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Review Article

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Influence of disinfecting solutions on the surface topography of gutta-percha cones: a systematic review of *in vitro* studies

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ABSTRACT

The surface integrity of gutta-percha cones is a crucial factor in the success of endodontic procedures. Disinfecting solutions play a pivotal role in sterilizing gutta-percha cones, but their influence on gutta-percha surface topography remains a subject of concern. This systematic review aimed to present a qualitative synthesis of available laboratory studies assessing the influence of disinfecting solutions on the surface topography of gutta-percha and offers insights into the implications for clinical practice. The present review followed PRISMA 2020 guidelines. An advanced database search was performed in PubMed, Google Scholar, Embase, Scopus, LILAC, non-indexed citations and reference lists of eligible studies in May 2024. Laboratory studies, in English language, were considered for inclusion. The quality (risk of bias) of the included studies was assessed using parameters for *in vitro* studies. A total of 28 studies were included in the qualitative synthesis. Based on the included in vitro studies, surface deposits and alterations in the physical properties of gutta-percha cones were observed after the disinfection protocol. A comprehensive review of the available literature indicates that the choice of disinfecting solution, its concentration, and immersion time significantly affect the surface topography of gutta-percha cones.

Keywords: Anti-infective agents; Disinfection; Gutta-percha; *In vitro* techniques; Microscopy; Root canal preparation

INTRODUCTION

Periradicular disease often arises from various factors, including chemical, physical, and mechanical factors, but microbial infection plays a pivotal role in this context. Microorganisms in the infected root canal space are a primary source of persistent microbial

Conflict of Interest
No potential conflict of interest relevant to this article was reported.

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irritation to the periradicular tissues, necessitating effective endodontic therapy to eliminate these microbes and promote healing [1].

Successful endodontic therapy hinges on several critical factors, including proper shaping strategies, disinfection protocols, and achieving a hermetic seal through 3-dimensional obturation of the root canal space [1]. In this regard, gutta-percha has long been recognized as the gold standard for root canal obturation due to its favorable properties. Gutta-percha is a chemically inert and cost-effective material derived from the latex of certain tree species. It is processed into various forms for dental applications, making it a versatile choice [2,3].

The dental gutta-percha typically comprises approximately 20% gutta-percha and 66% zinc oxide, along with various fillers, plasticizers, and metal salts to enhance its radiographic contrast and handling properties [4]. It is available in different forms, including solid points, thermomechanical compactable versions, thermo-plasticized solid core systems, and injectable medicated points. These versatile options cater to various clinical scenarios and practitioner preferences [5].

Traditionally, root canals have been filled using techniques like lateral condensation, which involves the use of a master cone and accessory cones, along with spreaders, to create a homogenous gutta-percha mass within the canal space. However, the advent of rotary instrumentation systems has popularized the single-cone obturation technique, which offers advantages such as ease of use, efficient fit to the prepared canal, and reduced reliance on accessory points [6].

Despite its benefits, gutta-percha, like other dental materials, can become contaminated during storage, handling, or transport. This contamination can pose a risk to the success of endodontic therapy by introducing microorganisms into the root canal system [7,8]. Conventional sterilization methods, such as moist or dry heat, are not suitable for gutta-percha due to concerns about structural integrity [7,9]. As a result, chemical disinfection has emerged as a rapid chairside solution to disinfect gutta-percha before use, forming an essential part of the aseptic chain during root canal procedures [9,10].

Numerous disinfectants, differing in concentration and duration of exposure, have been studied for their efficacy in sterilizing gutta-percha. This is a critical step in endodontic treatment, as highlighted by Patel *et al.* [11], who demonstrated that enhanced disinfection protocols during root canal treatment significantly improved the success rate. However, a detailed understanding of how these disinfectants affect the surface topography and structural integrity of gutta-percha remains an area requiring further investigation. This systematic review aims to determine the impact of various disinfectants on the surface of gutta-percha as reported in *in vitro* studies, enhancing our understanding of how these agents affect this essential endodontic material.

MATERIALS AND METHODS

The present study adhered to the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Statement [12]. The protocol for this systematic review was previously registered with PROSPERO (International Prospective Register of Systematic Reviews) under the registration number CRD42020158579.

Table 1. The inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
In vitro studies on gutta-percha	Review articles, case reports, book chapters, grey literature, animal studies or studies, in which data is missing or incomplete
Surface characteristics are analyzed using a microscope, SEM, AFM, or any other tool.	Articles, which have only assessed the antimicrobial efficacy of disinfectants and gutta-percha
	Articles not in English

SEM, scanning electron microscopy; AFM, atomic force microscopy.

Eligibility criteria

We considered studies for inclusion that met the following criteria (**Table 1**). The excluded articles are listed in **Supplementary Table 1**. Our eligibility criteria were established following the PICOS model, which outlines the following aspects: population (P): Gutta-perch or gutta-percha cones or points or root canal filling material; intervention (I): Disinfecting procedures utilized to disinfect the root canal filling materials; comparison (C): Comparing different concentrations and different chemical agents to disinfect gutta-percha; outcome (O): Surface characteristics or alteration of surface topography of disinfected gutta-percha, using scanning electron microscopy (SEM), atomic force microscopy (AFM), operating microscope; study design (S): *in vitro* [13].

Search strategy and terminology

We conducted a comprehensive search using predefined search strings and terms. This search was carried out in 6 electronic databases: PubMed, Google Scholar, Embase, Scopus, LILAC, and in non-indexed citations via Google search. The search was performed in May 2021, without any restrictions on date or language. Our search strategy included the following terms: (population terms) OR (intervention terms) OR (comparison terms) OR (outcome terms); combined with the Boolean operators 'OR' and 'AND.' The search term selection was based on previous works within this framework and their most cited descriptors. The search was performed till May 2024.

The search strategy included the following terms: ("gutta-percha" or "gutta-percha points" or "gutta-percha cone" or "gutta-percha cones" or "polycaprolactone" or "root canal filling material" or "gutta-percha pins") or ("sterilization" or "sterilization" or "rapid decontamination" or "sterilization techniques" or "rapid sterilization" or "rapid sterilization" or "cold sterilization" or "chemical disinfection" or "surface sterilization" or "surface sterilization" or "decontamination" or "chemical sterilization" or "chemical sterilization") or ("disinfectants" or "disinfecting solution" or "disinfectant solutions" or "antiseptics" or "chemical solutions" or "formocresols" or "photoactivated disinfection" or "chlorhexidine" or "chemical agents" or "sodium hypochlorite" or "paraformaldehyde" or "glutaraldehyde" or "cfc" or "electron beam" or "quaternary ammonia" or "ethanol" or "povidone iodine" or "reagents" or "cold sterilizing solutions" or "herbal") or ("efficacy" or "effectiveness" or "antimicrobial efficacy" or "antifungal efficacy" or "bactericidal activity" or "sporicidal effects" or "sporicidal efficacy" or "residual effects" or "disinfection potential" or "germicidal potency" or "sterile conditions" or "surface alteration" or "surface alterations" or "structural effects" or "physical properties" or "crystallization")'; combined with the Boolean operators 'OR' and 'AND'. The search term selection was based on previous works within this framework and their most cited descriptors. Search results were imported into a reference manager software (Rayyan, Boston), where duplicates were removed by 2 reviewers (N.R.S and L.M). In case of disagreement between 2 reviewers for including or excluding an article, a third reviewer (M.L.) was consulted and the decision was taken accordingly. Titles and abstracts were then reviewed

(F.D.) against the inclusion criteria, and studies meeting the criteria proceeded to full-text screening for qualitative synthesis. The search results were imported into a reference manager software (Zotero 5.0.96.2 version; Zotero, Fairfax, VA, USA).

Data extraction

Data extraction was conducted by 2 reviewers (G.D. and L.M.) under 3 main categories: study characteristics, methodology, and outcomes/results. Study characteristics encompassed authors and publication years. Methodological variables included details on disinfection protocols and concentrations, sample size, microorganisms used, antimicrobial assays performed, and observed surface characteristic changes following disinfection protocols. Outcome variables included significant results, the duration of measurements, and associated *p* values.

Quality assessment of included studies

To assess the quality of the included studies, we used (G.D. and L.M.) a modified CONSORT checklist for reporting *in vitro* studies of dental materials [14]. This checklist consists of 14 checklist items, and the assessment was conducted for each item to determine compliance.

For each of the 14 parameters in the quality assessment tool, studies were individually evaluated for fulfillment or non-fulfillment. The percentage of fulfilled items was subsequently calculated as follows: (Number of Fulfilled Items/Total Number of Items) × 100 (**Figure 1**).

RESULTS

Selection of studies

The results from the electronic database search and the study screening and selection process are summarized in a PRISMA flow diagram for study selection (**Figure 2**).

Characteristics of studies

The studies included in this review featured various sizes and brands of gutta-percha. Among the 28 studies, 14 used gutta-percha manufactured by Dentsply Maillefer (Tulsa, OK, USA), while other studies utilized gutta-percha from different manufacturers, including Tenarima Industrial (Tanariman Industrial, Manacapuru, AM, Brazil), Diadent (Cheongju, Korea), Konne Belo (Belo Horizonte, MG, Brazil), Odous de Deus (Belo Horizonte), Meta Biomed (Chungju, Korea), Sure Endo (Seongnam, Korea), VDW (Postfach, Munich), and Hygenic Corp (Coltene Whaledent, Altstätten, Switzerland) [9,15-27].

The studies also employed various sizes of gutta-percha, with #80 being used in 5 studies, #60 in 3 studies, #30 in 3 studies, #40 in 3 studies, #70 in 2 studies, #120 in 2 studies, and #100 in 1 study [7,15-19,21,22,24-34]. Four studies used medium-sized gutta-percha, while F1 gutta-percha (#20, 6%) and F3 gutta-percha (#30, 6%) were used in 2 studies, respectively [7,20,23,31,35,36]. Three studies did not specify the size of gutta-percha used [8,37,38]. Additionally, 4 studies mentioned that gutta-percha was procured from sealed or freshly opened packets, while 6 studies used pretreated gutta-percha [8,25,30,33]. Three studies employed ethylene oxide vapors, one study used 5.25% sodium hypochlorite (NaOCl) and distilled water, another study used nanopure water and nitrogen gas, and yet another study used 2% glutaraldehyde solution followed by saline rinsing [7,9,15,31,34,35]. Only one study

Section/topic	Checklist item
Abstract	· Item 1. Structured summary of trial design, methods, results, and conclusions
Introduction	
Background and objectives	· Item 2a. Scientific background and explanation of rationale · Item 2b. Specific objectives and/or hypotheses
Methods	
Intervention	· Item 3. The intervention for each group, including how and when it was administered, with sufficient detail to enable replication
Outcomes	· Item 4. Completely defined, pre-specified primary and secondary measures of outcome, including how and when they were assessed
Sample size	· Item 5. How sample size was determined
Randomization: Sequence generation	· Item 6. Method used to generate the random allocation sequence
Allocation concealment mechanism	· Item 7. Mechanism used to implement the random allocation sequence (for example, sequentially numbered containers), describing any steps taken to conceal the sequence until intervention was assigned
Implementation	· Item 8. Who generated the random allocation sequence, who enrolled teeth, and who assigned teeth to intervention
Blinding	· Item 9. If done, who was blinded after assignment to intervention (for example, care providers, those assessing outcomes), and how
Statistical methods	· Item 10. Statistical methods used to compare groups for primary and secondary outcomes
Results	
Outcomes and estimation	· Item 11. For each primary and secondary outcome, results for each group, and the estimated size of the effect and its precision (for example 95% confidence interval)
Discussion	
Limitations	· Item 12. Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses
Other information	
Funding	· Item 13. Sources of funding and other support (for example suppliers of drugs), role of funders
Protocol	· Item 14. Where the full trial protocol can be accessed, if available

Figure 1. Description of modified CONSORT table to assess the quality of the included studies.

used gutta-perchas taken directly from a hospital setting to evaluate the effect of disinfection protocols on the gutta-percha surface [37].

Various disinfecting agents were used in the included studies, with 24 studies disinfecting gutta-percha with 5.25% NaOCl, and 18 studies comparing NaOCl with chlorhexidine (CHX). The concentration of the disinfecting solutions and the methods used for surface analysis are summarized in **Table 2**.

The extracted data from the selected studies and the methodology used to evaluate the influence of disinfectants on the surface characteristics of gutta-percha are summarized in **Table 2**.

Surface changes on gutta-percha based on the included studies

A total of 28 studies reported surface changes. The findings from these studies are discussed according to the type of surface analysis performed:

1. SEM analysis

Out of the 16 studies that utilized SEM analysis, 10 of them reported the presence of surface

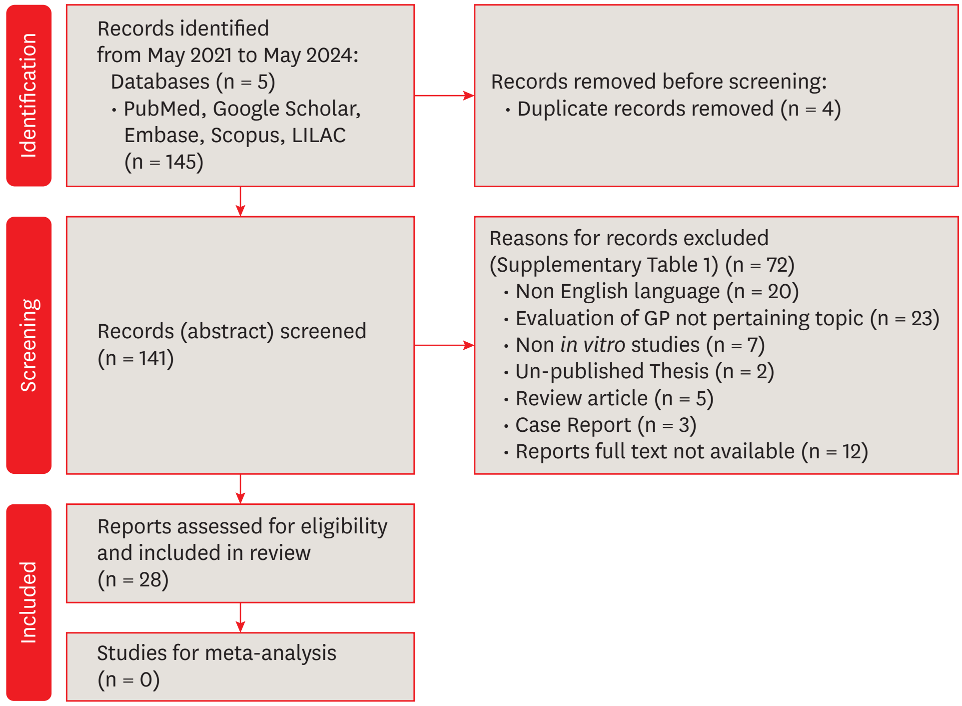

Figure 2. PRISMA flow diagram for study selection.

Table 2. Concentration of disinfecting solution and device used to analyze the surface of gutta-percha in the included studies

Study (Author, year)	Surface analysis method	% of NaOCl	% of CHX	Other disinfectants
Brito *et al*. 2013 [10]	SEM	1, 2.5	-	
Candeiro *et al*. 2018 [31]		1, 2.5	-	17% EDTA, 10% CA and 15% MA
Chandrappa *et al*. 2014 [17]		5.25	2	MTAD
Gomes *et al*. 2007 [35]		5.25	2	-
Nair and Bandhe 2017 [15]		5.25	2	Propolis
Pang *et al*. 2006 [37]		5.25	2	-
Pang *et al*. 2007 [8]		5.25	2	Chloraprep
Sahinkesen *et al*. 2011 [34]		2.5, 5.25	2	MTAD and Octenisept
Sharma *et al*. 2016 [26]		3	-	1% PAA and Octenisept
Short *et al*. 2003 [30]		2.5, 5.25	-	
Srivastava 2019 [25]		5.25	2	1% ALX
Varghese *et al*. 2018 [23]		5.25	3	MTAD and 13% BAK
Vitali *et al*. 2019 [9]		1, 5.25	-	
Prado *et al*. 2011 (II) [36]	SEM + EDS	5.25	2	MTAD
Turker *et al*. 2015 [33]		5.25	2	1% PAA and QMix
Topuz *et al*. 2011 [29]	SEM + EDS + AFM	6	-	
John *et al*. 2017 [18]	AFM	0.5, 2.5, 5.25	-	
Karunakar *et al*. 2021 [27]		5.25	-	AgNP
Mishra and Tyagi 2018 [19]		5.25	-	AgNP
Prado *et al*. 2012 [7]		5.25	2	MTAD
Tilakchand *et al*. 2014 [16]		5.25	2	-
Valois *et al*. 2005 (I) [22]		0.5, 2.5, 5.25	-	-
Valois *et al*. 2005 (II) [28]		5.25	2	-
Yadav *et al*. 2014 [24]		5	2	6% H_2O_2 and 2.2% GLD
Ismail *et al*. 2012 [32]	Stereomicroscope	0.5, 1.5, 5.25	1, 1.5, 2	-
Nanda *et al*. 2020 [20]		5.25	2	AV
Prado *et al*. 2011 (I) [39]	Rinehart goniometer	5.25	-	-
Nunes *et al*. 2019 [38]	Confocal microscopy	5.25	2	-

SEM, scanning electron microscopy; EDS, energy dispersive X-ray spectrometry; AFM, atomic force microscopy; NaOCl, sodium hypochlorite; CHX, chlorhexidine; MTAD, mineral trioxide aggregate; PAA, para acetic acid; OCPT, octenisept; AV, aloe vera; H_2O_2, hydrogen peroxide; GLD, glutaraldehyde; ChnpP, chitosan particles; AgNP, silver nanoparticle; QMix, a solution containing 2% CHX and 17% EDTA (ethylene diamine tetraacetic acid); ALX, alexidine; CA, citric acid; MA, maleic acid; BAK, benzalkonium chloride.

deposits on gutta-percha when disinfected with various concentrations of NaOCl, ranging from 0.5% to 5.25%. The characteristics of these deposits, including their shape and abundance, were detailed in each study. Additionally, the studies reported how the quantity of deposits was affected by exposure time and the concentration of NaOCl.

In the case of CHX, 10 studies using SEM analysis reported different findings, including wrinkling, shrinkage, and surface residues in some studies. The impact of different concentrations and exposure times of CHX on gutta-percha was discussed.

Other disinfecting agents, such as MTAD (a mixture of doxycycline, citric acid, and a detergent; Dentsply Maillefer), Octenisept (Schulke & Mayr, Norderstedt, Germany), para acetic acid (PAA), ethylenediaminetetraacetic acid (EDTA), citric acid, malic acid, benzalkonium chloride, and more, were assessed in different studies, and the surface changes observed using SEM analysis were summarized.

2. AFM analysis

Out of the 8 studies that used AFM analysis, the impact of NaOCl, CHX, and other disinfectants on the surface roughness and topography of gutta-percha was reported. Changes in surface roughness parameters, including defects, craters and folded areas were noted in relation to the disinfection protocols used in each study.

3. Other surface analysis techniques

The remaining 2 studies used different techniques, such as FTIR, XPS, and contact angle measurements, to assess the surface characteristics of gutta-percha. The effects of NaOCl, CHX, and other disinfectants on the chemical composition, wettability, and other surface properties were detailed.

Table 3 summarizes the main findings from the included studies in terms of surface changes observed on gutta-percha when exposed to different disinfectants.

Quality assessment

The risk of bias assessment for the included cross-sectional studies is presented in **Table 4**. The overall quality assessment revealed that all the included studies had either have moderate or high risk of bias, with none being categorized as low risk.

DISCUSSION

The antimicrobial efficacy of disinfecting solutions against root canal pathogens has been extensively investigated, but their interaction with gutta-percha surfaces remains a crucial area of research. This systematic review aimed to qualitatively synthesize available *in vitro* studies assessing the influence of disinfecting solutions on the surface topography of gutta-percha points. Due to methodological heterogeneity and data disparities, a meta-analysis was not feasible.

The studies considered in this review assessed the surface changes of gutta-percha after immersion in different disinfecting solutions at various time points. However, notable gaps and inconsistencies were observed in these studies.

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Table 3. Immersion time and surface changes on gutta-percha in the included studies

Study (Author, year)	Pre-treatment	Contact time with disinfecting solutions	Post-treatment rinsing done to any group	Surface changes or deposits
Brito *et al*. 2013 [10]	N	20, 30 min, 6, 12, 24 hr	N	Y
Candeiro *et al*. 2018 [31]	Y	1, 5, 10 min	N	Y
Chandrappa *et al*. 2014 [17]	N	0.5, 1, 5 min	Y	Y
Gomes *et al*. 2007 [35]	Y	1, 5, 10, 20, 30 min	Y	N
Ismail *et al*. 2012 [32]	N	10, 15, 20 min	N	Y
John *et al*. 2017 [18]	N	2, 5, 10 min	N	Y
Karunakar *et al*. 2021 [27]	N	1 min	N	Y
Mishra and Tyagi 2018 [19]	N	1 min	N	Y
Nair and Bandhe 2017 [15]	Y	5, 10 min	Y	N
Nanda *et al*. 2020 [20]	N	5 min	N	Y
Nunes *et al*. 2019 [38]	N	1, 10, 15 min	N	Y
Pang *et al*. 2006 [37]	N	1, 5 min	N	Y
Pang *et al*. 2007 [7]	Y	5 min	N	Y
Prado *et al*. 2011 (I) [39]	N	1 min	Y	N
Prado *et al*. 2011 (II) [36]	N	1 min	Y	Y
Prado *et al*. 2012 [7]	Y	1, 3, 6 min	N	Y
Sahinkesen *et al*. 2011 [34]	Y	1, 5, 10 min	N	N
Sharma *et al*. 2016 [26]	N	1, 5 min	N	Y
Short *et al*. 2003 [30]	N	1 min	Y	Y
Srivastava 2019 [25]	N	1 min	N	Y
Tilakchand *et al*. 2021 [16]	N	1, 3, 10, 20, 30 min	N	Y
Topuz *et al*. 2011 [29]	N	1, 5, 10, 20, 30 min	Y	N in SEM
Turker *et al*. 2015 [33]	N	5, 10 min	N	N
Valois *et al*. 2005 (I) [22]	N	1, 5 min	Y	Y
Valois *et al*. 2005 (II) [28]	N	1, 5, 10, 20, 30 min	Y	Y
Varghese *et al*. 2018 [23]	N	1, 5 min	N	Y
Vitali *et al*. 2019 [9]	Y	1 min	Y	Y
Yadav *et al*. 2014 [24]	N	1 min	N	Y

N, no; Y, yes.

First, the sources and sizes of the tested gutta-percha were not consistently justified. The lack of standardization in this aspect limits the generalizability of the findings across studies. Similarly, the quantity of disinfecting solution and the choice of SEM magnification varied without a clear rationale, further complicating data interpretation.

Disinfecting solutions play a critical role in the sterilization of gutta-percha cones; however, it is evident that they can also affect the surface topography and properties of the obturating material. Notably, the interaction between gutta-percha and disinfecting solutions can lead to significant surface changes that may impact the outcome of endodontic therapy. Gutta-percha surface irregularities may create interfaces with root canal walls, fostering microorganism retention and potential microleakage, which could result in secondary infections.

Most of the included studies (**Table 2**) predominantly evaluated the use of sodium hypochlorite (NaOCl) as a disinfecting agent. The choice of NaOCl is likely driven by its demonstrated effectiveness against a broad spectrum of microorganisms, even at low contact times [22,23]. The potent antibacterial and sporicidal activities of NaOCl make it a popular choice, but the concentration and contact time significantly influence its impact on gutta-percha surface topography [28,37]. High concentrations of NaOCl have been shown to deteriorate the gutta-percha surface, with SEM and AFM analysis revealing the presence of cuboidal crystals and dimensional changes [29,30]. These surface alterations, particularly in the folded areas of the gutta-percha cones, may affect the apical seal and overall treatment outcomes [8,9,17,23,25,26,30,31,37]. One approach to mitigating the deleterious effects of

Table 4. Modified CONSORT checklist of items for included *in vitro* studies

Study	Item															Score
	1	2a	2b	3	4	5	6	7	8	9	10	11	12	13	14	
Brito *et al*. 2013 [10]	Y	Y	Y	Y	Y	N	NA				Y	Y	Y	N	NA	8/10
Candeiro *et al*. 2018 [31]	Y	Y	Y	Y	Y	N					Y	Y	N	Y	NA	8/10
Chandrappa *et al*. 2014 [17]	Y	Y	Y	Y	Y	N					Y	Y	N	Y	NA	8/10
Gomes *et al*. 2007 [35]	Y	Y	Y	Y	Y	N					N	N	Y	Y	NA	7/10
Ismail *et al*. 2012 [32]	Y	Y	Y	Y	Y	N					Y	N	N	N	NA	6/10
John *et al*. 2017 [18]	Y	Y	Y	Y	Y	N					Y	Y	Y	N	NA	8/10
Karunakar *et al*. 2021 [27]	Y	Y	Y	Y	Y	N					Y	Y	N	Y	NA	8/10
Mishra and Tyagi 2018 [19]	Y	Y	Y	Y	Y	N					Y	Y	N	Y	NA	8/10
Nair and Bandhe 2017 [15]	Y	Y	Y	Y	Y	N					Y	N	N	Y	NA	7/10
Nanda *et al*. 2020 [22]	Y	Y	Y	Y	Y	N					Y	Y	N	N	NA	7/10
Nunes *et al*. 2019 [38]	Y	Y	Y	Y	Y	N					Y	Y	Y	Y	NA	9/10
Pang *et al*. 2006 [37]	Y	Y	Y	Y	Y	N					Y	N	Y	N	NA	7/10
Pang *et al*. 2007 [8]	Y	Y	Y	Y	Y	N					Y	Y	Y	N	NA	8/10
Prado *et al*. 2011 (I) [39]	Y	Y	Y	Y	Y	N					N	N	N	Y	NA	6/10
Prado *et al*. 2011 (II) [36]	Y	Y	Y	Y	Y	N					Y	Y	Y	Y	NA	9/10
Prado *et al*. 2012 [7]	Y	Y	Y	Y	Y	N					Y	Y	N	Y	NA	8/10
Sahinkesen *et al*. 2011 [34]	Y	Y	Y	Y	Y	N					N	Y	Y	Y	NA	8/10
Sharma *et al*. 2016 [26]	Y	Y	Y	Y	Y	N					Y	N	N	N	NA	6/10
Short *et al*. 2003 [30]	Y	Y	Y	Y	Y	N					N	N	Y	Y	NA	8/10
Srivastava 2019 [25]	Y	Y	Y	Y	Y	N					Y	Y	N	Y	NA	8/10
Tilakchand *et al*. 2014 [16]	Y	Y	Y	Y	Y	N					Y	Y	N	N	NA	7/10
Topuz *et al*. 2011 [29]	Y	Y	Y	Y	Y	N					Y	Y	N	N	NA	7/10
Turker *et al*. 2015 [33]	Y	Y	Y	Y	Y	N					Y	Y	N	Y	NA	8/10
Valois *et al*. 2005 (I) [22]	Y	Y	Y	Y	Y	N					Y	Y	Y	N	NA	8/10
Valois *et al*. 2005 (II) [28]	Y	Y	Y	Y	Y	N					Y	Y	N	N	NA	7/10
Varghese *et al*. 2018 [23]	Y	Y	Y	Y	Y	N					N	N	N	N	NA	5/10
Vitali *et al*. 2019 [9]	Y	Y	Y	Y	Y	N					Y	N	Y	Y	NA	9/10
Yadav *et al*. 2014 [24]	Y	Y	Y	Y	Y	N					Y	Y	Y	N	NA	8/10

Y, yes; N, no; NA, not applicable.

NaOCl is using lower concentrations or thorough rinsing with specific solutions to minimize crystal deposition [9,15,22,29,30,35].

CHX emerged as the second most widely used disinfecting solution in the studies (**Table 2**). CHX, especially at a 2% concentration, is known for its broad-spectrum antimicrobial activity [8]. Unlike NaOCl, 2% CHX had minimal surface deposits and less structural deterioration, making it a more favorable choice for gutta-percha disinfection [7,16,22,32]. However, immersion in 3% CHX resulted in surface alterations, likely due to its higher concentration [23].

Other disinfecting agents, such as MTAD, PAA, and Octenisept, presented varying effects on gutta-percha surface topography. MTAD, an organic agent with anti-collagenase activity, required a specific contact time for effective disinfection but could result in surface modifications if left to dry on gutta-percha cones [7,17,36]. On the other hand, PAA showed significant topographic changes and alterations in gutta-percha's physical properties, making it a less suitable choice for gutta-percha cones [26,33]. Octenisept, despite its broad-spectrum antimicrobial activity, exhibited minimal surface irregularities, potentially due to low solution concentrations [26,34].

Herbal agents, such as Aloe Vera and Propolis, have gained popularity for their natural origin and antimicrobial properties. They showed promise as alternatives to conventional disinfectants with minimal surface changes on gutta-percha [15,20].

Several other disinfecting agents, including EDTA, citric acid, malic acid, hydrogen peroxide (H_2O_2), glutaraldehyde, Alexidine, benzalkonium chloride, and nanoparticles like silver and chitosan, demonstrated varying effects on the gutta-percha surface. While some exhibited minimal surface alterations, others caused topographic changes and surface deposits [19,23-25,27,31,38].

In recent years, nanoparticles have shown promise due to their smaller size, larger surface area, and antimicrobial properties. However, further research is needed to explore their interactions with gutta-percha [19,27].

The findings of this qualitative synthesis provide valuable insights into how disinfecting solution concentration and immersion time affect the gutta-percha surface. These effects can significantly impact obturation techniques and overall treatment outcomes.

While this review assessed the quality of the studies using a modified CONSORT checklist for *in vitro* studies on dental materials, standardized reporting guidelines for laboratory studies are essential for enhancing the quality and transparency of future research in endodontics. Future investigations should consider evaluating the physical and mechanical properties of gutta-percha immersed in different disinfecting solutions, as this could further inform clinical practice. However, it is essential to recognize that the precise mechanisms underlying the interaction between disinfecting solutions and gutta-percha surfaces require further exploration.

CONCLUSIONS

This systematic review examined the influence of various disinfecting solutions on the surface topography of gutta-percha cones. Sodium hypochlorite, at concentrations above 5%, was found to cause significant surface erosion of gutta-percha. Conversely, 2% chlorhexidine generally maintained the structural integrity of gutta-percha, while higher concentrations had a more detrimental effect. This review highlights the importance of considering the type, concentration, and immersion time of disinfecting solutions used on gutta-percha cones. Further research is warranted to explore the clinical implications of these findings.

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SUPPLEMENTARY MATERIAL

Supplementary Table 1
Excluded articles

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