ASDJ
AINSHAMS DENTAL JOURNAL

Print ISSN 1110-7642
Online ISSN 2735-5039

AIN SHAMS DENTAL JOURNAL
Official Publication of Ain Shams Dental School
June2025 • Vol. 38

The Effect of Sodium Bicarbonate as a Disinfectant Solution on a Study Cast

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Aim: Dental impressions and stone casts are potential sources of cross-contamination in dental practice, as they can harbor pathogenic microorganisms.
Materials and Methods: This study included 60 stone cast samples, divided into four groups: three experimental groups treated with sodium bicarbonate at concentrations of 8.4%, 4.2%, and 2.1%, and a control group with no treatment. Each experimental group was permitted to rest for thirty minutes after applying the corresponding sodium bicarbonate solution. Microbial swabs collected from the castings post-disinfection were cultured on selective media: Mannitol salt agar for Staphylococcus aureus and Lactobacillus, and Mitis-Salivarius agar for Streptococcus mutans.To evaluate the antibacterial efficacy of sodium bicarbonate solutions, the colony-forming units of each microorganism were enumerated and compared across the groups.
Results: The finding showed a decrease significantly ($p<0.05$) in CFU counts for all three microorganisms in the sodium bicarbonate-treated groups compared to the control group. The highest concentration of sodium bicarbonate (8.4%) demonstrated the most pronounced antimicrobial effect, with mean CFU counts dropping to 0.028×10^6 CFU/mL for *Streptococcus mutans*, 0.312×10^6 CFU/mL for *Lactobacillus*, and 0.215×10^6 CFU/mL for *Staphylococcus aureus*. The lower concentrations (4.2% and 2.1%) also showed significant reductions, though to a lesser extent ($p< 0.05$).
Conclusion: Sodium bicarbonate, particularly at higher concentrations, is an effective disinfectant for dental stone casts, significantly reducing the microbial load of *Streptococcus mutans*, *Lactobacillus*, and *Staphylococcus aureus*. Its antimicrobial action, attributed to its alkaline nature and the release of carbon dioxide, makes it a viable alternative to more toxic disinfectants.

Keywords: microorganism, sodium bicarbonate, study cast

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Introduction

Many of the bacteria, fungus, and viruses found in the oral environment have been connected to either crippling or fatal disorders. Thus, every effort should be directed towards avoiding cross-contamination of these bacteria and stopping any disease transmission in the oral environment.[1] Both the dental office and the dental laboratory rely on the establishment and maintenance of comprehensive and effective infection control measures. These activities must be monitored and scrutinised to ensure they align with contemporary norms.[2]

Employees at a dental practice could not follow advised procedures for sterilising impressions and other objects coming into touch with a patient. Sixty-seven percent of the items submitted by Powell et al.[3] to laboratories exhibited the presence of several bacteria, including Enterobacter cloacae, Escherichia coli, and Klebsiella oxytoca. Leung et al.'s studies.[4] demonstrate that bacteria may be measured and transferred from contaminated impressions to the surface of the cast. The American Dental Association (ADA) and the Centres for Disease Control and Prevention have supported immersion in or spraying with a disinfectant as procedures for sterilising dental casts. It is essential that these materials do not impact dimensional precision. Alternative disinfection procedures for castings include integrating chemicals into gypsum during the mixing process or using die stone infused with disinfectant. Nevertheless, these techniques have been shown to influence mechanical qualities, including setting time, compressive strength, and dimensional precision.[5] Ivanovski et al. [6] found 2% glutaraldehyde to be the most effective disinfectant with the least adverse effects on the physical properties of a cast.

Sodium bicarbonate ($NaHCO_3$), commonly known as baking soda, is quite familiar among people due to its various uses and properties. One of the primary applications of sodium bicarbonate is the eradication of odours from objects, hands, or skin. Sodium bicarbonate decomposes upon heating to provide carbon dioxide and water. Cakes are leavened by the production of carbon dioxide foam resulting from this decomposition process. Heating sodium bicarbonate facilitates the formation of a porous structure in cakes, yielding a soft and spongy texture. In addition to its culinary function, sodium bicarbonate has several supplementary uses and attributes, including body neutralization capabilities and infection control. Negative moulds, used in many facial and dental investigations, are also fabricated from sodium bicarbonate. Sodium bicarbonate solution is often used as a disinfectant to sanitise items, including dentures. This process requires immersing the artificial teeth in a sodium bicarbonate solution for a certain duration to ensure adequate sterilization. [7]

Sodium Hypochlorite (NaOCl) is a chemical that is commonly used to disinfect items and has a good effective killing of bacteria. Nevertheless, NaOCl is a strong alkaline and can cause soft and hard tissue irritation, necrosis, abscess formation, and the most serious complication is sudden catheterization and upsets the hemodynamic stability. The complications that were mentioned previously might cause airway closure and lead to death. Hence, it is necessary to find an alternative solution that can be used in our daily life to avoid the harmful effects of using NaOCl. The use of sodium bicarbonate offers promise in maintaining hygiene and safety without the risks posed by sodium hypochlorite. Through comprehensive testing and evaluation, we aim to demonstrate the effectiveness of sodium bicarbonate as a viable alternative in disinfection applications. [8] Disinfectant solutions must be antimicrobial and not deteriorate gypsum castings. Studies reveal that sodium hypochlorite disinfects germs and viruses, including HIV and hepatitis B, in less than 30 minutes. Another benefit of sodium hypochlorite solution is its inexpensive cost.

However, its weak stability requires daily preparation to maintain effectiveness.

Streptococcus mutans is a Gram-positive, facultatively anaerobic bacterium commonly found in the human oral cavity. It is a primary contributor to dental caries (tooth decay) due to its ability to metabolize sugars and produce acid, which demineralizes tooth enamel. *S. mutans* forms biofilms on tooth surfaces, known as dental plaque, and thrives in acidic environments. It produces extracellular polysaccharides that enhance its adherence to teeth and promote plaque formation. The bacterium, often transmitted from mother to offspring, is present in saliva. Decreased sugar intake and proper oral cleanliness will aid in preventing its progression. [9] Studies on *S. mutans* keep looking at its part in oral health and possible preventative actions. [10]

Lactobacillus is a genus of Gram-positive, rod-shaped bacteria often found in several ecosystems, including the human digestive, urinary, and genital systems. These bacteria are recognised for their capacity to convert carbohydrates into lactic acid, hence maintaining an acidic environment and inhibiting the proliferation of harmful illnesses. [11] Yoghurt, cheese, and sauerkraut, along with other fermented foods, are mostly produced using Lactobacillus species. Moreover, the qualities of probiotics are fundamental elements that improve gut health and strengthen the immune system. Certain kinds of Lactobacillus bacteria, notably Lactobacillus acidophilus and Lactobacillus rhamnosus, have been specifically examined for their health advantages, including enhancing digestion and reducing infections, and are widely regarded as benign and advantageous for human health. [8]

Staphylococcus aureus, a Gram-positive bacterium, is often seen on human skin and inside the nasal cavities. From minor dermatological conditions such as boils and impetigo to severe diseases including pneumonia, bloodstream infections, and endocarditis, it may result in a range of infections. Certain types produce toxins that induce toxic shock syndrome or foodborne illness. [12] *S. aureus* is known for its ability to develop antibiotic resistance, notably methicillin-resistant *Staphylococcus aureus* (MRSA), which poses significant challenges in healthcare settings. Proper hygiene and infection control measures are crucial to prevent its spread. [13]

The danger of stone cast cross-contamination is very high in prosthodontics since impressions, record bases, occlusion rims, and trial dentures may transmit pathogenic organisms from blood and saliva. Stern et al. [14] suggest that it may be essential to disinfect the definitive cast a minimum of seven times (60 minutes each) using either iodophor or phenol disinfectants from the moment of creation until the placement of full or detachable partial prosthesis.

Aim of study

This study aimed to discover the effect of sodium bicarbonate as a disinfectant solution for the cast, which is the main medium for bacteria nesting before setting up the prosthodontic appliance. The different types of disinfectant solutions were then compared to see if there was any capability of inhibiting the growth of potentially implanted bacteria. If such a capability existed, what was the degree of effectiveness of the disinfectant solutions in being a bactericidal or bacteriostatic compound for several concentrated bacterial colonies and species that nested on the cast. Finally, was it significantly different.

Materials and methods:

(60) samples prepared for this study as following

(15) samples control group: no treatment

(15)samples sprayed with 8.4% sodium bicarbonate and waiting for 30 minutes

(15)samples sprayed with 4.2% sodium bicarbonate and waiting for 30 minutes

(15)samples sprayed with 2.1% sodium bicarbonate and waiting for 30 minutes
These concentration of diluted sodium bicarbonate obtained by addition three different concentration we weight it by using a sensitive electronic scale(w/v) (8.4, 4.2, 2.1)mg per I00 ml of distill water respectively figure(1) and then take impression for patients and poured the impression with stone type III Zhermack company and after setting 30 minutes remove the stone cast from the impression and sprayed the stone cast with sodium bicarbonate and waiting about 30 minutes to take swab by using disposable cotton swab with transport media figure(2)

Figure 1: sodium bicarbonate weighing by sensitive electronic scale

Figure 2: sprayed the stone cast with sodium bicarbonate and waiting about 30 minutes to take swab by using disposable cotton swab with transport media

The three examined bacteria were obtained from patient samples at the teaching hospital of the College of Dentistry at Al-Iraqia University in Baghdad, Iraq. A standardised inoculum of bacteria was used for each kind of susceptibility test for both the bacterial solution and the yeast preparation. The normal inoculum preparation resulted in a turbidity of 1.5 × 10^8 colony-forming units (CFU/ml), corresponding to 0.5 McFarland. The Mueller–Hinton broth was used for the culture and incubation of all microorganisms for 24 hours. [15]

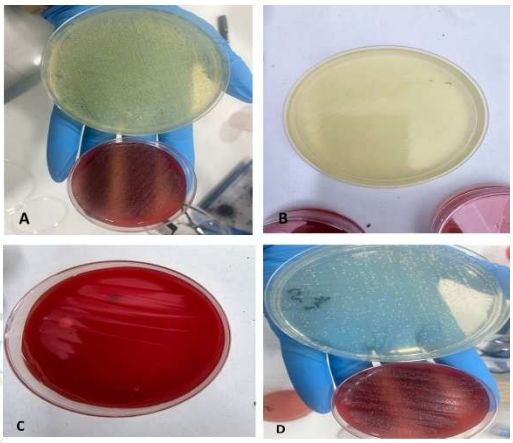

Figure 3: Antimicrobial efficiency test for different microorganisms. (A) Control group no treatment, (B) 8.4% sodium bicarbonate for 30 min, (C) 4.2% sodium bicarbonate for 30 min,and (D) 2.1% sodium bicarbonate for 30 min group.

Isolation and Identification of Streptococcus mutans, Lactobacillus, and Staphylococcus aureus

Streptococcus mutans:

Isolation:

Mitis-Salivarius agar (MS agar) is a selective and differential media that facilitates the proliferation of Streptococcus mutans. It comprises crystal violet and potassium tellurite to suppress the proliferation of Gram-negative bacteria and additional Gram-positive bacteria. [16]

Identification:

Colony morphology: *S. mutans* colonies on MS agar are small, convex, and typically blue-green with a dark brown halo.

Gram stain: Gram-positive cocci arranged in chains or pairs.

Catalase test: Negative

Other biochemical tests: Sucrose fermentation test (positive) and production of dextran (a sticky polysaccharide) from sucrose. [17]

Lactobacillus:

- **Isolation:**
- Rogosa agar is a selective medium for *Lactobacillus species*. It contains sodium acetate and yeast extract to inhibit the growth of other bacteria. [16]

- **Identification:**

Colony morphology: Lactobacillus colonies on Rogosa agar are small, white, and flat.
Gram stain: Gram-positive rods.
Catalase test: Negative
Other biochemical tests: Acid production from various carbohydrates (glucose, fructose, mannose, etc.). [18]

Staphylococcus aureus:

- **Isolation:** Mannitol salt agar (MSA) serves as a selective and differential media for Staphylococcus aureus. It has elevated salt concentrations (7.5%) to suppress the proliferation of the majority of other microorganisms. [16]

Identification:
Colony morphology: S. aureus colonies on MSA are large, yellow, and surrounded by a yellow zone of acid production due to mannitol fermentation.
Gram stain: Gram-positive cocci arranged in clusters.
Catalase test: Positive
Coagulase test: Positive (confirmatory test for S. aureus). [19]
Note: These are just a few of the tests that can be used to isolate and identify these bacteria. Other tests, such as biochemical tests and molecular methods, may also be used to confirm identification.
The colonies (CFU/ml) on the agar plates were enumerated post-incubation using the following equation. [20]

Numbers of CFU/ml= (number colony*dilution factor)/volume of the culture plate

Results:

Antimicrobial Efficiency Test

The CFU count means of the specimens disinfected with sodium bicarbonate and the control group for the various bacteria (Streptococcus mutans, Lactobacillus, and Staphylococcus aureus) are shown in Table 1 and Figure 3. The findings indicated a decrease in CFU count for all test groups, with the control group exhibiting the highest mean.

The mean value of *Streptococcus mutans* colony-forming units (CFU) in the control group was 15.935 × 10^6 CFU/mL. When treated with different concentrations of $NaHCO_3$, the mean CFU values decreased significantly. For the 8.4% $NaHCO_3$ solution, the mean CFU dropped to 0.028 × 10^6 CFU/mL, for the 4.2% solution, it was 0.267 × 10^6 CFU/mL, and for the 2.1% solution, it was 5.782 × 10^6 CFU/mL. As demonstrated in Table 1 and Figure 1.

Table 1: Descriptive statistics of colony forming unit (CFU) counts/ml × 10^6 for the different disinfectant solutions for streptococcus mutans, lactobacillus and staphylococcus aureus

Microorganism	Disinfectant	Mean	Std. Deviation	Std. Error of Mean	Minimum	Maximum
Streptococcus mutans	Control	15.935000	1.3929427	.3114715	13.9000	19.4000
	NaHCO3 (8.4%) (30min)	.702800	.0397844	.0088961	.6000	.7890
	NaHCO3 (4.2%) (30min)	.826700	.0277889	.0062138	.8000	.8750
	NaHCO3 (2.1%) (30min)	5.078230	9.0248501	2.0180178	1.0015	17.2116
lactobacillus	Control	16.43000	1.811687	.405106	13.600	19.700
	NaHCO3 (8.4%) (30min)	.31285	.021052	.004707	.300	.389
	NaHCO3 (4.2%) (30min)	.15985	.014651	.003276	.100	.169
	NaHCO3 (2.1%) (30min)	2.73480	7.873155	1.760491	.201	10.290
Staphylococcus aureus	Control	15.880000	1.65580319	.37024885	13.50000	19.40000
	NaHCO3 (8.4%) (30min)	.215800	.03860679	.00863274	.13900	.30500
	NaHCO3 (4.2%) (30min)	.126700	.02778887	.00621378	.10000	.17500
	NaHCO3 (2.1%) (30min)	4.22607	7.545565054	1.68723964	.00120	17.01000

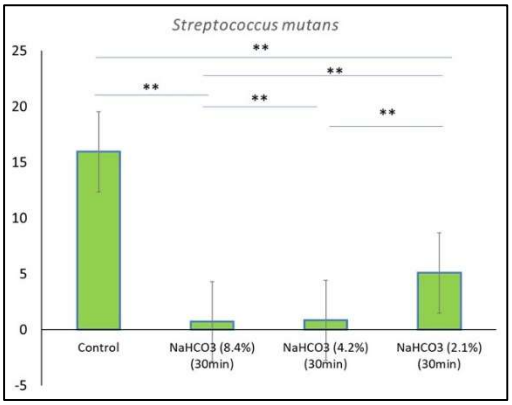

Figure 4: level of Streptococcus mutans in different concentration of NaHCO3

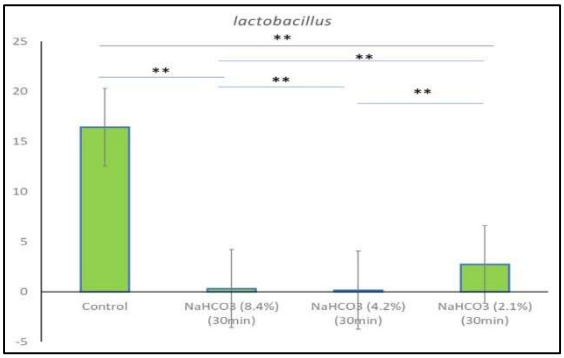

Figure 5: level of lactobacillus in different concentration of NaHCO3

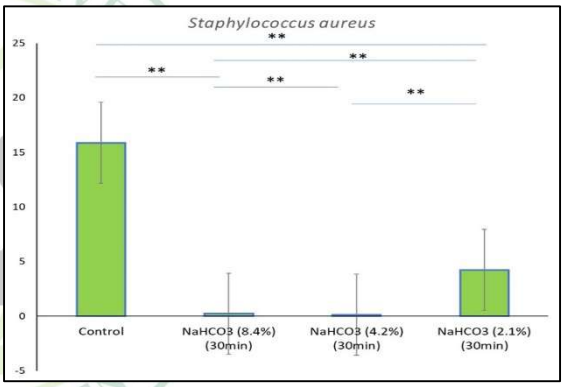

Figure 6: level of Staphylococcus aureus in different concentration of NaHCO3

The mean CFU value for Lactobacillus in the control group was 16.430×10^6 CFU/mL. After treatment with $NaHCO_3$, the mean CFU values decreased significantly. For the 8.4% $NaHCO_3$ solution, the mean CFU was 0.312×10^6 CFU/mL, for the 4.2% solution, it was 0.159×10^6 CFU/mL, and for the 2.1% solution, it was 2.734×10^6 CFU/mL. As shown in Table 2 and Figure 2.

The mean CFU value for Staphylococcus aureus in the control group was 15.880×10^6 CFU/mL. After treatment with $NaHCO_3$, the mean CFU values decreased significantly. For the 8.4% $NaHCO_3$ solution, the mean CFU was 0.215×10^6 CFU/mL, for the 4.2% solution, it was 0.126×10^6 CFU/mL, and for the 2.1% solution, it was 4.226×10^6 CFU/mL. As shown in Table 2 and Figure 3.

Table 2: Statistical analysis by one-way ANOVA of the means of CFU between the different test groups for all three types of microorganisms

Microorganism		Sum of squares	df	Mean square	F	Sig.
Streptococcus mutans	Between groups	3076.927	3	1025.642	49.197	.000
	Within groups	1584.421	76	20.848		
	Total	4661.347	79			
lactobacillus	Between groups	3622.792	3	1207.597	74.007	.000
	Within groups	1240.119	76	16.317		
	Total	4862.911	79			
Staphylococcus aureus	Between groups	3311.213	3	1103.738	73.978	.000
	Within groups	1133.910	76	14.920		
	Total	4445.124	79			

The one-way ANOVA analysis of CFU showed a significant difference between all the test groups for all three types of microorganisms (*Streptococcus mutans, lactobacillus and Staphylococcus aureus*) (*P* value <0.05), as shown in Table 2.

Discussion:

In teeth replacement, items possibly infected with harmful bacteria are transferred between the dental laboratory and the dental clinic. [7] It has been said that certain disinfection protocols must be adhered to in order to prevent cross-contamination. The conventional resolution to this issue in the literature has been the chemical disinfection of impressions and castings, with the effectiveness of these disinfectants being the focus of several investigations.

The results of the present study revealed that sodium bicarbonate ($NaHCO_3$) exhibits significant antimicrobial activity

against Streptococcusmutans, Lactobacillu, and Staphylococcus aureus when used as a disinfectant on dental stone casts. The highest concentration exhibited the most significant antimicrobial action, as seen by a reduction in colony-forming units (CFU) across all tested concentrations of $NaHCO_3$ (8.4%, 4.2%, and 2.1%). These findings endorse the use of sodium bicarbonate as a safe and effective disinfectant in dental practice, aligning with prior study by Ahuja et al. (2024), which demonstrates a significant reduction in microbial load on dental materials without compromising their physical properties. [7] Similarly, Deste et al. (2022) shown that sodium bicarbonate solutions significantly reduced bacterial contamination on dental prostheses, hence corroborating the results of the current study.[8] In addition, Silhacek & Taake, (2005) demonstrated that sodium bicarbonate significantly inhibits the proliferation of Streptococcus mutans when combined with hydrogen peroxide. [9]

The alkaline nature of sodium bicarbonate elucidates its antibacterial properties by disrupting the microbial habitat inside cells. The elevated pH of $NaHCO_3$ disrupts microbial cell membrane integrity and enzymatic function, resulting in cell death. Montville and Shih (1991) noted that sodium bicarbonate decreases the surrounding pH, so creating an inhospitable environment for microbial life and thereby restricting the development of mycotoxinogenic fungi. [21] Moreover, the release of carbon dioxide during the decomposition of sodium bicarbonate may elucidate its antibacterial properties by creating an inhospitable environment for microbial organisms. This method aligns with the findings of Ivanovski et al. (1995), who demonstrated that sodium bicarbonate, along with other alkaline disinfectants, effectively reduces microbial contamination on dental casts. [12]

However, Stern et al. (1991) noted that sodium bicarbonate had less antibacterial action than other disinfectants such sodium hypochlorite and glutaraldehyde. [14] They proposed that while sodium bicarbonate is less detrimental and more accessible, its antibacterial efficacy may be insufficient for high-level disinfection in some clinical settings. Differences in experimental conditions—such as the amount of $NaHCO_3$ used or the types of bacteria examined—may account for this discrepancy. Similarly, Pakdin et al. (2016) found that while sodium bicarbonate decreased microbial contamination, it was less effective than other disinfectants such hypochlorous acid, which shown superior antibacterial efficacy in their study. [22]

Conclusion

This investigation concluded the following conclusions: In comparison to the control stone castings, stone casts treated with 8.4% sodium bicarbonate exhibited a significant reduction in bacterial presence. The quantity of microorganisms in stone castings submerged in 4.2% sodium bicarbonate was much lower than that in the control stone casts. Stone castings submerged in 2.1% sodium bicarbonate exhibited a significant decrease in microorganisms compared to untreated stone casts, however the reduction was smaller than that seen with the two higher concentrations. Stone casts control shown no significant variation in microorganism proliferation.

Ethics approval and consent to participate

Written informed consent was obtained from parents prior to the study's commencement, and ethical approval was granted by two ethical committees. The ethical committee of College of Dentistry at Al-Iraqia University in Baghdad, Iraq. Ethics Board granted the approval with the project number (502).

Competing interests

The authors of this work declare no competing interests whatsoever.

Data availability

The study data is available upon request

Funding
Self-funded.

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