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Antimicrobial Activity of Ceramir CAD/CAM Blocks

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Abstract

Background: Modern restorative dentistry increasingly demands materials that not only mimic natural tooth structure but also offer antimicrobial protection. This study investigates the antimicrobial properties and microbial safety of these blocks using standard in vitro methods.

Objective: To evaluate the antimicrobial efficacy and microbial compliance of Ceramir CAD/CAM blocks against key oral pathogens.

Methods: The cured Ceramir CAD/CAM blocks were tested against *Streptococcus mutans* and *Lactobacillus acidophilus* using disc diffusion, antibiofilm assays, and bacterial growth curve analysis. Microbial limit testing was performed per United States Pharmacopeia (USP) guidelines using the pour plate method on Soybean Casein Digest Agar (SCDA) and Sabouraud Dextrose Agar (SDA).

Results: The material demonstrated significant inhibition of bacterial growth in liquid culture, with reduced optical densities for both pathogens in the presence of the blocks. Antibiofilm assays confirmed visibly reduced biofilm formation. No fungal growth was observed on SDA, and SCDA showed minimal bacterial counts at high dilutions (12.5 CFU/mL at 10^7), affirming microbial safety.

Conclusion: Ceramir CAD/CAM blocks exhibit strong in vitro antimicrobial properties, particularly against gram-positive bacteria, while maintaining compliance with microbial safety standards. Further clinical validation is recommended.

Keywords: Antibiofilm, CAD/CAM blocks, Ceramir, Fluoride, Zinc oxide

Introduction

Over the years, the evolution of dental materials has significantly advanced restorative dentistry, enabling clinicians to provide functionally superior and aesthetically pleasing restorations.[1] Despite these advancements, the pursuit of materials that mimic the mechanical and biological properties of natural teeth while also offering antibacterial protection continues to be a topic of ongoing research.[1,2]

Most traditional CAD/CAM blocks are composed of dental materials engineered for optimal mechanical strength and esthetics; however, they often exhibit limited or inconsistent antibacterial properties. This limitation becomes critical in patients at high risk for dental caries, where bacterial infiltration can compromise both treatment longevity and overall oral health. As noted by Ramburrun et al [1], lithium disilicate ceramics and hybrid composites demonstrate minimal antibacterial activity, limited biofilm inhibition, and insufficient remineralization potential. Ceramir CAD/CAM blocks (edelweiss dentistry products, GmbH, Wolfurt, Austria) address

these clinical challenges by incorporating zinc oxide nanoparticles—which disrupt bacterial membranes—and fluoride, which suppresses acidogenic bacteria while promoting enamel remineralization. The combination of these components, together with an ultrasmooth sintered surface that minimizes microbial adherence, results in a restorative material that not only offers strength and durability but also contributes to the prevention of dental disease.

To validate these properties, microbiological testing of Ceramir CAD/CAM blocks was performed against key oral pathogens, including *Streptococcus mutans*, *Lactobacillus acidophilus*. These microorganisms are recognized contributors to cariogenesis, periodontal disease, and oral biofilm formation.[7–9] Moreover, adherence to United States Pharmacopeia (USP) microbiological guidelines(60) ensures the safety and biocompatibility of these materials, aligning them with the rigorous standards required for clinical applications.[10]

This study presents the antimicrobial profile of Ceramir CAD/CAM blocks and provides an update on their place within the landscape of antimicrobial-enriched, and biocompatible CAD/CAM materials.

Materials and Methods

Test Material

Ceramir CAD/CAM blocks were used as the test material in this study to assess its antimicrobial and antibiofilm properties. The detailed composition of experimental test sample is shown in Table 1.

Table 1: Relative elemental composition of the Ceramir CAD/CAM Blocks (edelweiss dentistry products, GmbH, Wolfurt, Austria)

Sample Cohort	Aluminum*		Zinc*		Barium*		Silicon*		Fluoride**	
	mg/L	% (w/w)	mg/L	% (w/w)	mg/L	% (w/w)	mg/L	% (w/w)	mg/L.	% (w/w)
Pre-curing	550.44	53.8	165.64	16.2	9.42	0.92	13.30	1.53	95.41	9.3
Post-curing	446.78	50.7	133.58	15.2	7.72	0.88	10.82	1.47	90.61	8.9
% Difference	18.83	5.76	19.36	6.17	18.05	4.35	18.65	3.92	5.03	4.30

* Assessed using Inductively Coupled Plasma Mass Spectroscopy; ** assessed using ion chromatography.

Microbial Strains and Culture Conditions

Gram-positive bacterial strains *Streptococcus mutans* (Accession No. OQ947767) and *Lactobacillus acidophilus* (Accession No. NZ_CP130437) were used as representative oral pathogens. Both strains were cultured in Luria-Bertani (LB) broth (pH 7.0) at 37°C for 15 hours before experimental use.

Antimicrobial Activity: Disc Diffusion Assay

To assess antimicrobial potential, the disc diffusion method was employed. Briefly, individual bacterial colonies were streaked onto LB agar plates. Blocks containing Ceramir CAD/CAM material were placed on the agar surface. Plates were incubated at 37°C for 24 hours. Zones of inhibition (if any) were measured. Standard antibiotic discs served as positive controls, and plates without any discs served as negative controls.

Antibiofilm Assay

The antibiofilm properties of the material were examined using the crystal violet staining method. Discs of cured Ceramir CAD/CAM material were placed in 6-well polystyrene plates containing 2 mL of nutrient broth inoculated with 1×10^6 CFU/mL of *S. mutans* or *L. acidophilus*. Plates were incubated at 37°C for 72 hours. Post-incubation, the surfaces of the materials were washed, stained with 0.04% crystal violet, and observed under a binocular light microscope (Labomed, India) at 40× magnification. The treated groups showed a marked reduction in biofilm formation, suggesting effective antibiofilm activity likely facilitated by the immersion method and improved dispersibility of potential antimicrobial agents in liquid medium.

Bacterial Growth Curve Assay

To further evaluate antimicrobial effects, bacterial growth curves were generated in the presence and absence of the test material. Bacterial cultures were incubated at 37°C in LB broth, and optical density (OD) at 600 nm was recorded every 2 hours for 24 hours. In control groups, *S. mutans* and *L. acidophilus* showed peak OD_{600} values of 1.50 and 1.60 respectively at 8 hours. In the presence of the cured material, peak OD_{600} values reduced to 0.70 (*S. mutans*) and 0.85 (*L. acidophilus*), indicating significant inhibition of bacterial growth, with a slightly higher effect observed against *S. mutans*.

Microbial Limit Testing as Per USP Guidelines

Microbiological testing of Ceramir CAD/CAM blocks was performed at Accuprec Research Labs Private Limited, Ahmedabad, in accordance with the United States Pharmacopeia (USP) guidelines for microbial enumeration. The pour plate method was used to quantify Total Aerobic Microbial Count (TAMC) and Total Combined Yeast and Mold Count (TYMC).

A test sample was prepared by homogenizing Ceramir material at a concentration of 10.64 g/mL in 90 mL of sterile diluent, creating a 1:10 dilution (Homogenate-A). Serial dilutions from 10^2 to 10^7 were prepared. From each dilution, 1.0 mL aliquots were inoculated onto Soybean Casein Digest Agar (SCDA) for TAMC and Sabouraud Dextrose Agar (SDA) for TYMC. Plates were incubated at 30–35°C for 3–5 days (TAMC) and 20–25°C for 5–7 days (TYMC), after which colony-forming units per millilitre (CFU/mL) were recorded.

Results

Bacterial Growth Curve Analysis

The antimicrobial activity of Ceramir CAD/CAM material was assessed by monitoring bacterial growth curves for Streptococcus mutans and Lactobacillus acidophilus over 14 hours. In the control group, S. mutans showed typical exponential growth, reaching a peak OD600 of 1.537 at 8 hours. In the presence of the test material, the OD600 peaked at only 0.708, indicating substantial inhibition (Figure 1). A similar trend was observed for L. acidophilus, where the control group peaked at OD600 1.690, while the inhibition group showed a reduced OD600 of 0.853 (Figure 2). These findings confirm that the material inhibits bacterial growth significantly, with a slightly greater effect on S. mutans than on L. acidophilus.

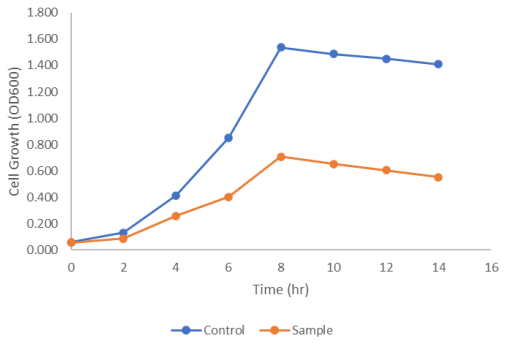

Figure 1: Growth curve of Streptococcus mutans monitored over 14 hours.
The control group (without Ceramir CAD/CAM) exhibited normal exponential growth peaking at OD600 = 1.537 at 8 hours. The inhibition group (with Ceramir CAD/CAM material) showed significantly reduced growth, peaking at OD600 = 0.708.

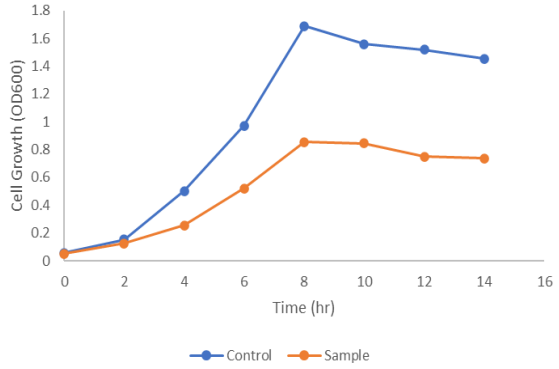

Figure 2: Growth curve of Lactobacillus acidophilus monitored over 14 hours.
The control group showed typical bacterial proliferation (peak OD600 = 1.690), while the inhibition group treated with Ceramir CAD/CAM material exhibited suppressed growth (peak OD600 = 0.853).

Disc Diffusion Assay

Disc diffusion plates were used to assess surface antimicrobial activity. Zones of inhibition were observed around standard antibiotic discs but not around Ceramir CAD/CAM blocks, confirming the limited leaching of antimicrobial components into solid media. These results are depicted in Figures 3 and 4.

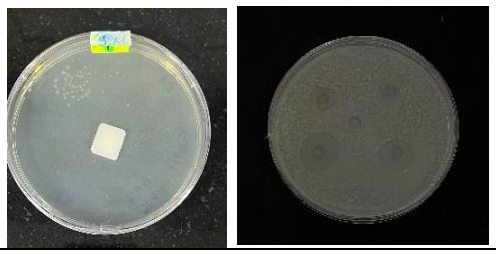

Figure 3: Disc diffusion assay for Streptococcus mutans showing zone of inhibition around standard antibiotic discs.
No inhibition zone is observed around the cured Ceramir CAD/CAM material, indicating limited surface diffusion in solid medium.

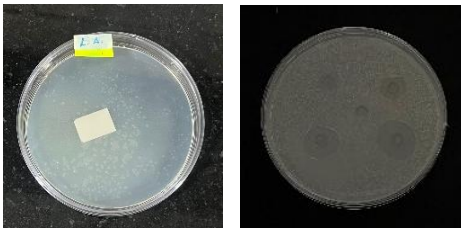

Figure 4: *Disc diffusion assay for* Lactobacillus acidophilus
Zone of inhibition observed only around standard antibiotic controls.

Antibiofilm Assessment

Biofilm formation was studied using crystal violet staining on the material surface after immersion in bacterial cultures for 72 hours. Microscopic observations revealed substantially reduced biofilm accumulation on Ceramir CAD/CAM surfaces compared to typical biofilm growth patterns, as seen in Figures 5 and 6.

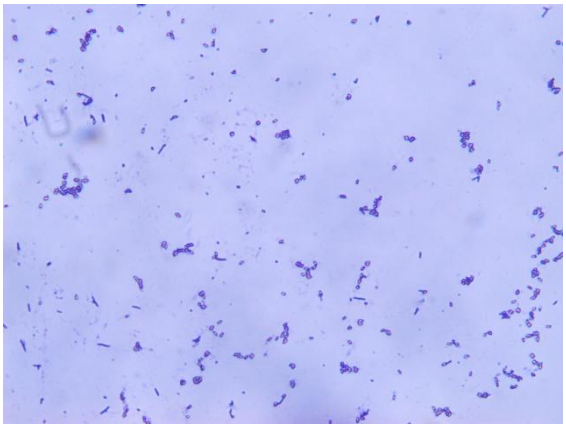

Figure 5: ***Microscopic view of*** **Streptococcus mutans** ***biofilm on cured Ceramir CAD/CAM surface after 8 hours in nutrient broth.***
Crystal violet staining reveals substantially reduced biofilm accumulation compared to control.

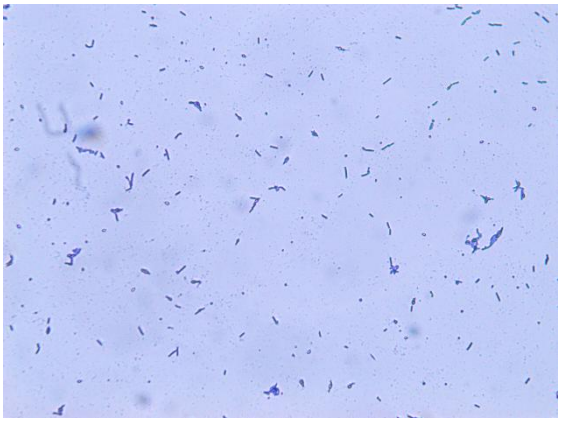

Figure 6: Microscopic view of Lactobacillus acidophilus biofilm on cured Ceramir CAD/CAM surface.
Minimal crystal violet uptake reveals effective antibiofilm activity

Microbial Enumeration Assay

Serial dilution pour plate assays revealed no microbial colonies in SCDA plates for 10^2–10^4 dilutions. TNTC (Too Numerous to Count) colonies were observed at 10^5 and 10^6, while the 10^7 dilution showed an average of 12.5 CFU/mL. SDA plates showed no growth across all dilutions, indicating the absence of yeast and mold contamination. Positive and media controls validated the integrity of the experimental procedures.

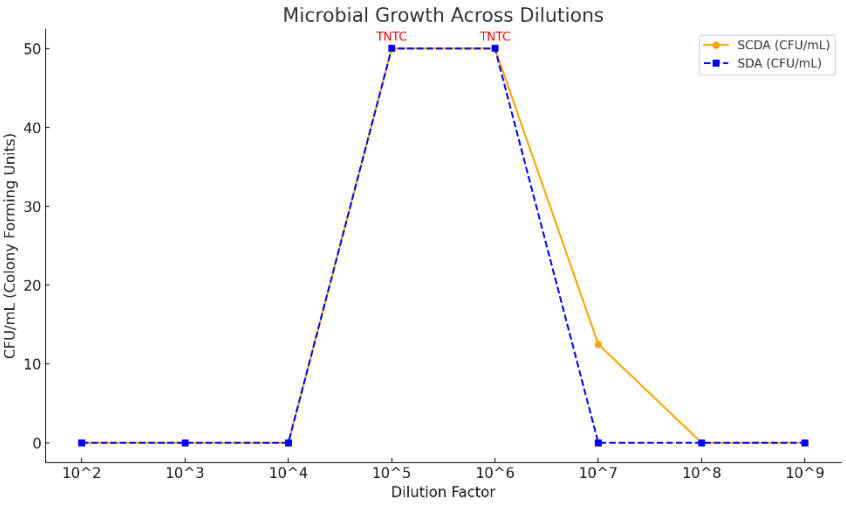

Figure 7: Microbial growth across serial dilutions.
TNTC: too numerous to count; SCDA: Soybean Casein Digest Agar; SDA (Sabouraud Dextrose Agar).

Overall, these results validate the microbial safety of Ceramir CAD/CAM blocks and demonstrate broad-spectrum antibacterial efficacy.

Discussion

This study evaluated the antimicrobial properties and microbial safety of Ceramir CAD/CAM blocks, with results confirming both efficacy and compliance with USP microbiological standards. The absence of fungal growth on Sabouraud Dextrose Agar (SDA) and minimal aerobic bacterial growth on Soybean Casein Digest Agar (SCDA) at high dilutions (notably 12.5 CFU/mL at 10^7) highlight the material's antimicrobial behavior.

These outcomes are consistent with the expected performance of Ceramir, which incorporates zinc

oxide (ZnO) nanoparticles and fluoride—two agents known for their complementary antimicrobial and remineralizing actions. Zinc oxide disrupts bacterial membranes, impairs metabolic functions, and inhibits biofilm formation, while fluoride aids in remineralization and limits bacterial acid production.[6]

The advanced manufacturing process of Ceramir, particularly high-temperature sintering, results in a densely compacted, non-porous microstructure with an exceptionally smooth surface finish.[11,12] This smoothness reduces the likelihood of bacterial adhesion and plaque retention—a feature critical to resisting early biofilm colonization. When coupled with zinc oxide's antimicrobial action[13], this physical barrier enhances the material's resistance to microbial infiltration and secondary caries development.

The significantly lower CFU/mL observed at 10^7 dilution reaffirms Ceramir's capability to inhibit bacterial proliferation, especially against gram-positive organisms such as Streptococcus mutans, and Lactobacillus spp., which are pivotal in dental caries and early plaque biofilm development. Furthermore, the absence of yeast and mold across all tested dilutions confirms Ceramir's broad-spectrum efficacy and fungal resistance.

In comparison with other CAD/CAM materials summarized in Table 2, Ceramir CAD/CAM blocks exhibit a unique profile.[12] While materials such as Shofu Block HC may offer some degree of fluoride release, their antimicrobial efficacy is either limited or primarily attributed to external factors such as the bonding cement rather than the block itself. In contrast, Ceramir's zinc oxide and fluoride content actively counters microbial colonization.

Table 2: An overview of CAD/CAM Blocks with Antimicrobial Properties[12, 14-17]

CAD/CAM Block	Antimicrobial Agent	Proposed Mechanism	Main Target Microorganisms	Additional Claimed Benefits
Ceramir CAD/CAM (edelweiss dentistry products, GmbH, Wolfurt, Austria)	• Zinc oxide • Fluoride	Alkaline pH, ion release disrupting membranes and inhibiting biofilm formation.	S. mutans, P. gingivalis	Biocompatible, Flexible and highly polishable
CeraSmart (GC)	• Fluoride	Fluoride ion may reduce bacterial metabolism and acid production	S. mutans, Lactobacillus spp.	Resin nano-ceramic; flexible and polishable
Lava Esthetic (3M)	-	No intrinsic antimicrobial agent; fluoride possible via cement, not block	None directly stated	High esthetics, radiopacity, fluorescence
IPS e.max CAD (Ivoclar Vivadent)	-	-	No direct data	High strength and esthetics; not inherently antimicrobial
Shofu Block HC	• Fluoride • Strontium • Borate	Releases F^-, Sr^{2+}, BO_3^{3-} ions — modulates pH and inhibits bacteria	S. mutans, Actinomyces spp., Lactobacillus spp.	Resin-based, radiopaque, proven bioactivity

Another distinction is the absence of bisphenol-A-glycidyl methacrylate (BIS-GMA) and other monomer-based resins in Ceramir.[12] This composition enhances long-term biocompatibility, minimizes the risk of leaching toxic substances, and positions Ceramir as a safer and more environmentally responsible alternative for restorative dentistry.

Importantly, the observed antimicrobial activity of Ceramir appears most pronounced against gram-positive pathogens, consistent with zinc oxide's mode of action targeting thick peptidoglycan cell walls. This targeted inhibition supports the material's potential clinical utility in high-caries-risk patients or those with a predisposition to periodontal conditions. Compared to widely used materials (Table 2), Ceramir integrates active antimicrobial strategies with sintered surface modification to provide a dual-function restorative platform—offering both disease prevention and structural resilience.

This in vitro research demonstrates strong antimicrobial properties and microbial safety of Ceramir CAD/CAM blocks yet it requires consideration of several important limitations. The

antimicrobial research analyzed only two clinically important but limited bacteria strains (Streptococcus mutans and Lactobacillus acidophilus) from the abundant oral microbial ecosystems. The study results become less applicable because it did not include gram-negative anaerobes and neglected to use models that replicate multiple bacterial species growing together in biofilms. The research limitations stem from the fact that the entire investigation took place in laboratory settings and excluded critical in vivo or clinical testing that would assess how well the materials function over time as well as their antimicrobial durability and how the host tissues react in real oral environments. The evaluation failed to correlate antimicrobial effectiveness with mechanic and aesthetic properties needed to attain complete clinical validation. Future research needs to expand its utilization of microbial panels and introduce both controlled clinical tests and study various biofilm stages to effectively validate these findings for dental practice.

Overall, the findings suggest that Ceramir CAD/CAM blocks are well-suited for long-term restorative use, particularly in cases where minimizing microbial contamination is essential. However, it is important to acknowledge that while in vitro results are promising, clinical studies with long-term follow-up are needed to validate these effects in vivo.

Conclusion

Ceramir CAD/CAM blocks demonstrate significant antimicrobial efficacy, particularly against aerobic, gram-positive bacteria, and show complete resistance to fungal contamination. By combining biocompatibility, antimicrobial action, and advanced manufacturing, Ceramir represents a next-generation solution for safe, durable, and health-promoting dental restorations.

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