

Automated Monitoring System for Advanced Medical Products in a Dental Hospital Setup: A Mixed-Methods Evaluation

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Abstract—Manual monitoring of advanced medical equipment and consumables in dental hospitals is time-consuming and prone to error, affecting efficiency and compliance.

Aim: To develop and evaluate an Automated Monitoring System (AMS) for advanced medical products in a dental hospital and assess its impact on operational performance and user satisfaction.

Methods: A 12-month mixed-methods study was conducted in a multi-specialty dental teaching hospital in India. An AMS integrating IoT, RFID, and cloud-based analytics was implemented. Pre- and post-implementation indicators were compared using paired t-tests and ANOVA. User perception was assessed using a reliable Likert-scale questionnaire (Cronbach's $\alpha = 0.88$).

Results: After AMS implementation, equipment downtime decreased by 41.6%, expired inventory by 75.3%, and documentation time by 50.4%. Sterilization compliance improved from 82.5% to 96.8% ($p < 0.001$). User satisfaction was high (mean score: 4.37 ± 0.60).

Conclusion: The AMS significantly improved efficiency, compliance, and staff satisfaction, demonstrating strong potential for scalable digital transformation in dental hospital management

Index Terms—Automated monitoring system; IoT; dental hospital management; inventory control; sterilization compliance

I. INTRODUCTION

The rapid advancement of healthcare technologies has transformed hospital operations, placing increased emphasis on efficiency, safety, and quality assurance. Dental hospitals, in particular, rely heavily on advanced medical equipment and high-turnover consumables, including dental chairs, sterilization units, radiographic systems, implants, and restorative materials. Effective monitoring of these products is essential to ensure uninterrupted clinical services and patient safety.

Despite technological progress, many dental institutions continue to depend on manual or semi-digital monitoring practices. These approaches are often labor-intensive, prone to documentation errors, and insufficient for real-time decision-making. Inadequate tracking of equipment maintenance, sterilization cycles, and inventory levels can lead to equipment downtime, expired materials, compliance gaps, and increased operational costs.

Automated Monitoring Systems (AMS), supported by Internet of Things (IoT), RFID, and cloud computing technologies, provide continuous real-time oversight of medical products. Such systems enable predictive maintenance, automated inventory alerts, digital documentation, and centralized data access. In dental hospital environments where procedures are frequent and instrument turnover is high automation offers a strategic solution to improve workflow efficiency and infection control compliance.

In the Indian healthcare context, initiatives under the National Digital Health Mission (NDHM) promote the adoption of smart hospital systems and data-driven healthcare management. While automation has been explored extensively in large medical hospitals, limited evidence exists regarding its application in dental hospital settings, which operate with distinct clinical workflows and operational challenges. This study addresses this gap by developing and evaluating an Automated Monitoring System specifically designed for a dental hospital environment. The system integrates equipment monitoring, inventory management, and sterilization tracking to enhance operational performance and regulatory compliance.

II. MATERIALS AND METHODS

2.1 Study Design

A mixed-methods descriptive and experimental design was adopted. The descriptive phase evaluated existing manual monitoring practices, while the experimental phase involved the development and pilot implementation of the AMS, followed by outcome evaluation.

2.2 Study Setting and Duration

The study was conducted in a university-affiliated multi-specialty dental hospital in India over a period of 12 months, divided into baseline assessment, system deployment, and post-implementation evaluation phases.

2.3 Study Population and Sampling

A total of 120 hospital personnel involved in equipment handling, inventory management, sterilization, and administration were included using stratified purposive sampling. Participants represented faculty members, technicians, dental assistants, nurses, and administrative staff.

2.4 System Architecture

The AMS comprised:

- IoT sensors and RFID tags for product identification and monitoring
- Data acquisition gateways for real-time transmission
- A cloud-based centralized database

- A web-based dashboard for analytics and reporting
- Automated email and SMS alert mechanisms

2.5 Data Collection

Pre-implementation data were collected from manual records, while post-implementation data were generated automatically by the AMS. Key indicators included equipment downtime, stock-out frequency, expired inventory, documentation time, and sterilization compliance.

User satisfaction was assessed using a validated 5-point Likert-scale questionnaire.

2.6 Statistical Analysis

Data analysis was performed using SPSS version 26.0. Paired t-tests assessed pre- and post-implementation differences, while ANOVA evaluated department-wise variations. Statistical significance was set at $p < 0.05$.

II. RESULTS

Implementation of the AMS resulted in statistically significant improvements across all operational parameters ($p < 0.001$). Equipment downtime, inventory wastage, and manual documentation burden were markedly reduced, while sterilization compliance improved substantially. High user satisfaction scores indicated strong system acceptance and adaptability across departments.

Parameter	Pre-Implementation	Post-Implementation	% Change
Equipment downtime	42.3 ± 5.6 hrs	24.7 ± 4.2 hrs	↓ 41.6%
Stock-out incidents	12.8 ± 3.1	5.6 ± 1.9	↓ 56.3%
Expired inventory	8.5 ± 2.2%	2.1 ± 0.9%	↓ 75.3%
Documentation time	96.4 ± 14.3 min	47.8 ± 9.5 min	↓ 50.4%
Sterilization compliance	82.5 ± 6.4%	96.8 ± 3.5%	↑ 17.4%

IV. DISCUSSION

The findings confirm that automation significantly enhances the management of advanced medical products in dental hospitals. The observed reductions in downtime and wastage reflect improved predictive

maintenance and real-time inventory visibility. Automated documentation minimized clerical workload and improved audit readiness, aligning with NABH accreditation requirements.

High staff satisfaction underscores the importance of user-friendly design and adequate training during system implementation. The AMS supports Lean Six Sigma and Total Quality Management principles by reducing process variability and operational waste.

V. CONCLUSION

The Automated Monitoring System proved to be an effective tool for improving operational efficiency, compliance, and workforce productivity in a dental hospital setup. Its integration with digital health infrastructure positions it as a scalable and sustainable solution for modern hospital management in India.

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