

Formulation of a Novel Chair-Side Anti-Microbial System and Its Evaluation in Dental Operatories: A Pilot Study

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Abstract

Background

Dental operatory surfaces are frequently exposed to bioaerosols and splatter during clinical procedures, making them high-risk sites for cross-contamination. Without effective disinfection, these surfaces may act as reservoirs for microbial transmission among patients and healthcare workers. Alcohol-based disinfectants are widely used; however, their effectiveness is often reduced by rapid evaporation, inconsistent application, and limitations with frequent use. This underscores the need for advanced surface disinfectants that provide rapid action, residual antimicrobial activity, and user-friendly safety profiles.

Aim

To formulate a novel chair-side antimicrobial system and evaluate its efficacy in laboratory and simulated clinical conditions.

Methods

A three-phase interventional pilot study was conducted. In Phase I, microbial contamination of non-autoclavable dental operatory surfaces was assessed via colony-forming unit (CFU) analysis, and gaps in existing protocols were identified. In Phase II, a novel antimicrobial system was formulated and tested *in vitro* against commonly encountered oral bacteria. In Phase III, the novel formulation was applied in a clinical operatory setting on the same surfaces used for baseline sampling, followed by swab collection and CFU analysis.

Results

The novel antimicrobial system demonstrated rapid bactericidal action and residual antimicrobial activity *in vitro*. In the clinical setting, there was a marked reduction in CFU counts following application of the novel disinfectant compared with baseline and conventional agents. No adverse effects on material compatibility were observed. The pilot study revealed that surfaces like the dental sitting chair, ultrasonic scaler, mobile phone, LA cartridge, and instrument trolley showed high CFU counts with Bectacept (up to 100), in contrast, the novel disinfectant reported a 100% reduction in CFU counts on all surfaces, demonstrating higher antimicrobial efficacy even within 24 hours. With Bectacept, contamination persisted and even increased on certain surfaces such as the instrument trolley (150 CFU), LA cartridge (100 CFU), and dental chair (80 CFU) after 48 hours. However, the novel disinfectant maintained complete inhibition (0 CFU) across all surfaces even at 48 hours.

Conclusion

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The novel chair-side antimicrobial system showed higher antimicrobial efficacy and residual action. It presents a promising alternative to conventional surface disinfectants for improving infection control in dental environments. Further research into long-term efficacy, resistance potential, and safety is warranted before widespread adoption.

Categories: Food and Pharmaceutical Engineering, Biotechnology and Engineering, Environmental and Sustainable Engineering

Keywords: chair-side disinfection, surface contamination, colony-forming units, dental operator, antimicrobial agents

Introduction

The dental operator is an environment with a high potential for microbial cross-contamination. Routine procedures such as ultrasonic scaling, high-speed handpiece use, restorative work, and periodontal therapy generate aerosols, droplets, and splatter that may contain microorganisms from saliva, blood, dental plaque, and even respiratory secretions [1]. These contaminants can remain viable in the air for up to several hours and persist on clinical surfaces for extended periods, thus increasing the risk of pathogen transmission to both patients and dental professionals [2].

Dental operatories contain numerous high-touch surfaces - such as dental chair controls, light handles, countertops, and instrument trays - that function as fomites, supporting microbial survival and cross-transfer between individuals [3]. Studies have demonstrated that pathogens including *Streptococcus mutans*, *Staphylococcus aureus*, *Candida albicans*, and even respiratory viruses can persist on inanimate dental surfaces for several days, highlighting the need for strict disinfection protocols [4].

Current infection control guidelines emphasize the use of alcohol-based disinfectants owing to their broad-spectrum antimicrobial activity, rapid action, and cost-effectiveness [5]. However, alcohols have notable limitations: they evaporate quickly, leave no residual antimicrobial effect, and may cause cumulative degradation of sensitive dental surfaces (e.g., acrylic, rubber, and certain polymers) after repeated use. Moreover, their effectiveness is compromised in the presence of organic matter and biofilm-associated microorganisms [6].

Disinfection protocols such as the Spray-Wipe-Spray method remain the standard of care and have shown efficacy in reducing microbial loads when strictly followed [7]. Yet, real-world compliance is often inconsistent due to operator fatigue, high patient turnover, and time constraints, leading to lapses in infection control. Compounding this challenge, microorganisms embedded within biofilms are inherently resistant to conventional disinfectants, necessitating more advanced antimicrobial strategies [8].

To address these limitations, emerging technologies are being explored. Antimicrobial nanocoatings (silver, titanium dioxide, copper-based) provide sustained antimicrobial activity and have been investigated for coating dental unit waterlines and operator surfaces [9]. Similarly, polymer-based sustained-release agents allow gradual antimicrobial release, thereby reducing the frequency of reapplication [10]. Surface-modifying disinfectants, such as quaternary ammonium compound-based polymers, can impart long-lasting antimicrobial activity by altering surface hydrophobicity and charge, preventing microbial adhesion [11]. These novel approaches offer the promise of enhanced infection control, prolonged residual action, and greater compatibility with delicate dental materials.

Against this background, the present study evaluates a newly developed antimicrobial disinfectant formulated to provide residual antimicrobial activity while ensuring compatibility with dental operator materials. Its performance is compared with conventional alcohol-based agents, with a focus on microbial reduction, residual effect, and material safety.

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Materials And Methods

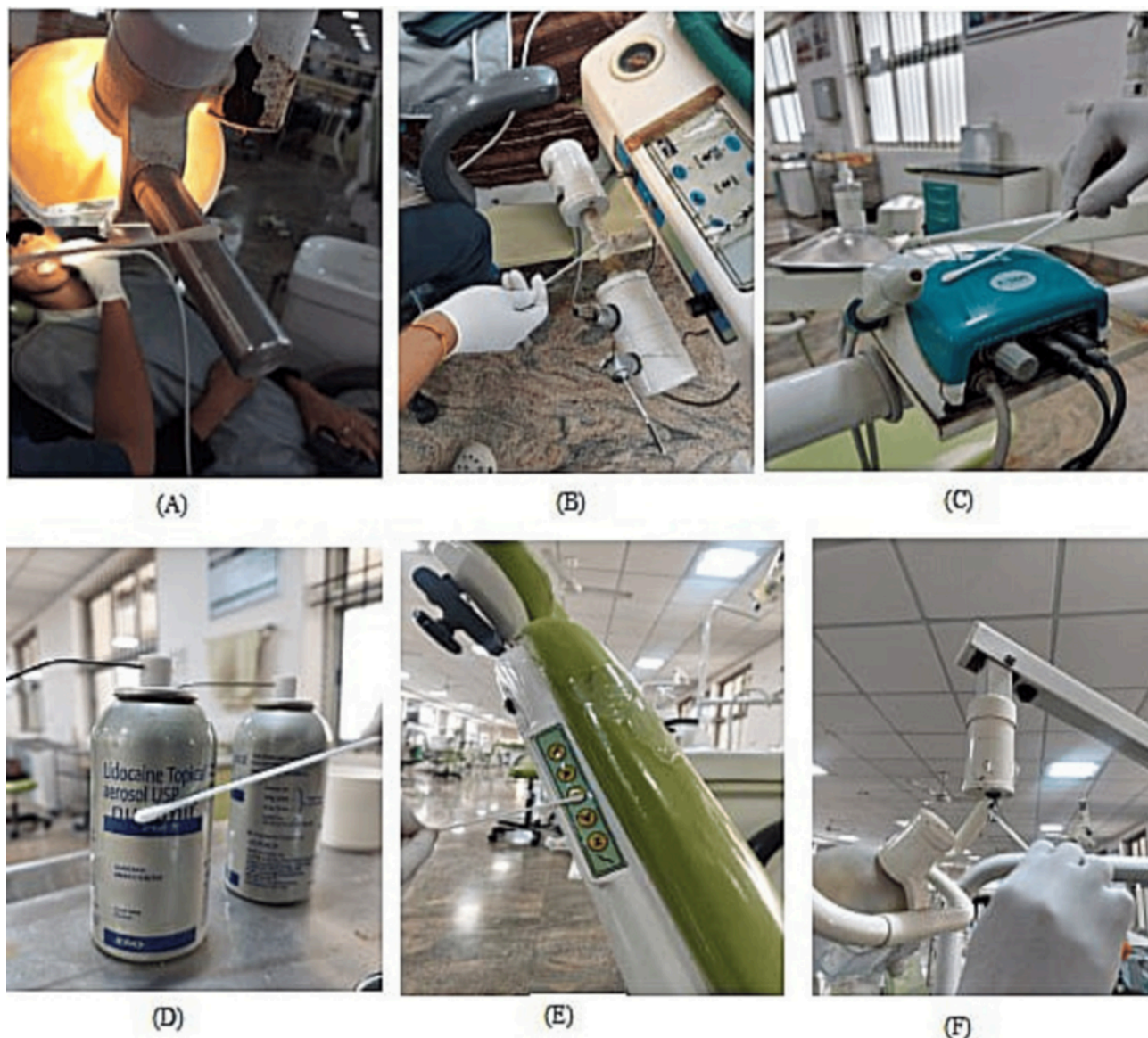


FIGURE 1: Sample collection using sterile swab sticks

(A) Dental light. (B) Dental chair handle. (C) Ultrasonic scaler unit. (D) LA spray. (E and F) Dental chair buttons.

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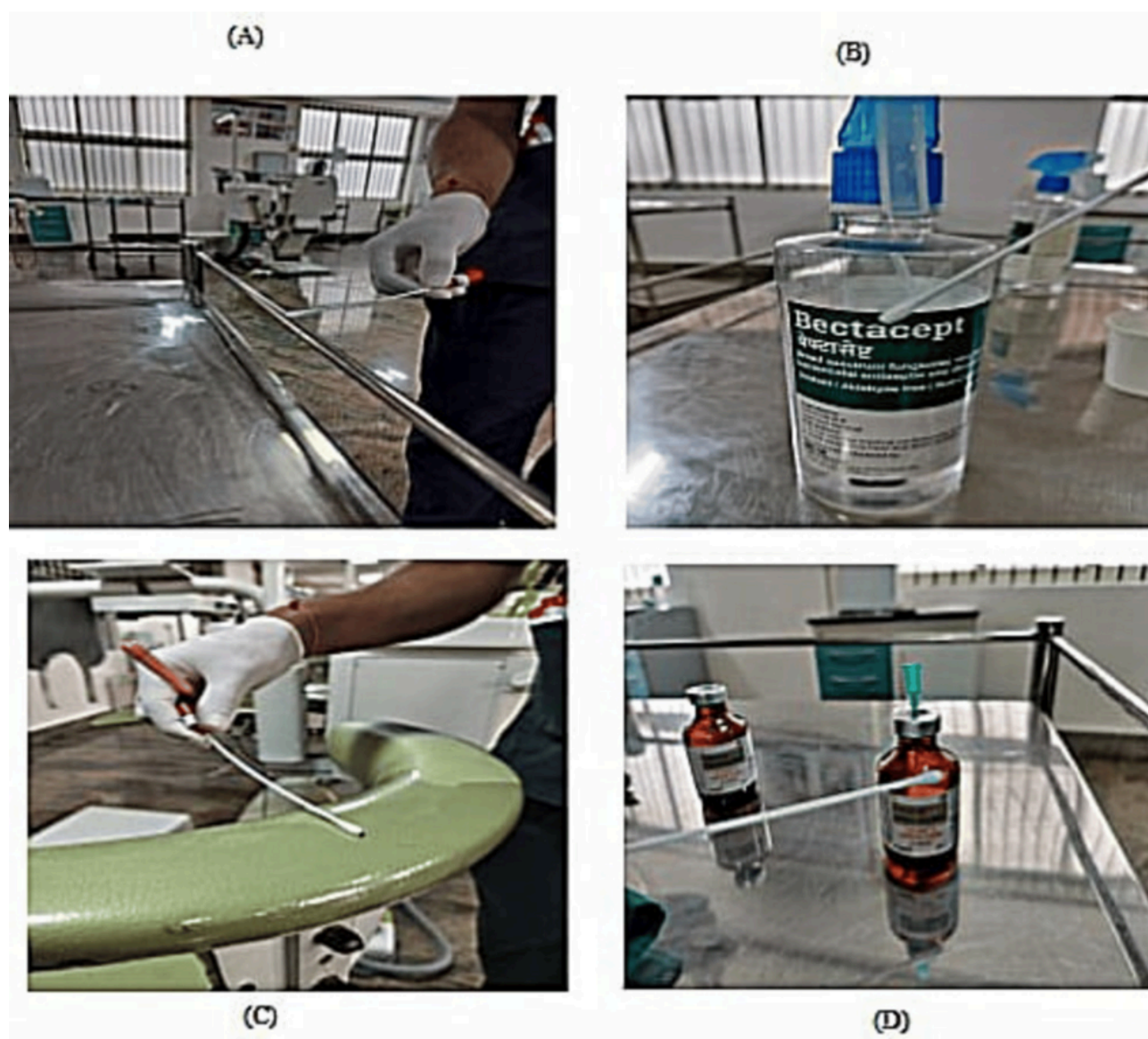


FIGURE 2: Sample collection using sterile swab sticks on other surfaces

(A) Instrument trolley. (B) Bectacept disinfectant. (C) Dental sitting chair. (D) LA cartilage.

It is a single-blinded study where the microbiologist is unaware of the type of swab samples received as they were just labeled numerically.

Phase I: baseline assessment

A cross-sectional baseline survey of microbial contamination was carried out in dental operatories. Swab samples were collected from frequently touched, non-autoclavable surfaces including dental chair control panels, light handles, spittoons, countertops, and instrument trays shown in Figure 1 and Figure 2. Sterile cotton swabs moistened with phosphate-buffered saline were rubbed across the surface using an aseptic technique. Samples were immediately transferred into sterile transport media and processed within 2 hours.

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Microbial quantification was performed by serial dilution and spread plate technique on nutrient agar and selective media (blood agar, MacConkey agar, Sabouraud's dextrose agar for fungi). Plates were incubated aerobically at 37°C for 24-48 hours, and colony forming units (CFUs/cm²) were enumerated using a digital colony counter. Baseline CFU values were used to evaluate the efficacy of existing disinfection protocols shown in Figure 3.

Phase II: formulation and *in vitro* testing

A novel antimicrobial solution was developed to provide immediate kill and residual antimicrobial action. The formulation was optimized for pH, stability, and material compatibility with acrylic, rubber, and metallic dental surfaces.

Antimicrobial assay by agar well diffusion method

The antimicrobial activity of a disinfectant was evaluated against *Escherichia coli* (*E. coli*) and *S. aureus* using the agar well diffusion method. Different concentrations were tested and Ciprofloxacin was used as the positive control.

Methodology

The antibacterial activity of the disinfectant was evaluated against *E. coli* (Gram-negative bacteria) and *S. aureus* (Gram-positive bacteria).

Preparation of bacterial culture: Fresh overnight cultures of *E. coli* and *S. aureus* grown on Mueller Hinton agar plates were used.

Preparation of disinfectant and ciprofloxacin: The disinfectant was prepared in concentrations of 100%, 50% and 25%. A 1 mg/ml ciprofloxacin was prepared from the stock solution.

Preparation of agar plates: Mueller-Hinton Agar was prepared and sterilized at 121°C for 15 minutes. Approximately 20-25 mL of sterile molten agar was poured into two sterile petri plates and allowed to solidify. The plates prepared for each organism were uniformly swabbed with well-isolated colonies using sterile cotton swabs. Wells were punched aseptically into the agar. A total of 20 µL of each concentration was carefully loaded into the respective wells. Ciprofloxacin was used as the positive control. Plates were incubated at 37°C for 18 hours.

Measurement of zone of inhibition: After incubation, the clear zones around each well were measured in millimeters (mm) using a ruler.

Result

Zone of inhibition: The disinfectant exhibited a zone of inhibition for all the concentrations used showing antibacterial activity against both tested organisms as shown in Figure 3. The zone of inhibition was measured in millimeters. All tests were performed in triplicate to ensure reproducibility.

Concentration	Zone of inhibition (in mm)	
	<i>E. coli</i>	<i>S. aureus</i>
100%	29	29
50%	25	28
25%	23	23
Ciprofloxacin	40	30

FIGURE 3: Measurement of zone of inhibition after incubation in millimeters (mm)

Phase III: clinical evaluation

In the clinical trial phase, the novel disinfectant was applied to the same surfaces tested during Phase I under standardized clinical operating conditions. The product was sprayed and left to act for 2 minutes before wiping with sterile gauze. Swab samples were collected at two time points: immediately after application and after 4 hours of routine clinical use. Samples were cultured using identical methods as in Phase I. CFU counts were compared to baseline values and to those obtained following routine alcohol-based disinfection. This allowed evaluation of both immediate and residual antimicrobial effects in real-world clinical settings.

Data collection and analysis

All microbial counts were expressed as CFU/cm². Data were entered into Microsoft Excel and analyzed. No statistical analysis was done since it is a pilot study.

Reproducibility and quality control

All experiments were conducted in a biosafety level 2 (BSL-2) laboratory. Each swab collection and plating procedure was performed in triplicate. Sterility controls (blank swabs and uninoculated media) were included in every experimental run. The disinfectant formulation was prepared under sterile conditions and stability tested for 30 days. All methods were described in sufficient detail to ensure reproducibility in independent settings.

Results And Discussion

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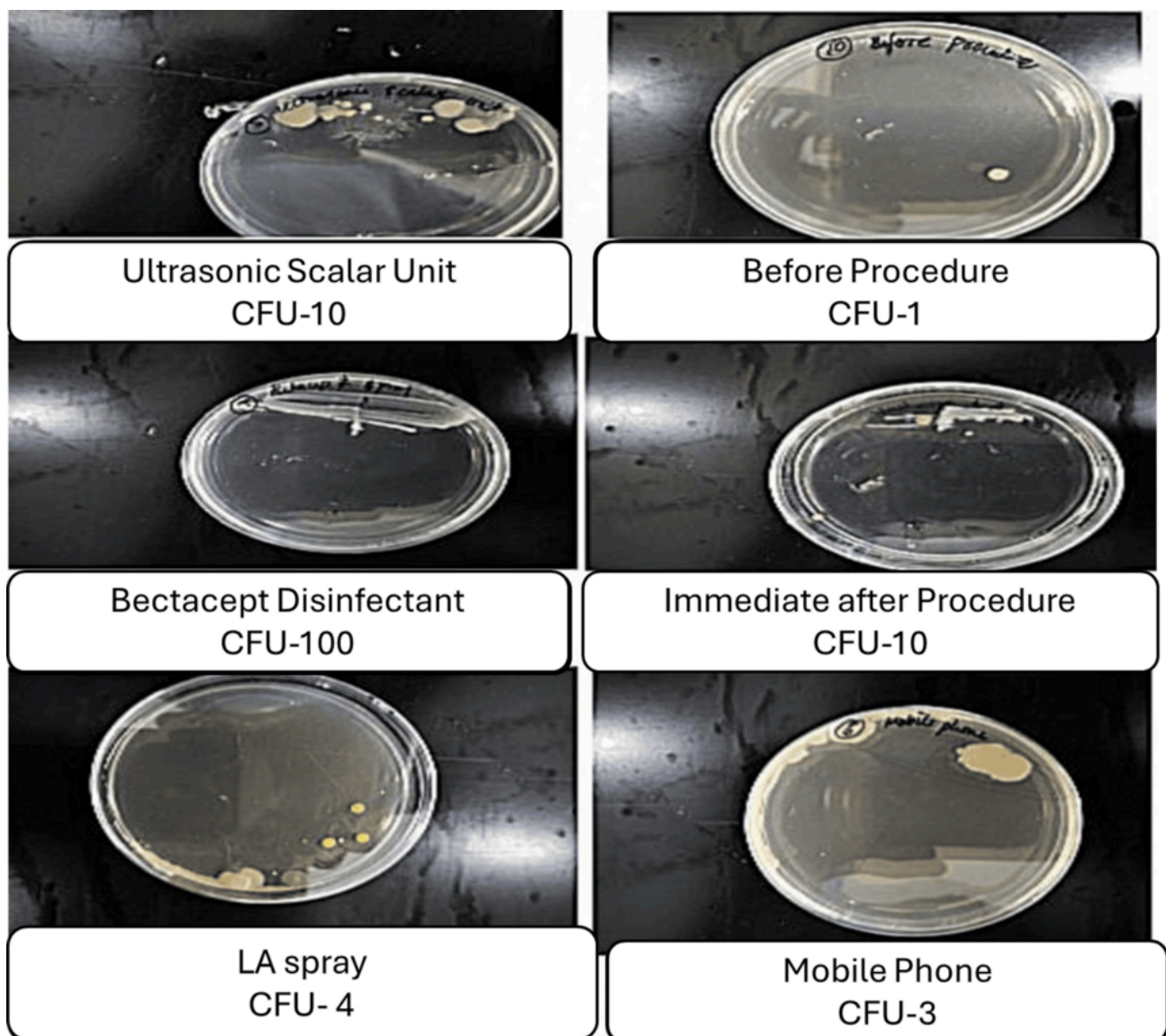


FIGURE 4: Colony forming units (CFUs) of the hand-touched inanimate surfaces before intervention

Results

Before intervention, all surfaces showed heavy microbial contamination, especially the dental sitting chair (100 CFU), ultrasonic scaler (100 CFU), mobile phone (100 CFU), Bectacept (100 CFU), instrument trolley (150 CFU), and LA Cartridge (ASPERGILLUS) shown in Figure 4. This confirms that dental operatory surfaces are highly contaminated during routine use and require effective disinfection.

Bectacept reduced microbial load initially, but significant regrowth occurred within 24-48 hours, particularly on dental sitting chair, ultrasonic scaler, mobile phone, and instrument trolley (60-150 CFU). After 24 and 48 hours without intervention, microbial growth increased exponentially, confirming that surfaces act as reservoirs of cross-contamination shown in Figure 5.

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In contrast, the novel disinfectant reported 100% reduction in CFUs on all surfaces, demonstrating superior antimicrobial efficacy immediately and at 24 and 48 hours after novel disinfectant application. The novel disinfectant maintained complete inhibition (0 CFU) across all surfaces even at 48 hours shown in Figure 6.

Surfaces	Baseline	Immediate after bectaccept application	24hrs	48hrs
LA Spray	4	2	0	0
Dental sitting chair	100	70	80	5
Curing Light	2	1	10	10
Dental chair	10	8	10	0
Ultrasonic scaler	100	50	80	90
Mobile phone	100	60	100	150
Bectaccept	100	70	500	600
Post procedure	10	7	10	10
L A cartridge	1(Aspergillus)	1	100	1000
Before Procedure	1	0	0	20
Instrument trolley	150	80	80	100

FIGURE 5: CFUs at baseline, immediately after, 24 and 48 hours after Bectaccept application

CFU, colony-forming unit

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Surfaces	Baseline	Immediate after Novel disinfectant application	24hrs	48hrs
LA Spray	3	No growth	No growth	No growth
Dental sitting chair	100	No growth	No growth	No growth
Curing Light	5	No growth	No growth	No growth
Dental chair	20	No growth	No growth	No growth
Ultrasonic scaler	120	No growth	No growth	No growth
Mobile phone	80	No growth	No growth	No growth
Bectacept	100	No growth	No growth	No growth
Post procedure	10	No growth	No growth	No growth
L A cartridge	1	No growth	No growth	No growth
Before Procedure	10	No growth	No growth	No growth
Instrument trolley	160	No growth	No growth	No growth

FIGURE 6: CFUs at baseline, immediately after application, and at 24 and 48 hours after the novel disinfectant application

CFU, colony-forming unit

Discussion

Infection control in dentistry has traditionally relied on rapid-acting disinfectants, primarily alcohol-based formulations. While these agents are effective for immediate microbial kill, their short-lived antimicrobial action, rapid evaporation, and dependence on operator compliance remain problematic [12]. The current study demonstrated that the novel disinfectant provided extended antimicrobial protection compared to conventional products, supporting a paradigm shift toward residual-effect disinfectants. Such agents reduce the need for frequent reapplication, potentially improving workflow efficiency and minimizing lapses in compliance in high-turnover clinical settings. Prolonged antimicrobial activity is particularly relevant in operatories where surfaces are frequently re-contaminated between patients, posing a continuous risk of cross-infection [13].

Recent advances in nanotechnology, polymer science, and biomaterial engineering have enabled the development of disinfectants and coatings with dual functionality: immediate microbial kill and prevention of biofilm re-formation [14]. These technologies offer not only enhanced microbial suppression but also surface-modifying properties that reduce microbial adhesion, thereby extending the protective effect. Integration of such innovations into dental practice could represent the next generation of infection control protocols, aligning safety, efficiency, and sustainability.

A notable advantage of the novel disinfectant evaluated in this study was its compatibility with dental operator surfaces and equipment, minimizing risks of corrosion, discoloration, or material degradation, which are common limitations associated with repeated alcohol use. By preserving the integrity and longevity of dental equipment, such agents may offer both clinical and economic benefits, reducing maintenance costs and extending equipment lifespan [15].

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The broader implications extend beyond dentistry. The COVID-19 pandemic underscored the vulnerability of healthcare workers to both airborne and fomite-mediated transmission of pathogens, highlighting the urgent need for innovative infection control solutions [16]. Incorporating disinfectants with residual antimicrobial activity into updated healthcare guidelines could provide enhanced protection in high-exposure environments such as dental operatories, surgical suites, and intensive care units [17].

Nevertheless, some limitations warrant consideration. Long-term safety and toxicity assessments are essential to confirm biocompatibility and ensure that extended exposure does not pose occupational or environmental hazards. Continuous resistance surveillance is necessary to prevent the emergence of disinfectant-tolerant microbial strains. Furthermore, large-scale, multicenter real-world clinical trials are needed to validate laboratory findings and establish standardized application protocols. Future research should also explore synergistic disinfection strategies, combining rapid-action agents for immediate microbial kill with residual-effect formulations for sustained protection, thereby achieving a comprehensive and robust infection control framework.

Conclusions

The novel chair-side antimicrobial system showed higher antimicrobial efficacy and residual action. Surfaces like the dental sitting chair, ultrasonic scaler, mobile phone, LA cartridge, and instrument trolley showed high CFU counts with Bectacept (up to 100 CFU). The novel disinfectant reported 100% reduction in the CFU on all surfaces, demonstrating higher antimicrobial efficacy even within 24 hours. With Bectacept, contamination persisted and even increased on certain surfaces such as instrument trolley (150 CFU), LA cartridge (100 CFU), and dental chair (80 CFU) after 48 hours. The novel disinfectant maintained complete inhibition (0 CFU) across all surfaces even at 48 hours. It presents a promising alternative to conventional surface disinfectants for improving infection control in dental environments. Further research into long-term efficacy, resistance potential, and safety is warranted before widespread adoption.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Prakash Punj, Lavanya R, Greeshma C, Tushar Shaw, Mahantesha Sharanappa

Acquisition, analysis, or interpretation of data: Prakash Punj, Lavanya R, Greeshma C, Tushar Shaw, Mahantesha Sharanappa

Drafting of the manuscript: Prakash Punj, Lavanya R, Greeshma C, Tushar Shaw, Mahantesha Sharanappa

Critical review of the manuscript for important intellectual content: Prakash Punj, Lavanya R, Greeshma C, Tushar Shaw, Mahantesha Sharanappa

Supervision: Lavanya R, Greeshma C, Tushar Shaw, Mahantesha Sharanappa

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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