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Sterilizing orthodontic appliances: A systematic review and meta-analysis on the available methods

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Abstract

Infection control is essential to protect both the doctor and the patient by preventing the spread of infectious diseases. There is no exception in the field of dentistry, particularly in orthodontics, where numerous appliances are used for a variety of functions and also because the mouth cavity has the highest concentration of bacteria of any body part. Through this systematic review, we aimed to assess the various methods of sterilization employed in an orthodontic setting. Using relevant keywords, reference searches, and citation searches, the databases such as PubMed, MEDLINE, Web of Science, Cochrane, and Scopus were all searched; a total of 206 documents were found, of which 113 were initially selected. The remaining 23 distinct papers were initially made available after 90 publications that were identical to or similar to one another were eliminated. The final selection was made from eight documents that met all inclusion and exclusion requirements. The existing methods of sterilization were found to be competent in dealing with the microorganisms found in a typical orthodontic setting. The chemical method of sterilization was the norm in most of the studies that we assessed, with glutaraldehyde and peracetic acid (PAA) being the most commonly employed compounds for disinfection.

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Keywords:

Chlorhexidine, disinfection, orthodontic wires, orthodontics, sterilization

Introduction

To stop the transmission of infectious diseases, infection control is crucial for the safety of both the doctor and the patient. In dentistry, this is especially important because the oral cavity contains more bacteria than any other areas of the body. Orthodontists had the second-highest incidence of hepatitis B among dental practitioners, according to a study.[1] Patients with herpes simplex viruses in their saliva may be asymptomatic hepatitis B carriers receiving treatment in a dental office. Such patients run the risk of spreading illness. Since diseases such as hepatitis B, human immunodeficiency virus (HIV), and tuberculosis have lengthy incubation periods, it can be challenging for dental professionals and other patients to determine the source of such illnesses.

An orthodontist and his staff face the greatest risk of skin puncture from sharp orthodontic tool edges and contaminated instruments because any cuts or abrasions allow microorganisms to enter the body. Additionally, the microorganisms can spread through direct contact with a lesion, indirect contact with contaminated tools or office supplies, inhalation of aerosols produced by hand pieces and ultrasonic cleaners, and instrument cleaning. The objectives of any responsible clinician

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should be to lower the quantity of harmful organisms to a point where the body's natural defenses can prevent infection and to end the infection cycle by preventing cross-contamination. Numerous authors have written articles and reviews in the past that express concern about the upkeep of sterilization in dental offices.[2-4]

The teeth, cheeks, lips, tongue, gingiva, gingival sulcus, and the hard and soft palates are only a few of the several microbial habitats found in the human oral cavity.[5,6] These environments, which serve as reservoirs for a number of pathogenic organisms, enhance the likelihood of cross-contamination and cause systemic infection.[7,8] By lowering pH, increasing dental plaque buildup, and boosting the microbial count in saliva, the introduction of fixed or removable orthodontic appliances into the oral cavity may create unique alterations in the oral microbiota. Additionally, these modifications raise the danger of cross-contamination.[7] Additionally, using infected devices or using orthodontic appliances directly out of the manufacturer's box without disinfection may potentially contribute to oral cavity infections.[9] Hepatitis B and C, herpes simplex, and human immunodeficiency virus are a few of the pathogens that are implicated in the transmission of the infection. Additionally, upper respiratory tract infections are brought on by bacterial contaminations and by Mycobacterium tuberculosis, Staphylococcal and Streptococcal spp., and other microorganisms.[10]

Gram-positive Staphylococci are thought to be the main culprit behind nosocomial infections among all these.[11] The most efficient ways to get rid of germs that cause contamination are heat sterilization and disinfection. However, compared with heat sterilization, chemical disinfection has been shown in the literature to be more successful at reducing contamination.[12] In the chemical sterilization procedure, disinfectants such as glutaraldehyde, hydrogen peroxide, alcohol, and chlorhexidine are frequently employed.[12,13] Due to its broad-spectrum bactericidal action against both gram-positive and gram-negative bacteria, chlorhexidine is currently the most effective disinfectant.[8] Microbial contamination in orthodontic appliances obtained directly from the manufacturers was observed in several *in vitro* and *in vivo* studies.[5,14,15] There is a paucity of information in the literature, nevertheless, about sterilizing procedures and the use of disinfectants to get rid of bacterial contamination. The orthodontic appliances, such as brackets, bands, and arch wires, are not thoroughly sanitized, even though the instruments used in dental practice are. The goal of a competent doctor is to prevent contamination to break the cycle of infection.

Our prime objective in conducting this systematic review and meta-analysis of selected studies was to examine the various sterilizing techniques currently being used to clean orthodontic equipment and devices.

Materials and Methods

Protocol employed

This systematic review was performed as per the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) strategy and rules from the Cochrane Group and the Book Orderly Reviews in Health Care: Meta-Examination.[16]

Review hypotheses

Through this systematic review, our primary objective was to review studies that analyzed the various sterilizing methods in use for the disinfection of orthodontic appliances/devices.

Study selection

After a thorough search of the online journals, 206 documents were found in all, and 113 of the papers were initially chosen. Then, 90 publications that were similar to or duplicated with one another were removed, leaving 23 distinct papers that were initially available. After reviewing the submissions' abstracts and titles, another 15 articles were disqualified. Ultimately, eight documents were selected that satisfied the necessary inclusion and exclusion criteria, primarily *in vitro* experiments, literature reviews, and comparative analyses [Figure 1].

Inclusion criterion

Articles that contained relevant data for our review objectives were selected for full-text screening. Studies that reported clinical trials, *in vitro* studies, randomized/non-randomized studies, systematic/literature reviews containing substantial sample volume, and detailed case reports were considered for inclusion in our review. We also monitored studies that possessed higher methodological quality.

Exclusion criteria

The following were excluded from the scope of our systematic review: incomplete data, seminar presentations, scholarly articles, placebo-controlled studies, and opinion articles.

Since the literature available on this topic was quite scant in volume, we did not limit our search in terms of the time period when the studies were published; i.e. we took into account all the papers that were published with context to our topic (where the number of papers itself was found to be quite sparse in number). Also, excluded were literature reviews and cases published in languages other than English.

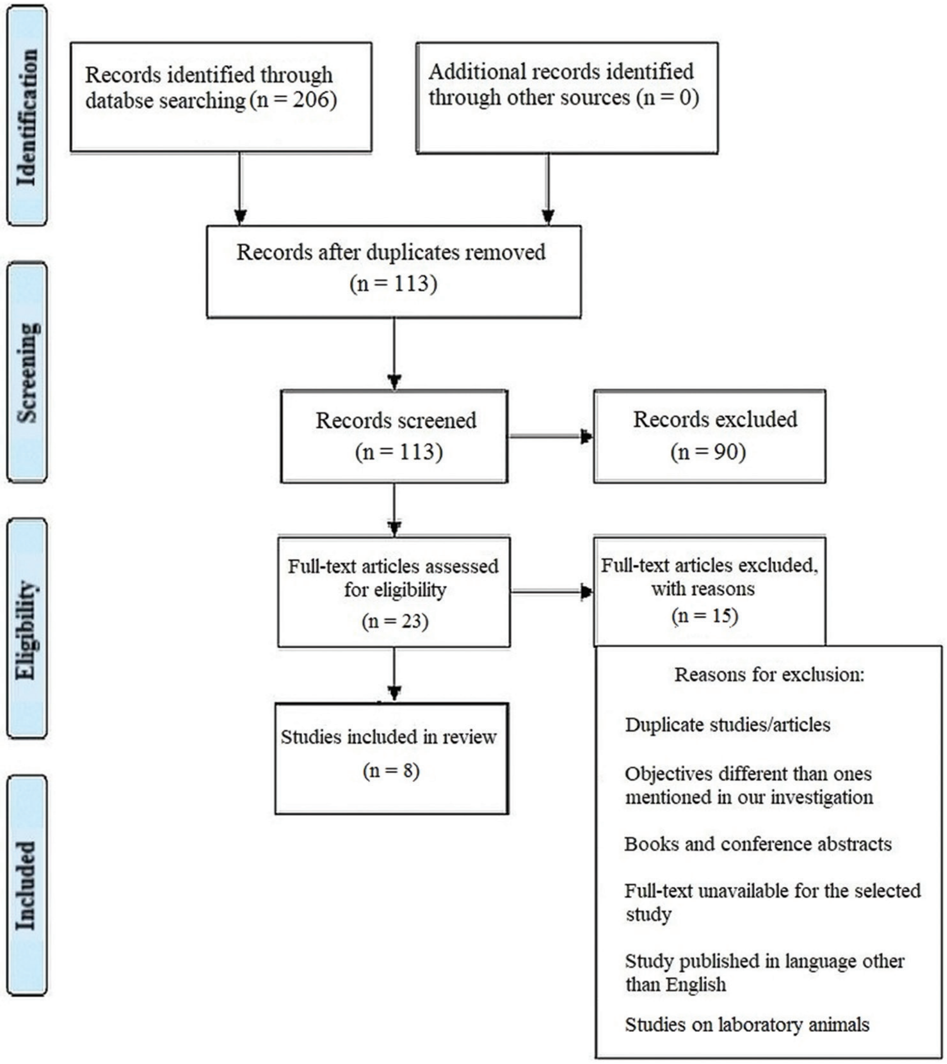

Figure 1: Representation of the selection of articles through the PRISMA framework

Search strategy

Using relevant keywords, reference searches, and citation searches, the databases such as PubMed, MEDLINE, Web of Science, Cochrane, and Scopus were all searched. "Chlorhexidine," "Disinfection," "Orthodontics," "Orthodontic wires," and "Sterilization" were the search terms used to access the database.

Data selection and coding

Two independent reviewers located the relevant papers using the right keywords in various databases and online search tools. The chosen articles were compared, and a third reviewer was brought in if there was a dispute.

After choosing the articles, the same two reviewers independently extracted the following data: author, year of publication, country, kind of publication, study topic, population demographics (n, age), outcome measure(s), relevant result(s), and conclusion(s). The data were compared, and any differences were discussed with the third reviewer.

Statistical analysis

The data were entered into the RevMan 5 program for meta-analysis after being chosen for information on the sample size, variables analyzed, and various aspects of the research. Figures 2, 3, and 4 show forest plots obtained as part of the meta-analysis for our study that indicates the odds ratio for various study approaches.

Risk-of-bias assessment

The AMSTAR 2 technique[17] was used to evaluate the risk of bias in the studies we chose. AMSTAR 2 joins a number of other instruments that have been released for this purpose as a critical evaluation tool for systematic reviews [Table 1]. As shown in Table 2, it is a 16-point checklist. Two instruments that have drawn a lot of attention served as the foundation for the creation of the original AMSTAR

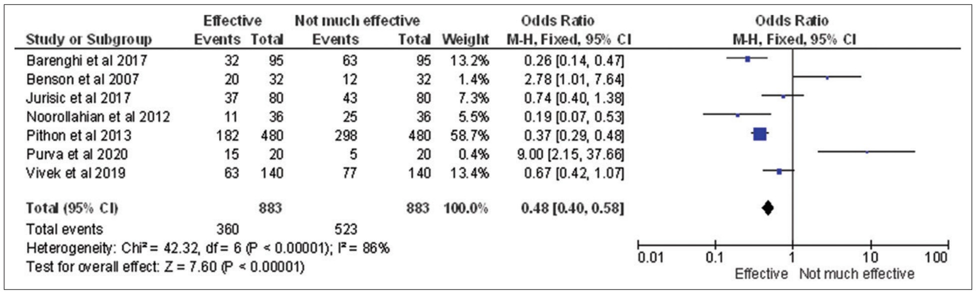

Figure 2: Odds ratio of investigations selected in this systematic review and the effectiveness of the sterilization methods used in them, respectively, displayed on a forest plot after meta-analysis

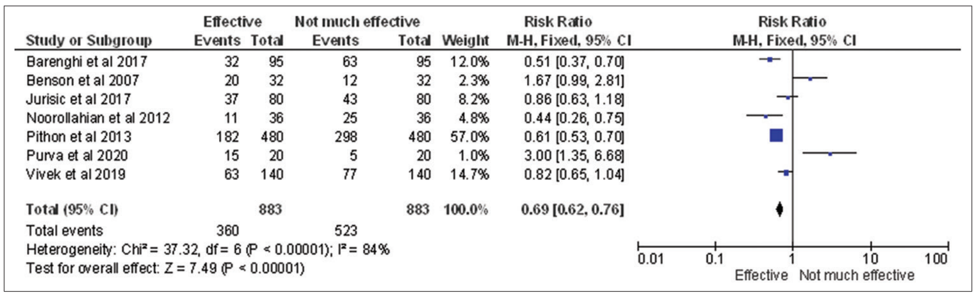

Figure 3: Risk ratio of investigations selected in this systematic review and the effectiveness of the sterilization methods used in them, respectively, displayed on a forest plot after meta-analysis

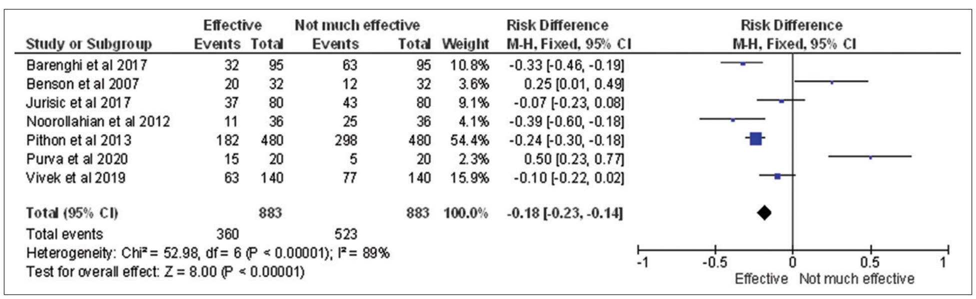

Figure 4: Risk difference of investigations selected in this systematic review and the effectiveness of the sterilization methods used in them, respectively, displayed on a forest plot after meta-analysis

tool. The original AMSTAR was duplicated in two newly produced instruments. The AMSTAR 2 risk-of-bias items identify the domains specified in the Cochrane risk-of-bias instruments for systematic reviews. In each case, these indicate an agreement that was achieved after input from more than 30 methodology experts.

Results

The study design, methodology employed, description, and outcome are mentioned in Table 2. The results of the meta-analysis are provided in Figures 2, 3, and 4.

Discussion

Before delivery in the oral cavity, materials may need to be sterilized or disinfected, according to studies.[26,27] However, it is still a common clinical practice to employ orthodontic appliances straight from the manufacturer's packaging. The orthodontic appliances were not sterile when they were taken out of the manufacturer's packaging, according to earlier investigations.[14,15] As a result, we assessed the various sterilization techniques employed by orthodontists and their effectiveness as seen in the chosen research.

Our review's findings were consistent with earlier research employing various orthodontic tools, including brackets,[15] orthodontic buccal tubes,[28] orthodontic pliers,[29] arch wires,[30] and toothbrushes[31] from various suppliers. According to these investigations, dental offices frequently employ orthodontic devices that are infected with microorganisms.

Orthodontic appliances are frequently contaminated with Staphylococci through skin contact during manufacturing and/or packing.[29,30] According to studies conducted in this area,[29,32] Staphylococci were frequently

Table 1: AMSTAR 2 16-point checklist of risk-of-bias assessment in studies selected for the systematic review

Studies selected	Question and inclusion	Protocol	Study design	Comprehensive search	Study selection	Data extraction	Excluded studies justification	Included study details
Barenghi *et al.* 2017[18]	Yes	Yes	Yes	Yes	Yes	No	No	No
Benson and Douglas 2007[19]	Yes	Yes	Yes	Yes	Yes	No	No	No
Jurišić *et al.* 2017[20]	Yes	Yes	Yes	Yes	Yes	No	No	No
Noorollahian *et al.* 2012[21]	Yes	Yes	Yes	Yes	Yes	No	No	No
Pithon *et al.* 2013[22]	Yes	Yes	Yes	Yes	Yes	No	No	No
Verma and Sivkumar 2020[23]	Yes	Yes	Yes	Yes	Yes	No	No	No
Rohmetra *et al.* 2018[24]	Yes	Yes	Yes	Yes	Yes	No	No	No
Vivek *et al.* 2019[25]	Yes	Yes	Yes	Yes	Yes	No	No	No

Studies selected	Risk of bias	Funding sources	Statistical methods	Risk of bias in meta-analysis	Risk of bias in individual studies	Explanation of heterogeneity	Publication bias	Conflict of interest
Barenghi *et al.* 2017[18]	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes
Benson and Douglas 2007[19]	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes
Jurišić *et al.* 2017[20]	Yes	N/A	Yes	N/A	Yes	Yes	Yes	Yes
Noorollahian *et al.* 2012[21]	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes
Pithon *et al.* 2013[22]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Verma and Sivkumar 2020[23]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rohmetra *et al.* 2018[24]	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes
Vivek *et al.* 2019[25]	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes

found in orthodontic bracket contamination. Following Streptococci, B. cereus and B. licheniformis were the other frequently isolated species highlighted in our systematic review. Food-borne illnesses and nosocomial epidemics are both brought on by Bacillus species in hospitalized patients with compromised immune systems.[32]

K. pneumoniae infection spreads from one person to another through hospital staff members' contaminated hands. In a study by Rastogi,[14] Klebsiella spp. were isolated from the braces. Additionally, the research found a direct link between Klebsiella spp. and autoimmune diseases such as Crohn's disease, rheumatoid arthritis, and ankylosing spondylitis.[33,34] In our study,[35] mention of Lactobacilli spp. that cause and advance dental caries/decay was comparatively minimal. Before placing the brackets in the oral cavity, it is crucial to sterilize or disinfect them because of the serious health risks posed by all these dangerous pathogens.

Chlorhexidine has a broad antibacterial action and is used in a variety of medical specialties, including gynecology, urology, and ophthalmology.[36] Chlorhexidine has been shown in numerous trials to be efficient as an antiplaque and antibacterial agent. It possesses both bacteriostatic and bactericidal effects, depending on the concentration.[36,37] Further studies have revealed that chlorhexidine has no effect on the shear bond strength of orthodontic brackets and that this bond strength is clinically acceptable.[38] Additionally, according to Speer *et al.*,[39] chlorhexidine decreased the bond strength of ceramic brackets while having no effect on the bond strength of metal brackets.

It is still unclear how precisely chlorhexidine works to kill bacteria, but it has been hypothesized that positively charged chlorhexidine molecules attach to negatively charged lipid molecules in cell membranes and osmosis is hampered as a result.[40]

The application of antimicrobial nanoparticles is another cutting-edge strategy that can be employed to lessen the bacterial contamination of orthodontic brackets.[41] The various techniques include adding a thin layer of nitrogen-doped titania nanoparticles to orthodontic brackets, mixing fluorapatite, fluorohydroxyapatite, or hydroxyapatite nanoparticles into glass ionomer or resin-modified glass ionomer cement, adding titania, silica, or silver nanoparticles to acrylic orthodontic materials, and adding nanofillers or silica/titania nanoparticles.

Studies have shown that gram-negative bacteria require slightly higher amounts of chlorhexidine to be killed than gram-positive pathogens.[42,43] Gram-positive bacteria are more easily eliminated than gram-negative bacteria because they have a porous cell wall.[44] Bacteria that were gram-positive and nonpathogenic made composed the organisms in group 2. Therefore, a lower concentration of chlorhexidine (0.01%) was sufficient to eradicate all the germs. However, in other groups, brackets were found to contain both gram-positive and gram-negative bacteria, which necessitated a greater chlorhexidine concentration (2%) for thorough disinfection.

The number of investigations that we selected for our systematic review and meta-analysis can be deemed

Table 2: Description and outcomes as observed in the studies selected for the systematic review

Author and year of study	Sample size	Study design	Study objective/description	Study inference/outcome
Barenghi *et al*. 2017[18]	95 articles	Systematic review	Concerning the quality of supplies, the steps necessary to follow the standard precautions of hand hygiene, the use of personal protective equipment (PPE), respiratory hygiene/cough etiquette, sharp safety, reconditioning orthodontic instruments, cleaning and disinfecting clinical contact surfaces and dental unit water lines, and impression dispensing, problems, and difficulties for orthodontic offices in applying the recommendations were divided into nine focus areas	The authors came to the conclusion that better knowledge, education, and training, ergonomics, and task-specific, evidence-based guidelines and resources are necessary to improve compliance with infection control recommendations based on their experiences in a university department of orthodontics and private orthodontic offices
Benson and Douglas 2007[19]	32 patients	Prospective, cross-sectional study	First molar bands were placed on four teeth before being taken off. They received a random assignment to either get no decontamination (control) or receive 15 minutes of decontamination in an ultrasonic cleaning bath (experimental). The bands were submerged in a preset amount of phosphate-buffered saline (PBS) and tested using an enzyme-linked immunosorbent assay (ELISA) to look for albumin, which can be used to identify blood, and amylase, which can identify saliva	Amylase, albumin, or both was detected in 50% of the decontaminated molar bands. When compared to the uncleaned bands, the amount of detectable amylase was much lower on the cleaned bands, but the decrease in albumin was not statistically significant. Salivary proteins (amylase) from tried-in bands were decreased but not completely removed by ultrasonic washing for 15 minutes. It has a lower capacity to eliminate serum protein (albumin)
Jurišić *et al*. 2017[20]	80 adolescents (mean age 14.2 years; 19 males)	Observational study	Eighty participants were randomly split into two equal groups based on the type of brackets: ceramic and metal–stainless steel. Subjects from each group were divided into two equal subgroups at random for four weeks following the insertion of the fixed orthodontic appliances, and they received two different types of mouthwash for 14 days: I alcohol-free mouthwash CHX and CHX with an anti-fade system (CHX-ADS). The assessment was carried out using the gingival index (GI), and oral hygiene index-simplified (OHI-S) measurements taken before the appliance was placed (t1), six weeks later (t2), and 18 weeks later (t3)	All groups' GI and OHI-S indices showed a statistically significant decline after six weeks, followed by an increase after eighteen weeks. After using the mouth rinse for 14 days, at t2, participants wearing ceramic brackets had decreased GI and OHI-S readings, with a statistically significant difference in GI
Noorollahian *et al*. 2012[21]	36 mini-screws	*In vitro* study	This study's objectives were to present a novel cleaning technique for mini-screws and evaluate its effectiveness (application of phosphoric acid 37% for 10 minutes, followed by sodium hypochlorite 5.25% for 30 minutes). It was determined how this processing affected the insertion, removal, and fracture torques of mini-screws	Used mini-screws were cleaned with phosphoric acid at 37% for 10 minutes and sodium hypochlorite at 5.25% for 30 minutes, which brought tissue remnants down to the same level as fresh mini-screws. As a result, it was proposed as a technique for processing used mini-screws. The insertion, removal, and fracture torque values as mechanical properties indices were not adversely affected by the prior insertion of mini-screws into the bone, the aforementioned processing technique, or resterilization with an autoclave
Pithon *et al*. 2013[22]	480 elastomeric ligatures	In vitro study	To create group TP (latex natural, bulk pack, TP orthodontics), group M1 (polyurethane, bulk pack, Morelli),	At the 1-hour time interval, there was no difference between the two types of Morelli elastomerics, but

Contd...

Table 2: Contd...

Author and year of study	Sample size	Study design	Study objective/description	Study inference/outcome
			group M2 (polyurethane, cane-loaded, Morelli), and group U, the 400 silver elastomeric ligatures were divided into four groups of 120 ligatures each (polyurethane, cane-loaded, Uniden). 100 of each group's 120 ligatures were sterilized in 0.25% peracetic acid (PAA) at intervals of one hour, two hours, three hours, four hours, and five hours (N=20). Each group's remaining 20 elastomeric ligatures functioned as controls and were not sterilized	there was a significant difference between TP, Morelli, and Uniden elastomerics (p 0.05). Additionally, except for groups CC and TP at the 1-hour time interval, there was a significant difference between group CC and the other groups evaluated. The cell viability of the non-sterilized elastomeric ligatures was comparable to that seen after standard sterilization for one hour. Therefore, after an hour of sterilization, PAA had no discernible effect on the cytotoxicity of elastomeric ligatures and was therefore advised for clinical use
Verma and Sivkumar 2020[23]	20 orthodontic pliers	Comparative study	Inoculated with Coagulase-negative streptococci were 20 orthodontic pliers. There were four sets of five pliers each in the divided set of pliers. One group served as the control, and each group received a different disinfection solution. Spirit (group 1), 5% glutaraldehyde (group 2), 2% sodium hypochlorite (group 3), and distilled water were used as disinfectants (control group)	Based on these findings, the authors came to the conclusion that the most effective chair-side cleaning techniques were the disinfection of orthodontic pliers with spirit and 5% glutaraldehyde
Rohmetra *et al*. 2018[24]	-	Literature review	The authors of this article made an effort to offer some useful suggestions for real-world infection control practices	Increased hand washing, the use of barrier techniques, the use of puncture-proof containers for the disposal of sharps, and heat sterilization of hand pieces and orthodontic tools were all specific difficulties in the orthodontic office that needed to be addressed. To prevent the spread of infections from patient to patient and from dentist to patient, this was of the utmost importance
Vivek *et al*. 2019[25]	140 orthodontic brackets	*In vitro* study	The study assessed both the bacterial load on orthodontic brackets and the effectiveness of chlorhexidine as a disinfectant. Four different manufacturers contributed a total of 140 brackets, which were then split into six groups: group 1 (American Orthodontics; n=30); group 2 (3M Unitek; n=30); group 3 (Ortho Organizers; n=30); group 4 (China Dental Orthodontic; n=30); group 5 (negative control; n=10); and group 6 (positive control; n=10). The brackets were subjected to a number of microbiological and biochemical tests to identify the type and development of bacteria. When brackets revealed microbiological contamination, they were cleaned using 0.01% and 2% chlorhexidine solutions	All brackets in the other groups harboring gram-negative bacteria showed complete decontamination with 2% chlorhexidine, whereas brackets in group 2 showed complete decontamination after disinfection with 0.01% chlorhexidine solution. The efficacy of 2% chlorhexidine to disinfect was very successful in eliminating both gram-positive and gram-negative germs. Therefore, it was recommended that orthodontic brackets be cleaned with 2% chlorhexidine in clinical settings before being inserted into the oral cavity

to be quite low, if compared to what an ideal review should look like, but the fact is we were very stringent in our selection criterion for selecting studies and thus only chose papers where the methodological quality was deemed to be fairly high. Moreover, a lot of studies present in the online databases were merely scoping reviews/presentations about how the pandemic has impacted the disinfection scenario in both medical and dental settings, without substantiated evidence to back it up; hence, we avoided studies carried out during or after the pandemic that analyzed these changes that were specific to coronavirus disease 2019 (COVID-19). Hence, we believe more studies are needed that examine the changes in sterilization protocol observed in the field of orthodontics and whether they are as effective as the ones that are currently being used.

Conclusions

Chemical method of sterilization was the norm in most of the studies that we assessed and meta-analyzed, with glutaraldehyde and peracetic acid (PAA) being the most commonly employed compounds for disinfection, and the existing methods of sterilization were found to be competent in dealing with the microorganisms found in a typical orthodontic setting. The literature also included a narrative regarding the adjustments in protocol seen following the COVID-19 pandemic, but it was impossible to locate validated evidence with regard to an orthodontic workstation.

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Conflicts of interest

There are no conflicts of interest.

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