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Research article

Factors influencing retention and durability of attachments for overdentures – adverse effects of cleansings, pH, and temperature: A systematic review

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ABSTRACT

Aim: The objective of this systematic review is to show the current state of the art on which type of attachment loses retention the most and has reduced durability and which factor causes these problems the most.
Material and methods: This review followed the Preferred Reporting Items for Systematic Review and MetaAnalysis (PRISMA) guidelines and it was registered with the Open Science Framework (OSF) (osf.io/2e3q5). The databases used for the electronic search of articles were Pubmed, Science Direct, Embase, and Scopus. Articles were selected by 2 independent reviewers according to the inclusion criteria. The risk of bias was analyzed by using the Joanna Briggs Institute (JBI) adapted quasi-experimental study evaluation tool.
Results: The studies included in this review indicate that the use of cleansing solutions, high temperatures, and a more acidic pH decrease the durability of the attachments, mainly due to the loss of retention that occurs in different models and materials of the attachments, which requires their replacement in a shorter period.
Conclusion: Of all the factors studied, the cleansing solutions proved to be the factor that most altered attachment retention. Different saliva compositions did not influence retention values. Aging changes retention values for attachments, mostly with loss of values.

1. Introduction

Implant-supported overdentures are removable dentures and the first option for oral rehabilitation, mainly in the mandible, due to significant improvement in stability, retention, masticatory efficiency, quality of life, and cost [1, 2, 3, 4]. These compared to complete fixed prostheses are better indicated for patients with manual dexterity limited by advanced age or diseases such as Parkinson's due to the possibility of their removal for cleaning by third parties, and the surgical procedure is considered less invasive, which is beneficial for patients with disabilities [5].

The adherence of microorganisms to dental materials can cause deleterious effects on oral and peri-implant tissues, halitosis, or severe diseases such as chronic obstructive pneumonia, and generalized infections of the respiratory tract, and reduce the success of rehabilitation work [6, 7, 8, 9]. Thus, overdentures must be cleaned daily to prevent the accumulation of microorganisms under their base mainly because this type of prosthesis is concave in relation to the residual ridge, which makes it impossible to clean it without removing it. Different methods can be used to clean dentures, such as mechanical, chemical, or a combination of both [10, 11]. For the chemical method solutions such as sodium hypochlorite (NaOCl) [7, 10, 11, 12, 13, 14, 15, 16], sodium bicarbonate-sodium perborate (SBSP) [11, 12], sodium bicarbonate [11, 12], and alkaline peroxides [7, 10, 13] are used.

However, the use of solutions and immersions for denture cleaning presents problems such as discoloration, corrosion, and loss of retention of the attachments used [12, 17, 18], the latter is the most common problem with overdentures [19, 20, 21, 22], which have salivary composition, different temperatures, and pH to which the oral cavity is subjected during food intake as factors associated with loss [14, 17, 21, 23].

In this sense, it is necessary to understand the correlation between the structure and properties of the materials to enable greater retention stability and durability of attachments for overdentures when exposed to different environments, chemical compositions, and temperatures. In the course of this article, we will present more in-depth features on what causes retention failure, what each factor causes in the structure of materials and attachments. Given the above, the present systematic review aims to evaluate the current state of the art regarding the effect of cleansing solutions, pH, and different temperatures on the retention and durability of attachments.

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2. Material and methods

This systematic review was carried out and structured according to the Preferred Reporting Items for Systematic Review and Meta-Analysis extension for Systematic Reviews [24] to answer the following question: "Which attachment presents alteration in durability and retention and what is the situation or substance that promotes this alteration?". Following its protocols, it was registered in the Open Science Framework (osf.io/2e3q5). Specific criteria were adopted in this review applied with framework PICOs shown in Table 1.

As criteria for inclusion, in vitro studies were selected that contained retention analyses with implants without angulation in analysis retention under different situations such as cleansing solutions, pH, and temperatures such as aging, journals with a selective editorial policy with journals that practice blinded peer reviews and indexed in the Journal Citation Reports^{tm} – Clarivate, 2022 (JCR), and in English. As an exclusion, it was adopted that all articles that did not contain retention analyses associated with the previously mentioned factors, retention analyses with angled implants, as well as book chapters, abstracts, letters, and conferences were excluded.

The databases used for the electronic search of articles were Pubmed, Science Direct, Embase, and Scopus. The terms were (attachments AND overdentures AND durability), (attachments AND overdentures AND retention), (attachments AND overdentures AND aging), (attachments AND overdentures AND pH), and (attachments AND overdentures AND cleansing solutions). Compound terms were used with double quotes, except for the Embase database, which used single quotes. The Rayyan reference management program (Rayyan Systems Inc. 2022. Qatar Foundation) was used to check for duplicates and facilitate the selection of articles for full reading and final selection.

As a first step, the theme of the present review and the articles found in the search were added by M.R.C in the Rayyan software. When carrying out this step, M.R.C invited J.A.M.A to be part of the project. However, for the choice of articles to be made correctly and without interference in the selection, the author J.A.M.A chose articles separately from M.R.C and in a blinding way, that is, none of the authors would be able to visualize the choices of the other. In this moment (M.R.C and J.A.M.A) read the titles and abstracts to identify possible studies to be included. In the second phase, the remained manuscripts were read in full by two reviewers (M.R.C and J.A.M.A), and the references that did not meet the inclusion criteria were excluded. Only at the end of the selection of each one, a meeting was held to check if the same articles that one included were present in the inclusion of the other. Finally, to give greater reliability to the results, the coordinator A.C.R made a review in the search for both and the final selection of articles and, through this meeting, it was decided according to the inclusion and exclusion criteria which articles.

3. Results

The search for studies was detailed using the PRISMA diagram (Figure 1). The databases found a total of 3914 references. After deleting the duplicates, 2150 remained. After reading the titles and abstracts of these references and applying the inclusion criteria, 30 articles remained. Of these, all were read in full for the final selection. A total of 14 articles were included in the present systematic review. The included studies are from the years 2007–2021.

Among the attachments analyzed is the Locator with six studies [10, 11, 13, 14, 16, 23], bar/clip with three [12, 15, 21], magnetic [17] with one, and a new model of o'ring for the ball attachment with four [7, 22, 26, 27]. The most analyzed cleansing solutions were NaOCl [7, 11, 12, 13, 15, 16], followed by different alkaline solutions with different commercial brands [7, 10, 11, 12, 13, 15, 16] with more details found in Table 2. Two studies evaluated the effect of pH [17, 21] on attachments. One study evaluated the simulation of the effect of saliva [14] and five studies evaluated the effect of aging on attachments [17, 22, 23, 26, 27].

It was not possible to perform a meta-analysis of the data due to the different methods and objectives used. Thus, the results were based on a descriptive analysis of the data. The articles were qualitatively evaluated for risk of bias to have greater reliability in the results according to the Joanna Briggs Institute (Figures 2 and 3) [25]. This assessment has three values: low risk when the article is easy to interpret and understand, so there is no risk of bias; "Unclear" when the manuscript presents some point of difficult interpretation where it is necessary to be justified by the author of this review; and high risk when the results are not fully understood.

For the criterion "were outcomes measured in a reliable way", twelve studies [7, 10, 11, 13, 15, 16, 17, 21, 22, 23, 26, 27] showed a high risk of bias. This is because the studies did not declare by how many authors, if they were trained, or if there was blinding regarding the analyzes performed. For the criterion "Was there a control group", two studies [14, 17] showed a high risk of bias. This refers to these studies there is not a control group for the performed analyses.

The data obtained from the articles included are in Table 2 and Table 3, which include author and year, objective, attachment, situation, analysis performed, sample number (n), control group, and results. The Word program (Microsoft, WA, USA) was used to create the Tables and tabulate the data.

Table 1. The PICOs strategy for this systematic review.

Population	Attachments used for overdentures
Intervention	Evaluation of durability and retention in the face of simulation of adversities found in the oral cavity
Comparison	Control Group (without immersion in cleansing solutions, different temperatures and pH)
Outcomes	Retention and durability
Study Design	In vitro studies

Legend: PICOS, Population, Intervention, Comparison, and Study Design.

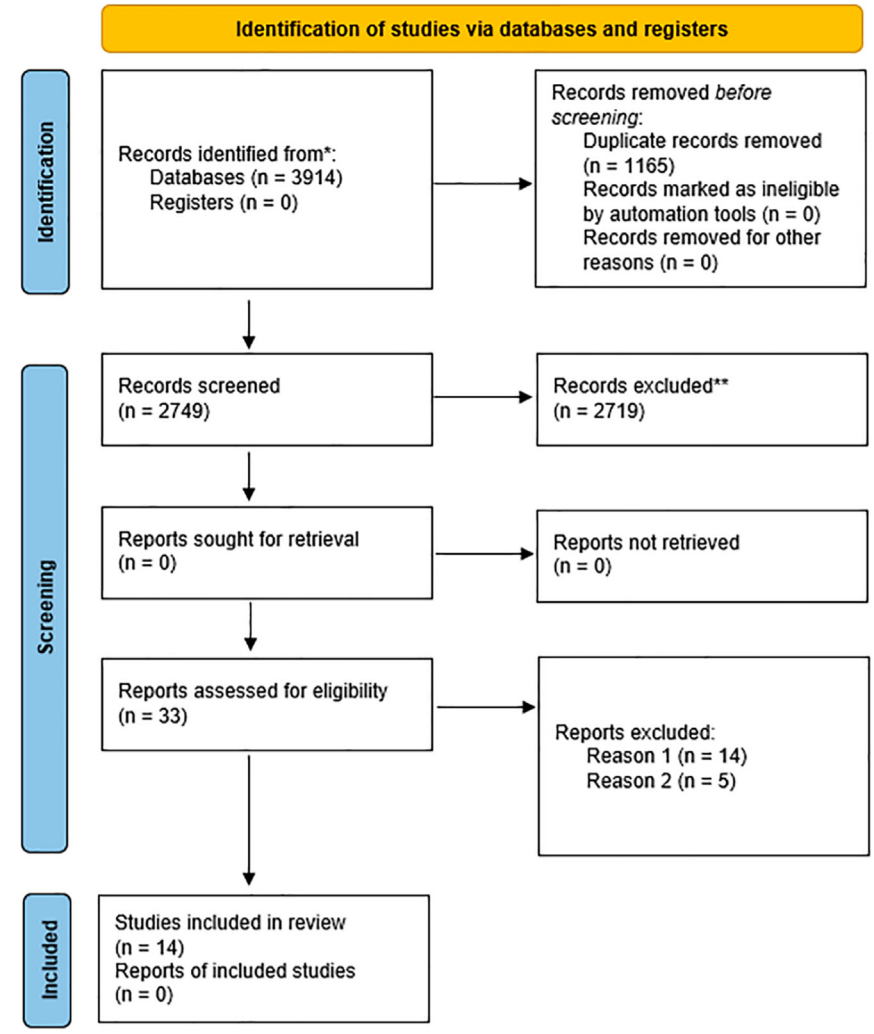
4. Discussion

The present systematic review addressed the most common problem found in attachments for overdentures, which is loss of retention. This is influenced by several factors, including masticatory habits, parafunctional habits, insertion and removal cycles, and the various alternations of temperatures, pH, and different solutions used for cleansing the dentures [7, 10, 11, 12, 13, 14, 17, 21, 23, 27, 28, 29].

Among the different situations to which overdentures are exposed, the ones that presented the greatest volume were cleansing solutions. Among these, the most present was NaOCl [7, 10, 11, 12, 13, 15]. Different studies demonstrated the antimicrobial activity of NaOCl against different species of microorganisms such as *Candida* spp. and *Streptococcus mutans* through the dissolution of organic substances that accumulate in dental materials due to the ability to release the hydroxyl ion and its high pH [11, 12, 30, 31]. However, this was the substance that most negatively interfered by significantly reducing retention values for different types and compositions of attachments [7, 10, 11, 12].

The changes that NaOCl promotes in the materials are difficult to understand because each material will present a different reaction to the solution. There is a limitation of studies that elicit the chemical interactions that occur between materials and NaOCl [11], which makes evident the need for further studies with this objective. However, Cornelius et al. [32] demonstrated through Scanning Electron Microscopy (SEM) of locator attachments that NaOCl promotes changes in the morphology of the polyamide surface, through the creation of porosities and cracks that may be the key to the loss of retention of these attachments [11, 16, 32].

Among the attachments analyzed in this systematic review, the locator was the one that most changed with NaOCl. The locator appeared in the 2000s (Zest Anchors, Inc., Escondido, CA, USA) and has since been widely used to retain overdentures [33, 34]. Due to its small vertical



Reason 1: Doesn't meet the inclusion criteria.

Reason 2: Doesn't have the Journal Citation Report (JCR) of the Journal.

Figure 1. PRISMA flow diagram quantitatively demonstrates searches in the article databases.

profile, it is used in regions with reduced space between arches, which reduces the risk of fracture of the overdenture base [33, 35]. In the analyzed studies, they evaluated three types: blue, pink, and clear, which are considered the standards of this attachment model. All models are made of Nylon, however, each one has its indication, and this is due to the average retention, where the clear has 22.2 N, the pink 13.3 N, and 6.67 N for the blue [36, 37]. Blue has the lowest initial retention among the three, this is because it is indicated for older patients, who do not have as much strength and manual dexterity to remove the overdenture [10]. While pink is the most popular of all, mainly because of its median retention for clear and blue, which indicates it is both for older and younger patients, while clear already presents retention that is considered regular, whereas it is indicated for younger patients, with greater muscle strength and more active life [10, 13, 16].

This difference found in the retention values of the locators, even made of the same material, refers to the different compositions for each one so that they have different elasticity and consequent retention [11]. In this way, the reaction of each one to different types of cleansing solutions can change, even more so because there are still no studies that demonstrate what chemical changes occur when these attachments are subjected to cleansing solutions [11].

Bar/clip attachments also suffered from loss of retention, as demonstrated by Küçükekenci et al. [12]. The clip made of Poly(tetrafluoroethylene) (PTFE) polymer showed the greatest loss of retention, with significant values that would have clinical importance. His biggest loss was also on. This is due to the creation of porosities and craters on the surface of the attachment, which reduces its durability, destroys its surface, and sharply decreases its retention [12]. However, demonstrating results contrary to those of Küçükekenci et al. [12] who used polyamide, PTFE, and PEKK clips, Varguese et al. [15] showed that nylon composite clips (Yellow Hader Clips) showed increased retention when immersed in NaOCl solution for 15 min. Compared to conventional locator and ball attachments, nylon clips also presented advantages in terms of retention, since all of these mentioned showed loss of retention when immersed in different solutions, even though the different locators are also composed of nylon. These results point to the need for further studies to assess this difference in results between the bar/clip attachment and the locator, even though both have the same material. However, it is necessary to

Table 2. Data from included studies that used different solutions for cleansing overdentures.

Author and year	Objective	Attachment	Situation	Analysis	n	Control	Results
Ayyildiz., 2020	To evaluate and compare the alterations in retention of three Locator attachments after immersion in denture cleansers	Locator (Blue, Pink, and Clear)	Corega, 6.15% NaOCl and Protefix	Retention tests	10	Yes	The denture cleansing solutions showed significant effects on retention values over time for all blue, pink, and clear locator attachments. The blue locator immersed in NaOCl showed the lowest retentive values and Corega the greater. For the pink locator, only NaOCl showed a significant difference with lower values compared to other solutions. But Corega, Protefix, and tap water were reduced too, however with similar amounts at all time intervals. After 1 year of simulated use for Clear Locator the soaked NaOCl showed significantly lower values compared to other groups.
Küçükekenci., 2021	To evaluate the retention of polymeric hader bar clips after being soaked in denture cleaning solutions	Polyamide, PTFE and PEKK	Distilled water (DW), 5% sodium hypochlorite (NaOCl), and sodium bicarbonate-sodium perborate (SBSP)	Retention tests with different solutions	10	Yes	The material that compounds the clips and the denture cleaning solutions affected the retention values. The polyamide clips had better initial and final retention values. After soaked in the cleansing solutions was observed that PTFE had a significant decrease in retention values after immersion in the NaOCl and DW solution and the Polyamide soaked in the NaOCl. All material clips had a significant decrease in retention when soaked in SBSP solution.
Kürkcüoğlu., 2016	To evaluate the retention of 3 Locator attachments after soaked in cleansing solutions	Locator (Blue, Clear, and Pink)	Sodium hypochlorite (NaOCl), sodium perborate-sodium bicarbonate (Protefix Active Cleanser), and sodium bicarbonate (Aktident – AKT)	Retention tests	7	Yes	All attachments were affected by the denture cleansing solutions. For the control group water tap, NaOCl, and Protefix the greatest retention values was for clear. For Aktident the pink attachment showed better retention values. Nothing of the three solutions affected pink attachment significantly. AKT affected the clear attachments within a significant decrease in retention values. NaOCl and AKT affected the blue attachments with a decrease in retention.
Mariotto., 2020	To evaluate the effects of different cleansing solutions on the physical-mechanical properties of three polymeric materials	Capsule for ball attachment with Polyacetal, PTFE, and PET	Distilled water, 0.5% NaOCl, Listerine Cool Mint Listerine, and Alkaline peroxide.	Roughness, hardness, and retention tests	60	Yes	The type of solution influenced the Polyacetal roughness. The NaOCl promoted greater reduction compared to alkaline peroxide. Only distilled water showed an impact on the hardness with a reduction in all materials. Considering the time factor, water, alkaline peroxide, and NaOCl showed an increase in strength of retention over time for PET. For polyacetal, the groups of Listerine and NaOCl showed lower strength. The group without immersion increases the values over time. PTFE doesn't show the influence of the time or immersion solution.
Nguyen., 2010	To evaluate changes in retention of pink Locator attachment after exposure to denture cleansing solutions	Locator (Pink)	Polident Regular, Efferdent, 6.15% sodium hypochlorite (NaOCl), Polident Overnight, and Listerine	Retention tests	20	Yes	Denture cleansing had significant effects on the retention values of pink Locator attachment. The NaOCl solution showed a reduction of 82.70% for retention compared to the control group. Polident Regular and Polident Overnight showed no significant difference in retention values. The Listerine solution showed a slight increase (12,93%) and Efferdent a slight decrease (9,81%) compared to the control group.

Table 2 (*continued*)

Author and year	Objective	Attachment	Situation	Analysis	n	Control	Results
Varguese., 2007	To evaluate the retention of yellow Hader clips after exposure to denture cleansing solutions	Hader clips (yellow)	Water, Polident Regular, Polident Overnight, Efferdent, 5.25% Sodium Hypochlorite (NaOCl)	Retention tests	18	Yes	The nylon clips soaked in NaOCl per 15 min/day showed significantly higher retention values than other solutions groups, except for water.
You., 2011	To evaluate the effect of denture cleansing solutions on retention of Locator attachments	Locator (Pink)	Efferdent, Polident Overnight, 6.15% sodium hypochlorite (NaOCl), and listerine	Retention tests	5	Yes	All denture cleansing had significant effects on the retentive values. After the immersion, the values of the initial pull tests were significantly lower for NaOCl than other groups. The smallest loss of retention at the final of the cycles was for listerine solution. The most loss of retention was for NaOCl.

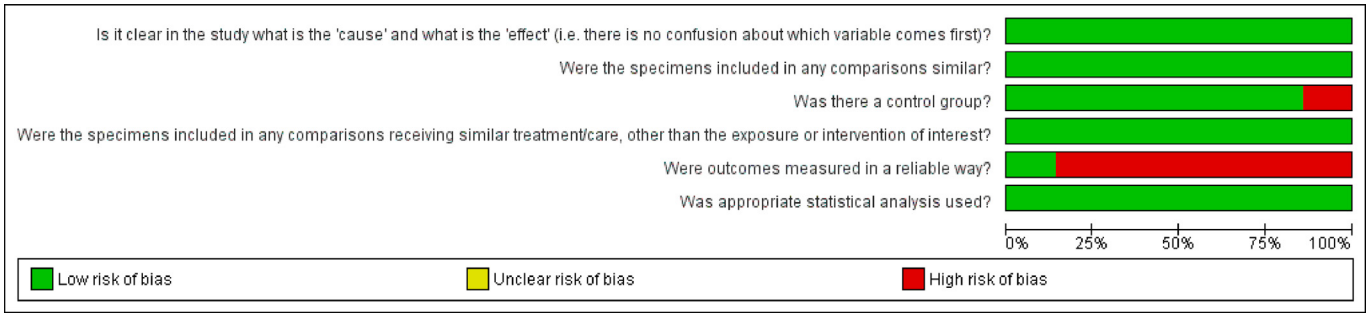


Figure 2. Risk-of-Bias graph.

carefully analyze whether the method of manufacture of both and the chemical composition are identical, as well as whether the difference in retention is also not related to the greater contact area present between the clip and the bar than the contact present. in the locator. In any case, this result points to the choice of nylon attachment when greater durability and retention stability are desired when using overdentures that will be subjected to a NaOCl sanitizing solution.

Another factor that must be considered is the cleansing of dentures in tap water, especially for people with low socioeconomic status, due to the inability to buy cleansing solutions. Tap water leads to reduced attachment retention, as demonstrated by Ayyildiz et al. [10]. This is due to the interaction between metal ions such as calcium and magnesium, chlorine, and pH. Water with this higher concentration of ions can induce limestone formation, which alters the dimensions and proper fit of the patrix and matrix, losing retention [10].

Subjected to different pH, the attachments showed reduced values [17, 21]. However, there was no statistically significant difference in the reduction between the different pHs. However, for the study by Silva et al. [21], it was observed that under more acidic pH, the clips of bar attachments showed reduced retention values, in addition to the presence of wear and corrosion areas [21]. These results are significant, due to the indication that the loss of retention does not occur only through mechanical phenomena, but also under chemical changes to which they are submitted. Thus, it is necessary to understand the chemical structure of which the attachments are composed to correlate it with the interactions and pH changes so that the durability of the components is preserved as much as possible. In any case, the differences found when submitted to different pH no longer showed significant differences, that is, clinically, this difference will represent something even smaller. Thus, it is suggested that pH is not presented as a single factor for the loss of retention, since it alone did not present important differences.

When submitted to aging, Chiu et al. [23] showed that the Locator attachment (pink) had a significant loss of retention, especially at 60 °C. When analyzed by SEM, the presence of cracks in the material was observed [23]. This result is a consequence of the beginning of the degradation of the polyamide, which undergoes continuous expansions and contractions during the thermal cycle, generating static fatigue of the material [38]. Polyamide has a high affinity for water molecules, which causes them to enter the polymer by diffusion [23]. This polyamide solubility is attributed to the amide groups, which directly depend on their concentration. However, this concentration can be changed through material engineering and make this material stronger and more durable [39]. This can also be attributed to the drop in retention of conventional o'rings, which presented polyamide as the composition of their materials [27]. Furthermore, in the studies by Fatalla et al. [26] and Galo Silva et al. [27], different groups of attachments also showed a decrease in retention in other groups of polymeric materials. These results point to the need for an in-depth study of the intrinsic properties of these materials, especially regarding the effect of temperature on crystallinity and their degradation, to reduce their onset, propagation, and consequent loss of retention.

Akin et al. [17] demonstrated that magnetic attachments, especially open-field ones, suffer from corrosion and loss of retention or attraction when subjected to oral simulations and thermocycling. This is because magnetic alloys are sensitive to increased temperatures [40], which can lead to their irreversible demagnetization [17]. In contrast, closed-fields did not show a significant decrease in retention after the analysis. A possible explanation for this is that the magnetic closed-fields have two poles of magnetic attraction, the south and the north, which means that between them there is an area of resistance to loss of retention due to this electromagnetic force [17].

On the other hand, PET [27] and PEEK [22] showed an increase in retention values after aging for the innovative model of attachments. PET is a thermoplastic polymer with an aromatic and semi-crystalline structure [41]. It has high chemical resistance, thermal stability, and hydrolytic stability due to the presence of its aromatic rings [27, 42]. Its increase in retention values is attributed to this chemical structure, in addition to its relationship with surface hardness, which increased after

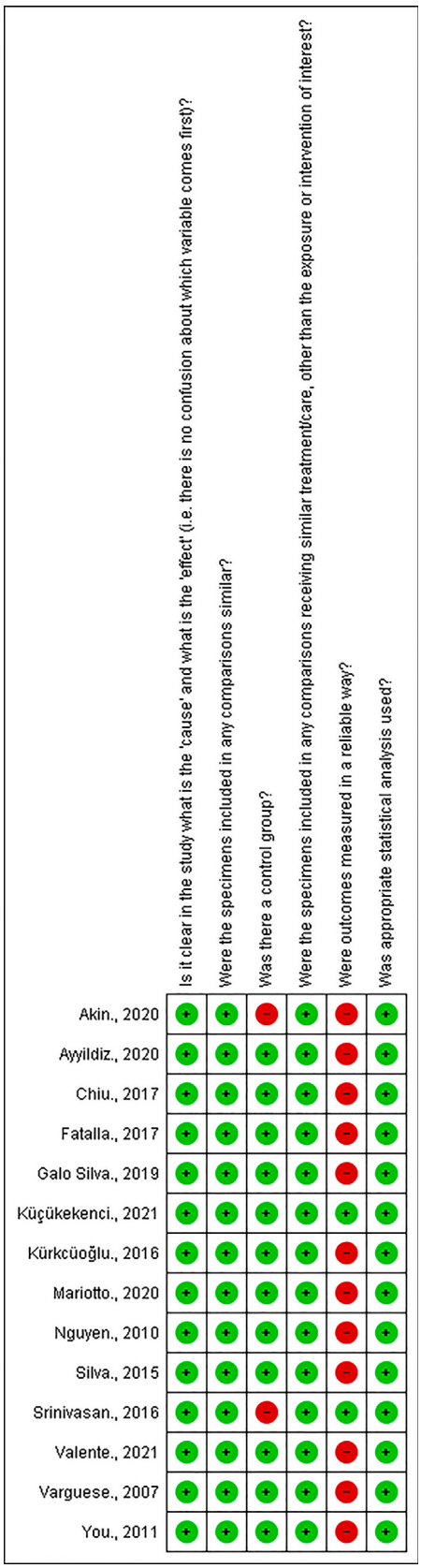


Figure 3. Risk-of-Bias summary.

Table 3. Data from studies included with analysis of retention and durability of attachments subjected to aging and different pH.

Author and year	Objective	Attachment	Situation	Analysis	n	Control	Results
Akin., 2012	To determine the effect of corrosive environments and thermocycling on the attractive force of different types of new generation magnetic attachments	Hyper slim, Hicorex slim, Dyna and Steco	1% lactic acid solution (pH 2.3), 0.9% NaCl solution (pH 7.3), and thermocycling.	Attractive forces with different pH values.	5	Yes	The better values of attractive force were found in the Hyper slim. A significant difference was found after immersion in the solutions with lower values. No difference was found between lactic acid and NaCl solutions regarding attractive force for Dyna, Steco, and Hyper slim systems. Hicorex and Hyper slim systems were not affected by the thermocycling procedure.
Chiu., 2017	To examine the changes in Locator attachments after exposure to different water temperatures and cyclic loading	Locator (Pink)	Distilled water at different temperatures (20 °C, 37 °C, and 60 °C).	Thermocycling, retention tests, and Scanning electron microscopy (SEM)	10	Yes	At the 60 °C temperature, the Pink Locator attachment showed cracking and significant loss of retention.
The study showed a significant difference in final retention between 60 °C and 37 °C, and between 60 °C and 20 °C.							
Fatalla., 2017	To examine newly model attachments by comparing them with conventional O-ring	Deflex M10XR, Deflex Classic SR, Deflex Acrilato FD, and flexible acrylic resin	0, 63 (3 months), and 126 (6 months) cycles	Retention and cyclic aging	10	Yes	The O'ring attachment showed the lowest values for retention tests, and Deflex M10 XR had the greater values. Significantly differences were found between the times 0, and 63 cycles with lower retention values for all groups. No differences were found between 63, and 126 cycles. The lowest reduction was found in O-ring attachment.
Galo Silva., 2019	To evaluate the physical-mechanical and morphological properties of polyethylene terephthalate (PET) for application as a attachment	Polyethylene terephthalate (PET), Polyacetal, Polytetrafluoroethylene (PTFE), and Polyethylene	5 °C–55 °C (10.000 cycles)	Retention tests, hardness, compressive strength, surface roughness, scanning electron microscopy (SEM), Fourier Transform Infrared (FTIR) and, X-ray Diffraction (XRD)	40	Yes	Surface roughness, hardness, and compressive strength didn't show significant differences before and after aging. For retention tests, O'ring and Polyacetal showed significant differences before and after aging. Both presented retention loss. PET, Polyethylene, and PTFE did not show statistical differences before and after aging. PET, PTFE, and polyacetal showed surface alteration after aging. No changes were shown in chemical composition, and crystallinity after aging.
Silva., 2015	To compare the durability and retention of 4 types of attachments over titanium bars subjected to different pH conditions	Hader yellow, Hader red, Ackerman gold, Ackerman stainless steel.	Saliva with different pH (4 and 7) conditions	Retention tests	4	Yes	No significant differences were found between different pH values for all attachments of the insertion and removal values. The insertion values decrease over time for all attachments. The Ackerman gold attachment had the better values at the final cycles and the Ackerman stainless steel

Table 3 (*continued*)

Author and year	Objective	Attachment	Situation	Analysis	n	Control	Results
							had the best initial and the lowest final. The Hader Yellow and Red showed visible wear and erosion zones without wear in the titanium bar. Ackerman Gold had a polished surface at the end of testing and the titanium bar present minor abrasions. The Ackerman Stainless Steel showed significant wear strips in their retention loops and titanium bars.
Srinivasan., 2016	To evaluate the influence of artificial saliva on the retentive force of a stud-type attachment locator	Locator	0.9% NaCl and laboratory-fabricated artificial saliva (AS)	Retention tests	10	No	The type of lubricant had no influence on retention values. At cycles 100 and 100 both groups had an increase in the values and for cycles 5000 and 10000 decreased.
Valente., 2021	To investigate the mechanical behavior of PEEK attachments before and after cyclic aging	Polyether ether ketone (PEEK)	5 °C–55 °C (10.000 cycles)	Retention tests, X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), Differential Scanning Calorimetry (DSC), surface hardness, surface roughness, and cyclic aging	20	Yes	The aging did not significantly change the hardness and surface roughness. The retention force was greater after thermocycling for PEEK. The crystallinity was lower after aging.

aging. This causes an increase in friction between the components, which makes it difficult to remove and insert the attachment and requires greater force for these movements [14, 43]. PEEK is a high-performance, semi-crystalline, thermally stable, high-temperature-resistant polymer [44, 45, 46, 47]. The high wear resistance of PEEK and the previously mentioned characteristics may explain its increase in retention after aging [22]. Therefore, polymers such as PEEK and PET can be used as an alternative to conventional attachments, especially for patients who consume foods that contain water at high temperatures, such as tea, coffee, or soups, as they do not show loss of retention under these conditions. Solutions and, in this way, maintain their durability and retention for a longer period.

The main limitation of the present review includes the heterogeneity of the data obtained, where different models, materials that make up the attachments, solutions, and pHs were used, which makes a direct correlation and comparison between the results difficult. On the other hand, the different methodologies and materials benefit a general assessment of the durability and retention of the attachments in the face of the challenges to which they will be submitted during use.

The results obtained showed that NaOCl is the cleansing solution that most affects attachment retention, even with good antimicrobial efficacy. Thus, it is valid to analyze its cost-benefit due to the need to exchange components in a shorter period. Allied to this, it is evident that it is necessary to carry out the correlation between the structure and properties of the materials since the loss of retention does not occur only for mechanical and physical reasons, but also chemical reasons. It is necessary to understand how each factor will interfere with the durability and retention of the attachments so that new materials are introduced in the market, allowing the attachments to be more durable and benefit the population by reducing the need for exchanges, maintenance, and consequently the cost.

5. Conclusion

Based on the findings found in the present systematic review, it was possible to conclude that:

1. Among the different types of locator pink, clear, and blue, blue was the most affected by cleansing solutions, presenting the lowest values for retention.
2. For the bar/clip attachments only clips made from PTFE were significantly affected by the cleansing solutions.
3. The cleansing solution that more affected the blue locator and PTFE clips attachments was the NaOCl with more loss of retention after the simulation tests.
4. Aging changes retention values for attachments, mostly with loss of values.
5. Nylon clips were not influenced for retention values after immersion in different solutions, including NaOCl.
6. Alternative polymers like PET and PEEK did not suffer from loss of retention by the cleansing solutions and can be used as an attachment for a more long period than conventional attachments.
7. New studies that intrinsically evaluate the chemical changes promoted by cleansing solutions, pH, and tap water are necessary so that it is possible to make a correlation with the loss of retention and seek alternatives that stabilize such changes to avoid the early loss of durability and retention of attachments.

Declarations

Author contribution statement

Andréa Cândido dos Reis: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Murilo Rodrigues de Campos and José Augusto Marcondes Agnelli: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data associated with this study has been deposited at osf.io/2e3q5.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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