Disinfection protocols during COVID-19 pandemic and their effects on prosthetic surfaces: a systematic review.

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**Purpose:** To describe the possible adverse effects of sodium hypochlorite (NaOCl) solutions, high-concentration alcohol solutions, and povidone-iodine products, which are indicated for disinfection of inanimate surfaces against human coronavirus of the severe acute respiratory syndrome (SARS-CoV), on prosthesis materials, including zirconia, lithium disilicate, and acrylic resin. **Materials and**
Methods: A systematic literature research for articles published between January 2010 and February 2020 was conducted in Scopus, PubMed/Medline, Web of Science, Embase, and Science Direct using a combination of the following MeSH/Emtree terms and keywords: sodium hypochlorite, alcohol, ethanol, povidone-iodine, dental ceramic, zirconia, lithium disilicate, and acrylic resin. Results: A total of 538 studies were identified in the search during initial screening, of which 44 were subject to full-text evaluation, and 24 fulfilled the inclusion criteria. Seven articles on zirconia and lithium disilicate investigated the effect of NaOCl (0.5% and 1%), 96% isopropanol, and 80% ethanol on bond strength after saliva contamination. The remaining articles evaluated color alteration, surface roughness modifications, decrease in flexural strength, and bonding strength of all cleaning agents on acrylic resin. Conclusion: NaOCl (1%) solution for 1 minute is recommended to reduce SARS-CoV infectivity and to minimize the risk of cross-contamination through prosthetic materials. The increase in surface roughness and color alteration were recorded using 1% NaOCl on acrylic resin, but this increase was not clinically significant. A decrease in bonding strength was determined after using 1% NaOCl, 96% isopropanol, and 80% ethanol solutions on lithium disilicate. Silanization before the try-in procedure and the application of the second layer of silane after cleaning methods are recommended to improve the bonding strength. Int J Prosthodont 2021. doi: 10.11607/ijp.7151

Introduction:

Chinese center for disease control and prevention officially announced the presence of a new disease called COVID-19 caused by novel severe acute respiratory syndrome coronavirus (SARS-CoV-2) in January 2020. It has rapidly spread from China to worldwide and the World Health Organization declared a public health emergency of international concern over this global pneumonia outbreak on 30th January 2020. Human-to-human transmission through cough, sneeze, and droplets of saliva have been confirmed, however, the transmission route of SARS-CoV2 from contaminated dry surfaces has
been postulated.\textsuperscript{6,7} Due to the incubation period (from 5 to 14 days)\textsuperscript{8} and the risk of transmission also from asymptomatic patients, continuous face-to-face communication with patients and the frequent exposure to saliva, blood, and other body fluids increase the risk of COVID-19 infection between clinicians, health-care operators, and patients in the dental care setting.\textsuperscript{9,10,11} The airborne, during a dental procedure, represents the main possible transmission route, because it is hard to control the diffusion of droplets mixed with the patient’s saliva and blood on the surface.\textsuperscript{6,10,12,13} Previous human coronaviruses like severe acute (SARS-CoV) and the middle east (MERS-CoV) respiratory syndrome coronavirus can remain infectious on inanimate surfaces like metal, paper, and plastic from 2 hours up to 9 days and persist better at 50\% compared with 30\% relative humidity.\textsuperscript{10,13,14} Therefore, materials such as dental ceramic, zirconia, and acrylic resin that are frequently used in prosthodontics to fabricate interim and definitive prosthesis, implant-supported prosthesis, and removable dental prosthesis are potential indirect transmission routes between patients, dental clinic, and laboratory.\textsuperscript{15} Several chemical agents are indicated to disinfect the oral-care setting,\textsuperscript{16,17} but few articles evaluated their antiviral efficacy against SARS-CoV\textsuperscript{18-25} and, to the best of our knowledge, no research on SARS-CoV-2 is available so far. All povidone-iodine products, including 7\% povidone-iodine gargle/mouthwash (Isodine Gargle; Meiji Seika Kaisha Ltd) for 30-120 seconds,\textsuperscript{18-20} high-concentration alcohol solutions (70\% or more) for 1 minute,\textsuperscript{21-23} 0.21\% and 1 \% of sodium hypochlorite (NaOCl) for 1 minute\textsuperscript{13,24} presented a log\textsubscript{10} viral reduction factor of >3, which is suggested as a benchmark for the effective virucidal activity against SARS-CoV on inanimate surfaces. Even though a temperature above 60\degree C for 30 minutes has been demonstrated to reduce the persistence of SARS-CoV on inanimate surfaces,\textsuperscript{25} this method is not applicable to the disinfection of prosthetic materials. All disinfection regimens were tested against SARS-CoV, therefore, all authors expected a similar virucidal effect against SARS-CoV2.\textsuperscript{13} Disinfection is crucial for preventing viral transmission from surfaces to humans,\textsuperscript{26} and knowledge of correct use of chemical agents to avoid cross-contamination and adverse effects on
prosthetic materials is essential for daily clinical activity. Therefore, the purpose of this literature review is to describe the possible adverse effects of the disinfectant agents recommended against SARS-CoV on prosthetic materials such as zirconia, lithium disilicate, and acrylic resin.

**Material and Methods:**

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews statement. The PICO question was: “In patients with prosthetic rehabilitations (P), does the use of disinfectant agents recommended against SARS-CoV (I) have any possible adverse effects on prosthetic materials such as zirconia, lithium disilicate, and acrylic resin (C) in terms of color alteration, surface roughness modifications, decrease in flexural strength, and bonding strength (O)?”

**Search Strategy**

Electronic database searches of MEDLINE, EMBASE, Web of Science, Science Direct and Scopus were performed using the following keywords and MeSH/Emtree terms based on a search strategy used for searching MEDLINE: “sodium hypochlorite”, “alcohol”, “ethanol”, “povidone-iodine”, “dental ceramic”, “zirconia”, “lithium disilicate”, and “acrylic resin.” In addition, a manual search of the bibliographies of the most relevant systematic review and of all included and excluded articles was employed to identify other eligible studies.

**Screening Method and Data Extraction**

Titles and abstracts were screened, and the full texts of all potentially relevant publications were reviewed independently by the 2 authors (A.D.F, C.M.). Any disagreements between the 2 reviewers regarding inclusion were resolved by discussion. Cohen’s kappa statistic was calculated at both the stages.

The investigators recorded the study title, authors, year of publication, journal in which the research was published, study type (**in vitro** or **in vivo** research), surface treatment proposed (i.e. disinfectant agent, concentration, timing), prosthetic materials investigated, and adverse effects.
Inclusion and Exclusion Criteria

The inclusion criteria were confined to full-text articles in English, published in peer-reviewed journals between January 2010 and February 2020, which evaluated the adverse effect of NaOCl, high-concentration alcohol solutions, and povidone-iodine products on zirconia, lithium disilicate, and acrylic resin. The exclusion criteria were articles that described other antiviral disinfectants, letters to the editor, personal communications, reviews and meta-analyses. Surface roughness, color alteration, flexural strength, and bonding strength were the primary factors evaluated in each article. Subsequently, scientific articles that brought a better understanding of the different adverse effects of disinfectants on prosthetic materials were identified to clarify and add knowledge.

Results:

A total of 538 were found in the search during initial screening. Five hundred and eight records were identified through database searching and 38 from the manual search. After duplicate studies had been removed, 311 records were screened. After title/abstract evaluation, 44 articles were selected for the full text evaluation, of which twenty-four fulfilled the inclusion criteria (Fig.1). As reported in Table 1, the main reasons for exclusion were that several studies investigated the antimicrobial efficacies after immersion in disinfectant solutions without verifying their effects on the prosthetic materials. The Cohen’s kappa agreement test showed an index of 0.91 for abstract and 0.95 for full-text. Seven articles on zirconia and lithium disilicate investigated the effect of NaOCl (0.5 and 1%), 96% isopropanol, and 80% ethanol on bond strength after saliva contamination simulating try-in procedure. Regarding acrylic resin, 13 articles tested the adverse effect such as color alteration, surface roughness, flexural strength, and bonding strength of the NaOCl at different concentrations and exposure times, 3 of the ethanol at a concentration of 40,70, and 99%, and 1 of the povidone-iodine product. Respective chemical regimens, and adverse effects about the studies included in the present review are provided in Table 2. Of 24
included studies, 23 were in vitro and only 1 in vivo. Few focused on the effect of cleaning solutions on the mechanical behavior of prosthetic materials. Adverse effects on acrylic resin after immersion in disinfectant agents resulted the most investigated topic.\textsuperscript{44-53}

Discussion:

This review attempted to focus on the adverse effects of NaOCl, high-concentration alcohol solutions, including ethanol and isopropanol, and povidone-iodine products on prosthetic materials. Virucidal efficacy of all chemical regimens was tested against SARS-CoV, therefore, the authors expected the same effects against SARS-CoV2. The articles reviewed suggest that adverse effects such as decreased bond strength, color alteration, and increase surface roughness may occur after the use of NaOCl,\textsuperscript{37-39,44-48} high-concentration alcohol solutions,\textsuperscript{40-43,49-51} and povidone-iodine products.\textsuperscript{52}

Aladag et al.\textsuperscript{37} assessed the influence of various surface cleaning regimens, including 0.5% NaOCl solution, on bond strength after saliva contamination of three all-ceramic surfaces such as zirconia (IPS e.max ZirCAD; Ivoclar Vivadent), leucite (IPS Empress CAD; Ivoclar Vivadent), and lithium disilicate (IPS e.max CAD; Ivoclar Vivadent). After the bonding procedure of the composite resin cylinders to the decontaminated surface, failure test was performed. Decrease in bond strength was recorded for lithium disilicate, instead, no for zirconia and leucite. Whereas, Kim et al.\textsuperscript{38} which immersed zirconia disk (Lava; 3M ESPE) in saliva for 1 minute following the simulation of try-in procedure, determined that 1% NaOCl solution used to decontaminate did not decrease the shear bond strength of resin cylinders bonded to the specimens. In addition, exposure to the disinfectant did not change the surface roughness value of the zirconia disks. No adverse effects of 96% isopropanol for 10 minutes and 1% NaOCl solutions for 20 seconds on retention of saliva-contaminated zirconia (Cercon Base; Degudent) implant-supported copings were found by Nejatidanesh et al.\textsuperscript{39} After immersion in fresh human saliva

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for 1 minute and decontamination, the copings were luted with a resin luting agent (RelyX Unicem; 3M ESPE) on titanium abutments and the retentive values were tested using a universal testing machine.

A negative influence on the bond strength of the lithium disilicate (IPS e.max Press; Ivoclar Vivadent) and zirconia (Cercon; DeguDent) after cleaning procedure using 96% isopropanol for 15 seconds was demonstrated by Klosa et al.40 and Quaas et al.41 Both specimens were immersed in saliva for 1 minute, decontaminated, and plexiglass tubes filled with composite resin (MultiCore Flow; Ivoclar Vivadent) were bonded using two different luting resin: Multilink Automix (Ivoclar Vivadent) for lithium disilicate and Panavia F2.0 (Kuraray Noritake) for zirconia. Before measuring tensile bond strength, specimens were stored for 3 or 150 days using a thermocycling test.

The opposite conclusion was obtained by Nikolaus et al,42 who indicated an increase in the bond strength using 80% ethanol cleaning solution. However, the authors used saliva and cleaning regimes on a silanized glass-ceramic surface (IPS Empress; Ivoclar Vivadent) and before adhesion protocol, applied a second layer of silane (Monobond S; Ivoclar Vivadent). The advantage effect of this procedure was demonstrated by Marfenko et al,43 who investigated the effect of different cleaning regimens including 80% ethanol for 1 minute on the adhesion of resin cement to lithium disilicate ceramic (IPS e.max CAD; Ivoclar Vivadent). Before contamination with saliva for 1 minute and cleaning methods, half of the specimens were silanized (Monobond; Ivoclar Vivadent) after etching.

Adverse effect on bonding strength with an average value of 5.4± 2.1 MPa was recorded in group exposed to 80% ethanol and without preliminary silanization. Whereas, the average bonding strength value of the group with silanization prior to saliva contamination and cleaning method with 80 % ethanol were 24± 3.6 Mpa.

Regarding the acrylic resin, NaOCl is the most tested. After immersion of 110 rectangles fabricated using heat polymerized acrylic resin (Triplex; Ivoclar Vivadent) in NaOCl at concentrations of 1, 2.5%, and 5.25% for 10 minutes, the flexural strength was not significantly affected by exposure in any of the
three solutions. In addition, flexural strength, color alteration and roughness surface were evaluated by Davi et al. After 180 days of complete immersion of 40 specimens of acrylic resin (Onda-Cryl; Artigos Odontologicos Classico Ltda), 1% NaOCl solution may adversely affect the color and flexural strength of the acrylic resin, instead, 0.5% concentration produced no significant changes in color and flexural strength. Same conclusions were reported using NaOCl at different concentration 1%, 2.5%, and 5.25%. No statistical significance regarding surface roughness was found between the concentrations 1%, 2.5%, and 5.25% NaOCl after 7 and 180 days of exposure time, instead, Fernandes et al after investigating three commercial types of acrylic resin (Lucitone 550; Dentsply Sirona, QC-20; DeguDent, and Vipi-Wave; Vipi) concluded that the immersion in 1% NaOCl solution for 30 and 60 min of QC-20 presented the highest average surface roughness values compared to the baseline. Moreover, higher color alteration values were detected after 60 min of immersion in the disinfectants, but without any clinical significance. Increase of surface roughness was obtained using 0.5% NaOCl solution after 7, 14, and 21 days and after 8 hours daily in a period of 3, 6, 12, 36, and 60 months. However, the average roughness in all the groups was below 0.2 µm, thus, clinically acceptable. Color changing using the same concentration and exposure time was registered by Hong et al, however, another study that simulated a period of 5 years of daily immersions for 20 minutes of 0.1% and 0.2% NaOCl solution, showed that these solutions did not cause color, surface roughness, and flexural strength alterations. No significant color and roughness changes, but high levels of satisfaction were reported from 15 participants, which immersed daily the complete prosthesis in a 0.5% NaOCl solution for 3 min over 90 days. Simulating 1.85 years of daily disinfection, no adverse effects were found using 1% NaOCl solution on surface microharness of the commercial artificial teeth, but a decrease in bond strength between the artificial tooth and microwave-cured acrylic resin was recorded. Deteriorate surface of denture base polymers was observed using ethanol at different concentrations (40, 70, and 99.9%) and exposure times (30, 60, and 120 seconds) and therefore their
use was not recommended.\textsuperscript{57,58} Effect of ethanol on the acrylic resin was attributed to absorbing water from varying concentrations of ethanol in 70\% and 40\%, that interfered with the polymer chains affecting the physical properties causing swelling of the resin network resulting in the relaxation of the stresses. Color change was observed on heat-curing acrylic resin (Procast DSP; GC) immersed in ethanol,\textsuperscript{59} as well as after immersion in povidone-iodine.\textsuperscript{60}

During the try-in procedure of zirconia or lithium disilicate fixed restorations, the surfaces may be contaminated by droplets mixed with the patient’s saliva and blood, therefore, cleaning procedures are needed to avoid cross-contamination between clinicians, health-care operators, and patients in the dental care setting. Even though the NaOCl\textsuperscript{37-40} and high concentration alcohol\textsuperscript{39,43} solutions did not influence the bonding strength on zirconia, decreasing was determined on lithium disilicate. However, preliminary silanization before try-in procedure and the application of the second layer of silane after cleaning methods on lithium disilicate ceramic is recommended to oppose the adverse effects of disinfectant solutions on the bonding strength. Air abrasion with 50 µm Al\textsubscript{2}O\textsubscript{3} at 2.5 bar pressure for 15 seconds on zirconia is recommended before the luting procedure, even though no decrease of bonding strength was recorded. Regarding acrylic resin, 1\% NaOCl-induced bleaching, surface roughness modifications, and flexural strength reduction, however, all alterations were considered clinically not relevant.\textsuperscript{44-56} Instead, high concentration alcohol solutions irreversibly deteriorated the surface of the acrylic resin due to chemical interactions with water, therefore its use is not recommended.\textsuperscript{57-59}

A limitation of this work is the lack of studies on the adverse effects of the povidone-iodine on surface. Future studies are needed to fill the gap in the literature and to provide processes that explain the adverse effect of disinfectants effective against SARS-CoV2 on prosthetic materials.

\textbf{Conclusion:}

Based on the findings of this systematic review, the following conclusions were drawn:
1. The sodium hypochlorite at concentration 1% for 1 minute is recommended to reduce SARS-CoV infectivity and to minimize the risk of cross-contamination through cough, sneeze, and a droplet of saliva on prosthetic materials. The virucidal effect of the agents was tested against SARS-CoV, therefore, similar effects against the SARS-CoV2 are expected.

2. Decrease of bonding strength was determined after using 1% NaOCl or 96% isopropanol or 80% ethanol solutions on lithium disilicate. Preliminary silanization before of the try-in procedure and the application of a second layer of silane after cleaning methods are recommended to improve the bonding strength.

3. 1% NaOCl or 96% isopropanol or 80% ethanol solutions did not influenced the bonding strength on zirconia, however, air abrasion with 50 µm Al₂O₃ at 2.5 bar pressure for 15 seconds on zirconia is recommended before of the luting procedure.

4. Color alteration and increase in surface roughness were recorded after the use of NaOCl at different concentrations and exposure times on acrylic resin, however, the adverse effects are clinically acceptable.

5. Daily disinfection with 1% NaOCl solution for 1 minute of all restorations realized using acryl resin is recommended. High-concentration alcohol solutions irreversibly deformed the acrylic resin.

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References:


### Tables and figures

Table 1. Main reasons for exclusion after full-text analysis

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moorer et al</td>
<td>2003</td>
<td>No assessment of adverse effects on the prosthetic materials</td>
</tr>
<tr>
<td>Pavarina et al</td>
<td>2003</td>
<td>Study did not investigated the antiviral efficacies of disinfectants</td>
</tr>
<tr>
<td>Hota et al</td>
<td>2004</td>
<td>Study did not investigated the antiviral efficacies of disinfectants</td>
</tr>
<tr>
<td>Rabenau et al</td>
<td>2005</td>
<td>No assessment of adverse effects on the prosthetic materials</td>
</tr>
<tr>
<td>Rabenau et al</td>
<td>2005</td>
<td>No assessment of adverse effects on the prosthetic materials</td>
</tr>
<tr>
<td>Kariwa et al</td>
<td>2006</td>
<td>No assessment of adverse effects on the prosthetic materials</td>
</tr>
<tr>
<td>Da Silvia et al</td>
<td>2008</td>
<td>Study did not investigated the antiviral efficacies of disinfectants</td>
</tr>
<tr>
<td>Machado et al</td>
<td>2009</td>
<td>Study did not investigated the antiviral efficacies of disinfectants</td>
</tr>
<tr>
<td>Dellanno et al</td>
<td>2009</td>
<td>No assessment of adverse effects on the prosthetic materials</td>
</tr>
<tr>
<td>Iser et al</td>
<td>2011</td>
<td>Study did not investigated the antiviral efficacies of disinfectants</td>
</tr>
<tr>
<td>Hulkower et al</td>
<td>2011</td>
<td>No assessment of adverse effects on the prosthetic materials</td>
</tr>
<tr>
<td>Machado et al</td>
<td>2012</td>
<td>Study did not investigated the antiviral efficacies of disinfectants</td>
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<tr>
<td>Kumar et al</td>
<td>2012</td>
<td>Study did not investigated the antiviral efficacies of disinfectants</td>
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<tr>
<td>Salvia et al</td>
<td>2013</td>
<td>Study did not investigated the antiviral efficacies of disinfectants</td>
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<tr>
<td>Eggers et al</td>
<td>2015</td>
<td>No assessment of adverse effects on the prosthetic materials</td>
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<tr>
<td>de Foggi et al</td>
<td>2016</td>
<td>Study did not investigated the antiviral efficacies of disinfectants</td>
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<tr>
<td>Eggers et al</td>
<td>2018</td>
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<tr>
<td>Masetti et al</td>
<td>2018</td>
<td>Study did not investigated the antiviral efficacies of disinfectants</td>
</tr>
<tr>
<td>Procopio et al</td>
<td>2018</td>
<td>Study did not investigated the antiviral efficacies of disinfectants</td>
</tr>
<tr>
<td>Kampf et al</td>
<td>2020</td>
<td>No assessment of adverse effects on the prosthetic materials</td>
</tr>
</tbody>
</table>
Table 2. Studies include, surface treatment proposed, prosthetic material and adverse effect investigated.

<table>
<thead>
<tr>
<th>Prosthetic Material</th>
<th>Surface Treatment</th>
<th>Effect</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zirconia</td>
<td>NaOCL (Different Solutions)</td>
<td>No decrease in bonding strength.37,38,39</td>
<td>Aladag et al37; Kim et al38; Nejatidanesh et al39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No increase in surface roughness.38</td>
<td></td>
</tr>
<tr>
<td>Alcoholic Solutions</td>
<td></td>
<td>No decrease in bonding strength.39</td>
<td>Nejatidanesh et al39; Quaas et al41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decrease in bonding strength (with 96% isopropanol)41</td>
<td></td>
</tr>
<tr>
<td>Povidone-Iodine</td>
<td></td>
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<td>/</td>
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<tr>
<td>Lithium Disilicate glass ceramics</td>
<td>NaOCL (Different Solutions)</td>
<td>Decrease in bonding strength (with 0.5% NaOCL)</td>
<td>Aladag et al37;</td>
</tr>
<tr>
<td></td>
<td>Alcoholic Solutions</td>
<td>Decrease in bonding strength (with 96% isopropanol)40</td>
<td>Klosa et al40; Nikolaus et al42; Marfenko et al43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No decrease in bonding strength (with 80% ethanol and preliminary silanization)42,43</td>
<td></td>
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<tr>
<td>Povidone-Iodine</td>
<td></td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Leucite-based glass ceramics</td>
<td>NaOCL (Different Solutions)</td>
<td>No decrease in bond strength.37</td>
<td>Aladag et al37;</td>
</tr>
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<td></td>
<td>Alcoholic Solutions</td>
<td>/</td>
<td>/</td>
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<tr>
<td></td>
<td>Povidone-Iodine</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Acrylic Resin</td>
<td>NaOCL (Different Solutions)</td>
<td>No decrease in flexural strength.44,45,52</td>
<td>Ellakwa et al44; Davi et al45; Orsi and Andreade46; Azevedo et al47; Fernandes et al48; Badaro et al49; Paranhos et al51; Hong et al52; Arruda et al53; De Sousa et al54 (in vivo study); Vasconcelos et al55; Matos et al56</td>
</tr>
<tr>
<td></td>
<td>Alcoholic Solutions</td>
<td>Deteriorate surface of denture base (40, 70, and 99.9% ethanol)</td>
<td>Basavarajappa et al57; Basavarajappa et al58; Sideridou et al59</td>
</tr>
<tr>
<td>Povidone-Iodine</td>
<td>Color alteration</td>
<td>/</td>
<td>Piskin et al60</td>
</tr>
</tbody>
</table>
Figure 1. Flowchart of study selection.

- Records identified through database searching (n = 508)
- Additional records identified through other sources (n = 30)
- Records after duplicates removed (n = 311)
- Records screened (n = 311) → Records excluded (n = 267)
- Full-text articles assessed for eligibility (n = 44) → Full-text articles excluded, with reasons (n = 20)
- Studies included in qualitative synthesis (n = 24)