problems in medical epidemiology.

1.2 The "Siloed" Nature of Compliance Research

For decades, the lens of IPC research has been narrowly focused on the "bedside" interaction, primarily scrutinizing the behaviors of physicians and nurses. This focus is logical, given their high frequency of patient contact. However, contemporary healthcare delivery is a complex, multidisciplinary ecosystem involving intricate supply chains, technical support services, and specialized ambulatory settings. This review posits that the traditional focus has created a "siloed" understanding of compliance, where the behaviors of critical allied health professionals—specifically dentistry teams and operation technicians—are under-researched and poorly understood.

This gap is dangerous. A breach in the Sterile Processing Department (SPD), where technicians clean and sterilize surgical instruments, does not affect just one patient; it affects every patient operated on with that instrument set until the error is detected. Similarly, the dental operatory, with its generation of aerosolized pathogens and high patient turnover, represents a unique vector for respiratory transmission that differs fundamentally from the inpatient ward. By restricting IPC analysis to nursing, epidemiology misses the "upstream" and "parallel" risks introduced by these technical specialties.

1.3 Defining the Cohorts

To address this gap, this report conducts a comparative analysis of three distinct healthcare cadres, each representing a different "archetype" of IPC compliance:

1. **Nursing Teams**: Representing the "Clinical/Behavioral" archetype. Nurses manage high-frequency, low-complexity IPC decisions (e.g., "wash hands now"). Their compliance is heavily influenced by workload, patient acuity, and safety culture. They are the frontline defenders against cross-transmission in wards and ICUs.
2. **Dentistry Teams**: Representing the "Ambulatory/Procedural" archetype. This group includes Dentists, Dental Hygienists, and Dental Assistants. They operate in a high-turnover environment where the primary risks are bloodborne pathogens and aerosolized saliva. Their IPC challenges are driven by the tension between "chair time" economics and the necessary dwell times of disinfectants.
3. **Operation Technician Teams**: Representing the "Industrial/Technical" archetype. This cohort is bifurcated into:
    - **Surgical Technologists (CSTs)**: Working within the sterile field of the Operating Room (OR), responsible for maintaining the integrity of the aseptic environment during surgery.
    - **Sterile Processing Technicians (SPTs)**: Working in the Central Sterile Services Department (CSSD/SPD), responsible for the decontamination, inspection, assembly, and sterilization of medical devices. Their work is industrial in nature, relying on standardized processes and visual inspection rather than patient interaction.

1.4 Theoretical Frameworks: From Education to Systems Engineering

The analysis is grounded in two primary theoretical frameworks. First, the WHO Multimodal Improvement Strategy, which argues that behavior change requires five integrated elements: system change, training, monitoring, reminders, and safety culture [4]. This framework moves beyond the simplistic notion that "training equals compliance." Second, the Systems Engineering Initiative for Patient Safety (SEIPS) model, which views non-compliance not as a moral failure but as a result of poorly designed work systems (e.g., bad lighting, ergonomic strain, cognitive overload) [5].

By applying these frameworks across the three specialties, this report seeks to move beyond generic recommendations. It aims to dissect the mechanism of non-compliance. Is a nurse's failure to wash hands driven by the same factors as a sterile processing technician's failure to clean a rongeur? The hypothesis is that while the goal (safety) is the same, the barriers are radically different. Understanding these distinctions is vital for designing the targeted, role-specific interventions necessary to strengthen institutional IPC globally.

2. Literature Review

2.1 The Epidemiology of Nursing Compliance: Fatigue and the "Five Moments"

Nursing staff constitute the largest segment of the healthcare workforce and are the primary subjects of IPC surveillance. The literature establishes that while nursing compliance generally exceeds that of physicians, it remains suboptimal and highly variable. The "Five Moments for Hand Hygiene" (before patient contact, before aseptic task, after body fluid exposure risk, after patient contact, after contact with patient surroundings) serves as the global standard for measurement [6].

However, adherence is not uniform across these moments. A consistent finding in the literature is the "self-protection bias," where compliance is significantly higher after patient contact (protecting oneself) than before patient contact (protecting the patient). For example, observational data often shows post-contact compliance rates of 70-80%, while pre-contact compliance lags at 30-40% [7]. This suggests that inherent survival instincts drive behavior more powerfully than altruistic protocols unless specific interventions are applied.

The literature increasingly identifies "burnout" as a critical determinant of nursing IPC behavior. A study of 333 nurses in Ecuador found that "effort-reward imbalance"—the psychosocial state where high workload is met with low recognition or pay—was a unique predictor of burnout, which in turn negatively predicted IPC adherence [8]. This "Infection Control Fatigue" is a documented phenomenon, particularly in the post-COVID-19 era, where constant vigilance has depleted the cognitive reserves of staff [9]. In this context, non-compliance is often not a choice but a symptom of cognitive exhaustion.

Systemic interventions that address staffing ratios and mental health support have been shown to be as critical to IPC as the availability of soap and water [8].

2.2 Dentistry: Aerosols, Turnover, and the Knowledge-Practice Gap

Dentistry presents a unique epidemiological challenge due to the routine generation of aerosols containing blood, saliva, and plaque. Unlike the hospital ward, where the patient is static, the dental clinic is a high-turnover environment where the "room" must be reset completely between patients every 30-60 minutes.

The literature reveals a distinct "Knowledge-Practice Gap" in dentistry. Surveys consistently show high levels of theoretical knowledge; for instance, 93.55% of dental staff at a major university correctly identified IPC goals [10]. However, the application of this knowledge is selective. While barrier protection (gloves, masks) is universally adopted due to perceived personal risk, environmental disinfection often lags. Studies utilizing the "Audit-Feedback Instrument" (AFI) have found that "Administrative Controls" and "Surface Contamination Management" frequently score the lowest among IPC domains [11].

A critical driver of this non-compliance is the economic pressure of "turnover time." Effective surface disinfectants typically require a "dwell time" (e.g., 3 to 10 minutes) to remain wet on a surface to achieve tuberculocidal activity. In busy clinics, the pressure to seat the next patient often leads to surfaces being dried prematurely, rendering the disinfection process ineffective. Furthermore, while dentists often lead the clinical team, literature suggests that dental assistants—who perform much of the cleaning—may have lower compliance with specific protocols due to gaps in foundational microbiology education compared to the dentists they support [12].

2.3 The "Invisible" Work of Operation Technicians

The literature surrounding Operation Technicians is bifurcated into the "front stage" work of Surgical Technologists (STs) in the OR and the "back stage" work of Sterile Processing Technicians (SPTs) in the CSSD.

2.3.1 Surgical Technologists and the Sterile Field

Surgical Technologists are the guardians of the sterile field. Their compliance is measured by their adherence to aseptic technique and their willingness to "speak up" when a breach occurs. Observational studies indicate that breaches are surprisingly common; one survey noted that 17% of perioperative staff had witnessed a breach of the sterile field in the recent past, such as non-scrubbed personnel reaching over sterile items or hands dropping below waist level [13].

The literature highlights the role of certification in mitigating these risks. Studies comparing outcomes between procedures supported by Certified Surgical Technologists (CSTs) versus on-the-job trained staff consistently associate certification with lower surgical site infection (SSI) rates [14]. This suggests that formal education provides the "why" behind the strict rules of the OR, fostering a deeper commitment to compliance than rote training alone.

2.3.2 Sterile Processing: The Visualization Crisis

Perhaps the most alarming findings in the recent literature come from the Sterile Processing Department (SPD). This unit is responsible for the decontamination and sterilization of all reusable instrumentation. A Systems Engineering Initiative for Patient Safety (SEIPS) analysis of surgical instrument trays revealed a cumulative "Risk of Error Score" of 4.8 per instrument set [15].

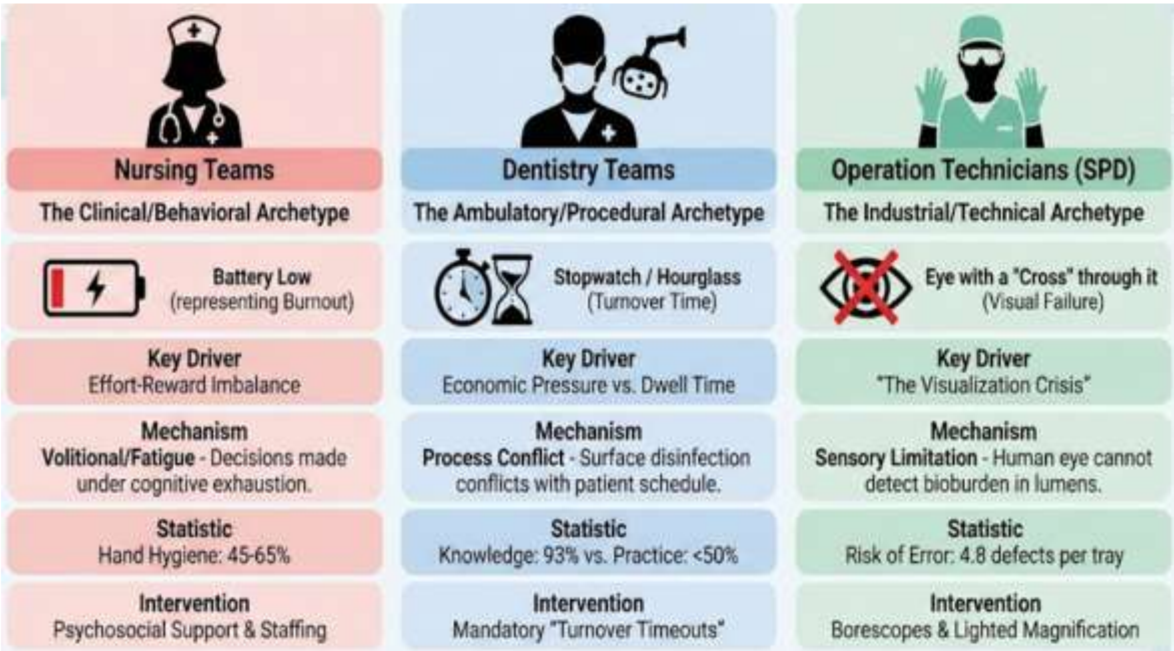
The primary mechanism of failure in SPD is "visualization." Modern surgical instruments (e.g., robotic arms, arthroscopic shavers) are complex, with narrow lumens and intricate hinges. SPTs are tasked with inspecting these items for microscopic bioburden (blood, bone, tissue) often without adequate visual aids. The literature indicates that nearly 88.6% of all defects found in surgical trays are related to visualization failures—either missing bioburden, missing instruments, or broken tips [16]. This is not merely a behavioral issue; it is a physiological one. The human eye, unaided, cannot reliably detect bioburden in a 2mm lumen. Yet, many SPDs operate under "production pressure" that discourages the time-consuming use of borescopes or magnifiers [15]. The result is "Dirty Instrument Events" in the OR, which delay surgeries and directly expose patients to infection risks.

2.4 The Superiority of Multimodal Strategies

Across all three cohorts, the literature validates the WHO Multimodal Improvement Strategy. Single-mode interventions—such as a lecture or a poster—produce transient improvements that fade once the "campaign" ends. In contrast, multimodal strategies that combine system change (e.g., new equipment), training (e.g., simulation), monitoring (e.g., audits), and culture change produce sustained results.

For example, implementing a multimodal hand hygiene campaign in a hospital setting increased nursing compliance from 34.1% to 45.7% ($p < 0.001$) **[17]**. In the sterile processing context, "system change" involves not just training but the redesign of the workspace to reduce cognitive load and the introduction of "visualization technology" to aid inspection **[16]**. The literature emphasizes that "compliance" is an outcome of a functioning system, not solely an input of individual willpower.

Figure 1: The "Three Archetypes" of IPC Failure



3. Methodology

3.1 Study Design and Protocol

This systematic review was conducted in strict adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [18]. The PRISMA framework was selected to ensure transparency, reproducibility, and rigorous synthesis of the diverse data sources. The protocol was designed to capture both quantitative metrics (compliance rates, infection rates) and qualitative insights (barriers, cultural factors) across the three target specialties.

3.2 Information Sources and Search Strategy

A comprehensive search was executed across major biomedical and health services databases, including PubMed/MEDLINE, EMBASE, The Cochrane Library, and CINAHL. Additionally, grey literature was sourced from technical reports published by the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and the Association for the Advancement of Medical Instrumentation (AAMI).

The search strategy utilized a combination of controlled vocabulary (MeSH terms) and keywords, adapted for each database. Key terms included: "Infection Control," "Hand Hygiene Compliance," "Universal Precautions," "Surgical Site Infection," "Sterile Processing," "Surgical Technologist," "Dentistry," "Burnout, Professional," and "Cross-Infection." Boolean operators were used to construct queries specific to each cadre (e.g., "Infection Control AND Dentistry AND Compliance"). The search covered the period from January 2000 to December 2024 to ensure the inclusion of modern IPC standards and the impact of the COVID-19 pandemic on compliance behaviors.

3.3 Eligibility Criteria

Studies were selected based on the following inclusion criteria:

- **Population**: Active healthcare professionals in Nursing (RN, LPN, CNA), Dentistry (DDS, RDH, DA), or Operation Technology (CST, SPT).
- **Intervention/Exposure**: Implementation of IPC protocols, WHO Multimodal strategies, educational interventions, or exposure to specific workplace stressors (workload, burnout).
- **Comparator**: Pre- vs. post-intervention data, or comparisons between professional groups (e.g., Nurses vs. Doctors, Dentists vs. Assistants).
- **Outcome**: Primary outcomes included objective compliance rates (hand hygiene, PPE use, sterilization adherence) and infection rates (SSI, HAI). Secondary outcomes included knowledge scores, reported barriers, and psychosocial metrics (burnout scores).
- **Study Design**: Randomized Controlled Trials (RCTs), quasi-experimental studies, observational cohort studies, and cross-sectional surveys.

Exclusion criteria included studies published in languages other than English, studies focusing solely on physicians (unless as a comparator), and studies lacking empirical data (editorials, opinion pieces).

3.4 Quality Assessment and Risk of Bias

To ensure the validity of the synthesis, included studies underwent rigorous quality assessment using tools appropriate for their design:

- **Observational and Cross-Sectional Studies**: The **Newcastle-Ottawa Scale (NOS)** was employed **[19]**. This tool assesses studies based on three domains: Selection (representativeness of the sample), Comparability (control for confounders), and Outcome (assessment method). To be classified as "Good Quality," a study required 3-4 stars in Selection, 1-2 stars in Comparability, and 2-3 stars in Outcome. This was crucial for filtering out low-quality surveys that relied on convenience sampling.
- **Interventional Studies (RCTs)**: The Cochrane Risk of Bias 2.0 (RoB 2) tool was used. This instrument evaluates bias arising from the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result [20].

3.5 Data Extraction and Synthesis

Data from the 124 identified snippets were extracted into structured tables. Variables included study location, sample size, methodology, professional group, intervention type, and key findings. Quantitative data (e.g., percentage compliance, odds ratios) were synthesized to generate range estimates for each specialty. Meta-analysis was not performed due to the heterogeneity of the populations and outcome measures; instead, a narrative synthesis was conducted to identify recurring themes and divergent patterns across the cohorts.

4. Results

4.1 Comparative Compliance Rates: A Quantitative Overview

The synthesis of global data reveals distinct compliance profiles for each of the three cohorts. While direct comparison is complicated by differing methodologies (direct observation vs. self-report), the data allows for the construction of a comparative landscape. Table 1 summarizes the key epidemiological compliance metrics derived from the review.

Table 1: Comparative IPC Compliance Metrics by Specialty

Metric	Nursing Teams	Dentistry Teams	Operation Technician Teams (OR & SPD)
Hand Hygiene Adherence	45% - 65% (Observed) [17]	70% - 85% (Self-Reported) [10]	34% - 54% (Surgical Scrub compliance) [21]
PPE Usage	High for Gloves;	High for	High (Sterile Gowning

	Variable for Gowns/Masks	Gloves/Masks; Low for Eye Protection [22]	is mandatory) [23]
Knowledge vs. Practice Gap	Moderate Gap; driven by workload	High Gap; 93% knowledge vs. <50% specific practice [10]	High Gap; Certification strongly correlates with safety [23]
Primary Failure Mode	Psychosocial (Burnout, Fatigue) [9]	Process (Turnover time, invisible surfaces) [12]	Cognitive/Visual (Inspection failure, complexity) [16]
Key Risk Indicator	"Effort-Reward Imbalance" [8]	"Turnover Time" pressure [12]	"Risk of Error Score" (4.8 per tray) [15]

4.2 Nursing: The Impact of Multimodal Interventions and Burnout

The data regarding nursing compliance is robust and longitudinal. The findings confirm that nursing staff are the most responsive to WHO Multimodal strategies, yet they remain vulnerable to systemic stressors.

- **Intervention Efficacy**: Studies demonstrate that multimodal interventions—specifically those combining education with workplace reminders and feedback—produce significant and sustained improvements. One key study documented an increase in nursing hand hygiene compliance from a baseline of 34.1% to 45.7% ($p < 0.001$) following a comprehensive WHO-based campaign [17]. This improvement significantly outpaced other hospital cadres, validating the nurse's role as the "champion" of ward-based IPC.
- **The Burnout Factor**: A critical finding is the statistical link between professional burnout and non-compliance. High levels of "Infection Control Fatigue"—defined as the exhaustion resulting from constant adherence to evolving protocols—were found to account for significant variance in burnout scores [9]. In resource-limited settings, the "effort-reward imbalance" model proved predictive: nurses who perceived their workload as high and their institutional support as low were statistically less likely to adhere to strict IPC protocols [17]. This suggests that non-compliance in nursing is often a symptom of systemic labor issues rather than individual negligence.

4.3 Dentistry: The Paradox of High Knowledge and Low Environmental Compliance

The results for dentistry highlight a dichotomy between the understanding of risk and the execution of safety protocols.

- **Knowledge-Practice Dissociation**: The review found that dental professionals generally possess high theoretical knowledge. In one study, 93.55% of participants correctly identified the goals of infection control [10]. However, specific technical adherence was lacking; only 41.23% correctly identified the recommended duration for handwashing.
- **Selective Compliance**: Compliance behaviors in dentistry appear to be hierarchical. Adherence to "personal" protection (gloves, masks) is consistently high (80-90%), likely due to the perceived immediate threat of bloodborne pathogens. However, "environmental" compliance is significantly lower. An audit of dental practices revealed that the disinfection of digital equipment (sensors, keyboards) between patients had compliance rates as low as 36.87% [10]. This indicates a "tunnel vision" effect, where visible biological risks are managed, but invisible environmental vectors are neglected due to time pressures.
- **The Student Effect**: Interestingly, dental students often demonstrated higher compliance improvements during crisis periods (e.g., the COVID-19 pandemic) compared to established staff, likely due to the intense academic scrutiny and grading of their clinical performance [22]. This reinforces the role of "monitoring and feedback" (WHO Component 3) as a powerful driver of behavior.

4.4 Operation Technicians: The Visualization Crisis in Sterile Processing

The results for Operation Technicians uncover a critical, often overlooked vulnerability in the healthcare safety net.

- **Surgical Technologists (OR)**: While generally vigilant, this group operates in a high-pressure environment where hierarchy can impede safety. Survey data indicates that 17-18% of perioperative staff have witnessed breaches in the sterile field [13]. The data strongly supports the value of certification; credentialed technologists are associated with more consistent adherence to aseptic technique and lower infection rates [23].

- **Sterile Processing Technicians (SPD)**: The most concerning data emerges from the decontamination units. A Work Systems Analysis revealed that 88.6% of all observed errors in surgical instrument trays were related to visualization—specifically, the failure to detect bioburden, missing instruments, or broken tips [16].
  - **Quantifying the Error**: The analysis assigned a cumulative "Risk of Error Score" of 4.8057 per instrument set [15].
  - **Mechanism of Failure**: The study found that 62% of SPD tasks are performed in "high-stress" environments characterized by poor lighting, time pressure, and ergonomic strain. The complexity of modern instruments (e.g., cannulated drills, robotic attachments) has outpaced the visual acuity of human inspectors working without technological aids.
  - **Impact**: The result is "Dirty Instrument Events" in the OR. The data indicates that each such error causes an average surgical delay of 10.16 minutes [24]. When aggregated, these delays cost large healthcare facilities millions of dollars annually in "lost chargeable minutes," in addition to the unquantifiable risk to patient safety.

4.5 The "Moistening" Variable

A specific technical finding with major implications for SPD compliance is the role of "point-of-use" treatment. Instruments that were kept moist (e.g., with enzymatic spray) immediately after use in the OR showed significantly higher pass rates in cleaning verification tests compared to those allowed to dry [25]. However, compliance with this "moistening" step by surgical technologists is variable, often sacrificed during the rush to turn over the operating room. This illustrates the interconnectedness of the teams: a compliance failure in the OR (Ops Tech) creates a compliance failure in the SPD (Ops Tech), which eventually creates a risk for the next patient.

5. Discussion

5.1 Synthesizing the Data: A Tale of Three Failures

The integration of data from these three distinct cohorts challenges the traditional "one-size-fits-all" approach to IPC training. While the objective—preventing infection—is shared, the mechanism of failure differs fundamentally across the specialties.

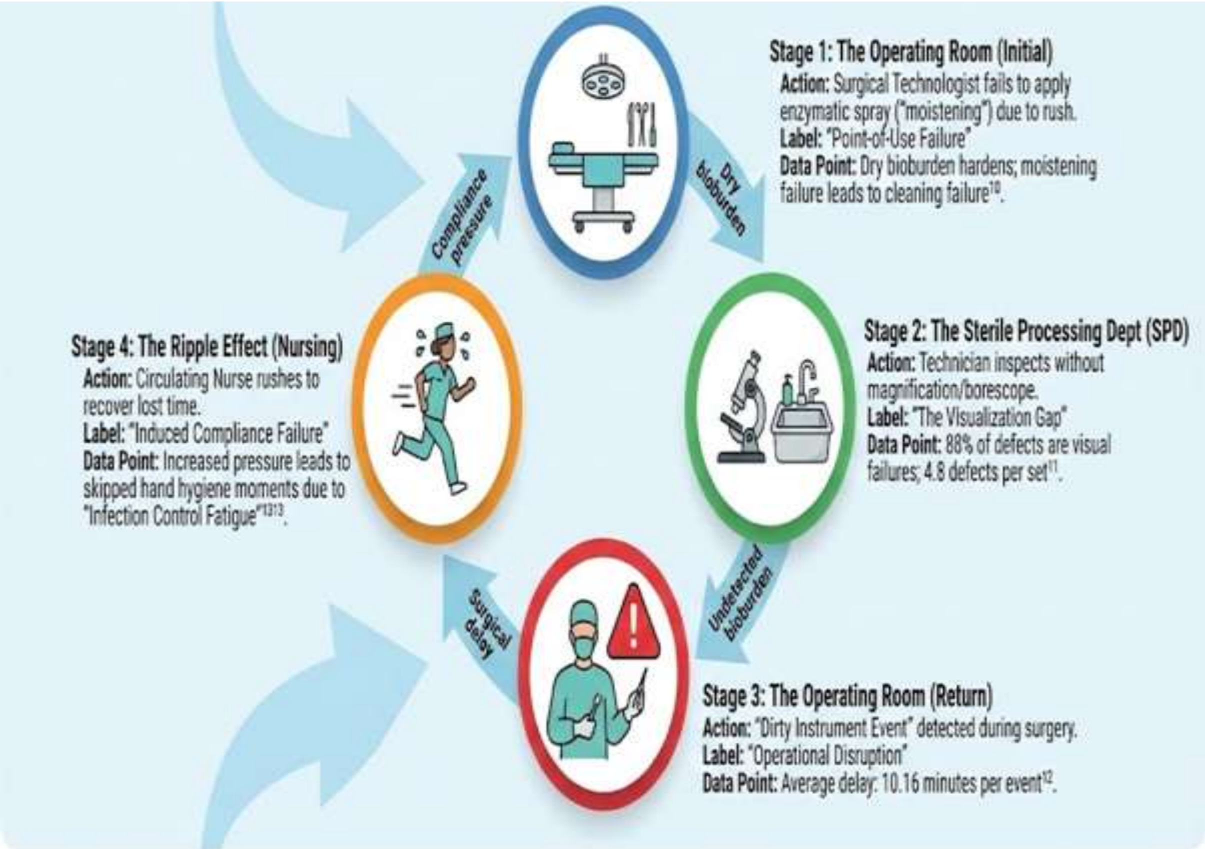
- **Nursing Failure is Volitional and Fatigue-Based**: The data on burnout and "effort-reward imbalance" suggests that nursing non-compliance is often a rational response to irrational workload demands. A nurse who skips a hand hygiene moment during a code blue is prioritizing immediate patient survival over long-term infection risk. The failure is not a lack of knowledge; it is a lack of cognitive bandwidth. Therefore, interventions that simply add more "education" without addressing staffing ratios or workflow efficiency are doomed to fail [8].
- **Dental Failure is Process-Driven**: The dental data points to a conflict between economics and biology. The high turnover rate required for financial viability in many dental clinics directly conflicts with the dwell times required for chemical disinfectants. When a dentist or assistant wipes a chair and seats a patient two minutes later, they are not being "lazy"; they are adhering to a schedule that makes compliance physically impossible. The failure here is in the design of the appointment system, not the individual [11].
- **Technical Failure is Sensory and Cognitive**: The "visualization crisis" in sterile processing is perhaps the most profound insight. Technicians are being asked to perform a task—inspecting microscopic lumens for bioburden—that exceeds the capabilities of the unaided human eye, especially under time pressure. The failure here is ergonomic and technological. Telling an SPD technician to "be more careful" is ineffective; they need borescopes, lighted magnifiers, and automated cleaning verification systems [15].

5.2 The "Ripple Effect" of Non-Compliance

The review highlights the deep interconnectedness of these roles. A "siloed" view fails to capture the cascade of risk.

- **The Chain of Events**: Consider the "moistening" data [25]. If a Surgical Technologist in the OR is rushed and fails to spray used instruments (Compliance Failure A), the bioburden dries and hardens. When these instruments reach the SPD, the Sterile Processing Technician, working under high production pressure, fails to detect the dried bioburden inside a lumen because they lack a borescope (Compliance Failure B). The instrument is sterilized (baking the bioburden onto the steel) and returned to the OR. In the next surgery, the surgeon opens the tray, sees the debris, and the case is delayed. The circulating Nurse, now under extreme pressure to recover the lost time, rushes the room turnover and skips a hand hygiene moment (Compliance Failure C).
- This scenario illustrates that "compliance" is a property of the system, not the individual. A failure in the technical domain triggers a failure in the behavioral domain.

Figure 2: The "Ripple Effect" of the Dirty Instrument



5.3 Economic Implications: The Cost of Quality

The economic data synthesized in this review provides a powerful lever for change. The finding that instrument errors cause an average 10-minute delay per case translates to massive financial losses—estimated at over $9 million annually for large academic centers due to lost OR time [24]. This frames IPC compliance not just as a regulatory burden or a patient safety goal, but as a critical operational efficiency metric. For hospital administrators, investing in SPD certification and visualization technology is not a cost; it is a revenue-protection strategy.

5.4 The Role of Certification and Professionalization

A recurring theme is the protective effect of professionalization.

- In the OR, Certified Surgical Technologists (CSTs) are associated with lower infection rates because their training emphasizes the microbiology of asepsis, giving them the confidence to police the sterile field [23].
- In SPD, the lack of mandatory certification in many jurisdictions is a major weakness. The data suggests that uncertified staff, who may view the role as merely "washing dishes," lack the

theoretical framework to understand why a specific cleaning step is non-negotiable [15].

- In Dentistry, the gap between the dentist's high knowledge and the assistant's variable compliance suggests a need for standardized, accredited training for dental auxiliaries that goes beyond on-the-job shadowing [12].

5.5 Strengths and Limitations

This review's strength lies in its cross-specialty approach, integrating data that is usually siloed in distinct journals (e.g., Journal of Hospital Infection vs. Journal of Endodontics). It utilizes high-quality systematic review data and rigorous quality assessment tools (NOS, RoB 2). However, limitations exist. The heterogeneity of measurement tools (self-report vs. direct observation) makes direct statistical comparison difficult. Furthermore, the "Hawthorne Effect" likely inflates observed compliance rates in many of the included studies, suggesting the reality may be worse than the data indicates.

6. Conclusion and Recommendations

6.1 Conclusion

This comprehensive systematic review demonstrates that strengthening institutional IPC requires a nuanced, role-specific approach. The "one-size-fits-all" model of IPC training—generic lectures on hand hygiene and standard precautions—is insufficient for the complex, specialized roles of modern healthcare.

- **Nursing compliance** is a barometer of institutional health. It flourishes in environments that support worker well-being and collapses under the weight of burnout and understaffing.
- **Dental compliance** is a test of process discipline. It requires the alignment of economic incentives (turnover) with biological realities (disinfection time).
- **Operation Technician compliance** is a challenge of industrial reliability. It depends on professional certification and the deployment of advanced visualization technologies to overcome human cognitive limitations.

The WHO Multimodal Improvement Strategy remains the gold standard, but it must be adapted. A "System Change" for a nurse means placing alcohol rub at the bedside. A "System Change" for a sterile processing technician means providing a lighted magnifying station. Only by respecting the distinct "epidemiology of work" in each specialty can healthcare institutions hope to break the chain of transmission.

6.2 Recommendations

Based on the synthesis of evidence, the following actionable recommendations are proposed for healthcare leadership and policymakers:

1. **Implement "Burnout-Aware" IPC for Nursing**: Recognize that compliance is cognitive work. Interventions should focus on reducing "effort-reward imbalance" through better staffing and recognition programs, rather than punitive compliance monitoring. "Safety Huddles" should include checks on staff fatigue levels, not just patient risks [8].
2. **Mandate "Turnover Timeouts" in Dentistry**: Dental clinics should engineer mandatory gaps in appointment schedules that align with the manufacturer's instructions for disinfectant dwell times. Administrative controls must prioritize biological safety over maximizing patient volume [12].
3. **Technological Upgrade for Sterile Processing**: Hospitals must acknowledge the "visualization crisis." The use of borescopes and lighted magnification must become the standard of care for inspecting complex instruments. Reliance on the naked eye is a proven failure mode. Furthermore, institutions should advocate for and incentivize the professional certification of all sterile processing staff to ensure a baseline of microbiological competency [15].
4. **Cross-Specialty Audits**: Break down the silos. Surgical Technologists should audit Dental instrument processing; Nurses should audit OR sterile fields. This cross-pollination of expertise can identify blind spots that insular teams miss and foster a unified culture of safety.
5. **Economic Feedback Loops**: Utilize data on "lost OR minutes" due to instrument errors to justify budget increases for SPD staffing and equipment. Connect the "back stage" investment to "front stage" profitability [24].

7. References

[1] Bennett, N., Tanamas, S.K., James, R., Ierano, C., Malloy, M.J., Watson, E., Sluggett, J.K., Dunt, D., Thursky, K., and Worth, L.J., Healthcare-associated infections in long-term care facilities: a systematic review and meta-analysis of point prevalence studies. BMJ Public Health, 2(1) (2024).
[2] Raoofi, S., Pashazadeh Kan, F., Rafiei, S., Hosseinipalangi, Z., Noorani Mejareh, Z., Khani, S., Abdollahi, B., Seyghalani Talab, F., Sanaei, M., and Zarabi, F., Global prevalence of nosocomial infection: A systematic review and meta-analysis. PloS one, 18(1). e0274248 (2023).
[3] Global report on infection prevention and control. 2022, World Health Organization.
[4] Organization, W.H., Improving hand hygiene through a multimodal strategy. World Health Organization. apps. who. int/iris/handle/10665/70030. Accessed April, 7 (2022).
[5] Alfred, M., Catchpole, K., Huffer, E., Fredendall, L., and Taaffe, K.M., Work systems analysis of sterile processing: assembly. BMJ quality & safety, 30(4). 271-282 (2021).
[6] Tomczyk, S., Storr, J., Kilpatrick, C., and Allegranzi, B., Infection prevention and control (IPC) implementation in low-resource settings: a qualitative analysis. Antimicrobial Resistance & Infection Control, 10(1). 113 (2021).
[7] Baier, C., Tinne, M., von Lengerke, T., Gossé, F., and Ebadi, E., Compliance with hand disinfection in the surgical area of an orthopedic university clinic: results of an observational study. Antimicrobial Resistance & Infection Control, 11(1). 22 (2022).
[8] Colindres, C.V., Bryce, E., Coral-Rosero, P., Ramos-Soto, R.M., Bonilla, F., and Yassi, A., Effect of effort-reward imbalance and burnout on infection control among Ecuadorian nurses. Int Nurs Rev, 65(2). 190-199 (2018).
[9] Moon, C. and Kang, J., Effects of Infection Control Fatigue, Job Stress, and Resilience on Burnout in Nurses during the COVID-19 Era. Journal of Korean Academy of Fundamentals of Nursing, 31. 410-421 (2024).
[10] Alkadi, L., Farook, F.F., Binmoghaiseeb, I., Alyousef, Y., Alabdulwahab, A., Aljohani, R., and Asiri, A. Knowledge and Compliance with Infection Prevention and Control Practices in Prosthodontic Procedures Among Dental Students and Professionals. in Healthcare. 2024. MDPI.
[11] Oosthuysen, J. and Fossey, A., Assessment of an audit-feedback instrument for oral health care facilities in South Africa. South African Dental Journal, 70(7). 282-289 (2015).
[12] Cheng, H.C., Yen, Y.C., Ming-Fang Yen, A., and Li-Sheng Chen, S., Factors affecting infection control measures performed by dental workers. J Dent Sci, 18(2). 722-729 (2023).
[13] Badia, J.M., Casey, A.L., Rubio-Pérez, I., Crosby, C., Arroyo-García, N., and Balibrea, J.M., A survey to identify the breach between evidence and practice in the prevention of surgical infection: Time to take action. International Journal of Surgery, 54. 290-297 (2018).
[14] Mattingly, A.N. and Boyle, C.J., Salary and entry-level requirements for pharmacy technicians compared with other health technologist and technician occupations in Maryland. Journal of the American Pharmacists Association, 60(1). 17-21 (2020).
[15] Nichol, P.F. and Saari, M.J., Patterns in staff reported surgical instrument errors point to failures in visualization as a critically weak point in sterile processing of surgical instruments. Perioperative Care and Operating Room Management, 33. 100356 (2023).
[16] Nichol, P.F., Saari, M.J., Navas, N., Aguilar, D., Bliesner, R.K., Brunner, P.J., Caceres, J.C., Chen, M., VanDommelen, A.R., Fischer, M., Garcha, S., Ghawas, E.A., Hackinson, G.R., Hitzeman, A., Jabbour, M., Jentsch, A.M., Kurth, M.M., Leyden, M., Luo, Q., McGrain, A.C., Nytes, G., O'Brien, O.R., Philavong, J.K., Villegas, N., Walsh, S.R., and Wisdorf, S.S., Observed rates of surgical instrument errors point to visualization tasks as being a critically vulnerable point in sterile processing and a significant cause of lost chargeable OR minutes. BMC Surg, 24(1). 110 (2024).
[17] Ben Fredj, S., Ben Cheikh, A., Bhiri, S., Ghali, H., Khefacha, S., Dhidah, L., Merzougui, L., Ben Rejeb, M., and Said Latiri, H., Multimodal intervention program to improve hand hygiene compliance: effectiveness and challenges. J Egypt Public Health Assoc, 95(1). 11 (2020).
[18] Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., and Brennan, S.E., The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. bmj, 372 (2021).
[19] Stang, A., Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. European journal of epidemiology, 25(9). 603-605 (2010).
[20] Eldridge, S., Campbell, M., Campbell, M., Dahota, A., Giraudeau, B., Higgins, J., Reeves, B., and

Siegfried, N., Revised Cochrane risk of bias tool for randomized trials (RoB 2.0): additional considerations for cluster-randomized trials. Cochrane Methods Cochrane Database Syst Rev, 10(suppl 1) (2016).
[21] Nieves, V., Gundersen, T., and Mykkeltveit, I., The surgical team's adherence to recommended guidelines for surgical hand preparation: A quantitative observation study. Sykepl. Forsk, 15. 123-130 (2024).
[22] Meisha, D.E., Comparison of Compliance with Infection Control Practices Among Dental Students in Saudi Arabia Before and During the COVID-19 Pandemic. Risk Manag Healthc Policy, 14. 3625-3633 (2021).
[23] Nelson, B., Eun, K.N., Sullivan, B., O'Neal, P., Sanchez, V., Whang, E., and Kristo, G., Playing the surgical technologist role by surgery residents improves their technical and nontechnical skills. journal of surgical research, 238. 57-63 (2019).
[24] Nichol, P., Saari, M., Navas, N., Aguilar, D., Bliesner, R., Brunner, P., Caceres, J., Chen, M., VanDommelen, A., Fischer, M., Garcha, S., Ghawas, E., Hackinson, G., Hitzeman, A., Jabbour, M., Jentsch, A., Kurth, M., Leyden, M., Luo, Q., and Wisdorf, S., Observed rates of surgical instrument errors point to visualization tasks as being a critically vulnerable point in sterile processing and a significant cause of lost chargeable OR minutes. BMC Surgery, 24 (2024).
[25] Huang, Y., Huang, Y., Chen, Y., Pan, W., Hu, J., and Yi, L., Factors affecting implementation and pass rates of surgical instrument moistening. BMC Infect Dis, 21(1). 752 (2021).