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Systematic Review

Evaluating and Comparing the Tensile Strength and Clinical Behavior of Monofilament Polyamide and Multifilament Silk Sutures: A Systematic Review

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Abstract: Objective: This systematic review was carried out with the primary objective of verifying which suture (polyamide or silk) of two non-resorbable suture materials with different structures had better/greater tensile strength/resistance to tension, thereby presenting better mechanical behavior. The secondary objective was to verify which one had better performance. The null hypothesis was that both types of sutures had the same behavior. Methods: This systematic study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards. The focused clinical question was: "In patients that underwent oral surgery treatment (P), is there significantly higher tensile strength/resistance for silk sutures (I) or for polyamide sutures (C) when comparing the outcomes (O)?". The bibliographic search was conducted on ScienceDirect, B-On, and PubMed/MedLine between March and May 2023. The following MeSH terms were defined: sutures, breaking strength, tensile strength, oral surgery, and dentistry, which were articulated and combined using Boolean operators. There were restrictions, such as articles published in Portuguese, Spanish, or English between 1 January 2018 and 3 April 2023. The quality assessment involved the use of the Joanna Briggs Institute (JBI) checklist for RCTs and the QUIN tool (Quality Assessment Tool For In Vitro Studies) for in vitro assays. Results: Ten articles were included in this review (eight in vitro studies and two RCTs). For the RCTs, there were moderate and high levels of bias, whereas in the in vitro studies, three were classified as having a high risk of bias and five as moderate risk. The results proved that suture thread with a monofilament polyamide physical structure causes a less inflammatory reaction owing to less bacterial retention and capillarity, while multifilament sutures, such as silk, have superior mechanical characteristics. Regarding hydration, the evidence demonstrated that the preservation and stability of mechanical properties lacked uniformity. Otherwise, hyaluronic acid (HA) presents a promising solution with the same characteristics and antibacterial capabilities. Conclusion: It was possible to reject the null hypothesis that both types of sutures had the same behavior and result. It was proven by the results above that sutures with a monofilament polyamide physical structure cause a less inflammatory reaction owing to less bacterial retention and capillarity. In contrast, multifilament sutures (silk) have superior mechanical characteristics. Regarding hydration using chlorohexidine in surgical sites, the evidence demonstrated in the preservation and stability of mechanical properties lacks uniformity and congruence. However, HA seems to present a promising option with the same characteristics and antibacterial capabilities.

Keywords: sutures; oral surgery; dentistry; tensile strength; silk; polyamide

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1. Introduction

In dentistry, the most common way to close and stabilize the operative field/surgical wounds is through sutures [1]. Currently, a broad and diverse range of suture materials is available. Therefore, professionals must understand the indications and limitations inherent to each type. In this regard, it is crucial to adapt each suture to the oral features of each individual, such as the quantitative and qualitative characteristics of saliva, oral microbiota, vascularization level, and functional movements of the oral cavity, including chewing and swallowing [2].

Sutures promote more favorable first-intention healing, restore tissue to its original/desired position and function, reduce the risk of postoperative infection, and maintain homeostasis, helping to control exudate from the alveolar bone and protect the clot in the scar zone [3]. Tissue healing in oral surgery is crucially related to the blood clot's development, organization, and consolidation. Thus, the blood clot serves as a provisional matrix for all basic cellular processes, such as cell adhesion and neoangiogenesis, to restructure the tissues. The entire complex process is the basis for the approximate time it takes to maintain the suture in the oral cavity [4]. Then, blood clot stabilization must be effective and closely interconnected with the tension of the suture thread and all its biomechanical properties. An ideal suture material comprises several relevant properties: (1) high and uniform tensile strength, capable of promoting healing by first intention; (2) predictable behavior; (3) flexibility for easy handling and security of nodes; and (4) low capillarity, with an absence of irritating substances or impurities that favor bacterial growth [5].

1.1. Suture Types and Characteristics

Sutures are qualified based on their origin (natural or synthetic), resorbable capability (resorbable [natural (gut and chromic gut) or synthetic (polyglycolic acid and polydioxanone)] or non-resorbable), and macrostructure (monofilament or multifilamentary) [6]. Natural sutures are composed of highly purified collagen derived from animals, such as bovines, sheep, and intestines. Surgical gut sutures are absorbed rapidly by enzymatic degradation, with complete resorption in 3 to 5 days. Hence, they are reserved for scenarios where there is minimal tension. Plain gut suture thread loses 50% of its tensile strength within 24 h of exposure to the intraoral environment. Chromic gut sutures are treated with chromium salts, which increase their absorption time to approximately 7 to 10 days. These sutures maintain stable tensile strength for up to 5 days. Gut sutures are the most common material utilized in oral surgery. Otherwise, they are contraindicated in scenarios where the intraoral pH is relatively low or decreased and may rapidly dissolve, resulting in surgical flap dehiscence (such as in cases of gastroesophageal reflux disease [GERD], antipsychotic drug therapy, and Sjogren's Syndrome) [7–9].

The most used non-resorbable materials are silk and polyester. Silk is simple to find, readily available, and inexpensive; it is manufactured using fibers in a braided configuration, allowing for elasticity and maintaining tension within the knot. Therefore, silk sutures are more likely to cause infection, and removal is recommended after one week of placement. The braided arrangement of its fibers increases surface area, thereby wicking fluid and bacteria into the composition of the thread. This fact results in the accumulation of bacteria that distribute into the wound, increasing the likelihood of infection. Then, silk sutures are contraindicated in sites where permanent structures are present (implants or particulate grafts) [5]. Polyester sutures are another widely used non-resorbable material. Polypropylene, black monofilament, and polytetrafluoroethylene (PTFE) are the primary polyester sutures used in oral surgery. It is critical to use a surgeon's knot versus a slipknot when closing with this suture because of the material memory. The surgeon's knot will prevent the knot from coming untied. Non-absorbent polyester fibers have a lower capacity for accumulation, decreasing the likelihood of bacterial growth [5]. Table 1 summarizes the sutures.

Table 1. Suture Materials.

Suture Name (Type)	Material	Degradation	Absorption Time	Tensile Strength	Retention of the Resistance	Tissue Response
Vicryl (Absorbable, Synthetic, Multifilament)	Polyglactin 910	Hydrolysis	Complete between 56 and 70 days	Good	Approximately 75% remains at 2 weeks. Approximately 50% remains at 3 weeks, 25% at 4 weeks.	Minimal acute inflammatory reaction
Vicryl Rapide	Polyglactin 910	Hydrolysis	Complete by 42 days	Good	50% remains at 5 days; all tensile strength is lost at approximately 14 days.	Minimal to moderate acute inflammatory reaction
Silk (Non-absorbable, Natural, Multifilament)	Silk	Non-absorbable	Gradual encapsulation by fibrous connective tissue	Excellent	Progressive degradation of fiber may result in gradual loss of tensile strength over time.	Acute inflammatory reaction
Chromic Catgut (Absorbable, Natural, Monofilament)	Chromic Catgut	Phagocytosis and enzyme degradation	Absorbed by proteolytic enzymatic digestive process	Poor–fair	10–14 days.	Moderate reaction
Monocryl (Absorbable, Synthetic, Monofilament)	Poliglecaprone 25	Hydrolysis	91–119 days	Excellent	Approximately, 50–60% (violet: 60–70%) remains at 1 week. Approximately 20–30% (violet: 30–40%) remains at 2 weeks. Lost within 3 weeks (violet: 4 weeks).	Minimal acute inflammatory reaction
Nylon (Non-absorbable, Synthetic, Monofilament)	Nylon	Non-absorbable	Gradual encapsulation by fibrous connective tissue	Excellent	Progressive hydrolysis may result in a gradual loss of tensile strength over time.	Minimal acute inflammatory reaction
Prolene (Non-absorbable, Synthetic, Monofilament)	Polypropylene	Non-absorbable	-	Excellent	Not subject to degradation or weakening by the action of tissue enzymes.	Minimal acute inflammatory reaction
Ethibond (Non-absorbable, Synthetic, Multifilament)	Polyethene Terephthalate	Non-absorbable	Gradual encapsulation by fibrous connective tissue	Excellent	No significant change is known to occur.	Minimal acute inflammatory reaction

1.2. Tensile Strength/Resistance to Traction

Tensile strength is an essential factor in sutures, defined as a mechanical property that directly links the maximum load a suture thread can carry until it reaches its breaking point along its cross-section. This tension force should ideally be high so that, in addition to approximating the surgical margins, it can support chewing, swallowing, speaking movements, and all other movements and functions underlying the oral cavity [4]. Elongation, another very relevant mechanical property, is defined as the degree of change in the length of the suture until it reaches its tensile strength [10].

In oral surgery, non-resorbable sutures are the most commonly used. According to scientific evidence, silk sutures continue to prevail despite the variety of choices available [11]. Multifilament silk sutures are made up of silk fibroin, a water-insoluble protein. It is considered a non-resorbable material, although reabsorption occurs once placed in the human body, but this happens through slow degradation by proteolysis [12]. The physical structure of the polyamide monofilament is non-resorbable, as it is slowly degraded by hydrolysis at a rate of 15–20% [13].

The choice and setting/type of surgical stitches after a procedure is also a variable that conditions the profile and mechanical behavior of the suture threads. Then, selecting the correct suture and technique is essential. However, when searching for the ideal suture, the effects of the stitches setting are still commonly ignored [10]. Often, after an oral surgical intervention in which the use of a suture is required, it is recommended to use either mouthwashes, chlorhexidine (CHX), or anti-inflammatory gels and even tissue firming agents, such as hyaluronic acid (HA) [14]. However, the influence of chemical solutions on the mechanical properties of the suture or the prior preparation of the skin for closure of the surgical wound and subsequent healing is a promising topic but remains controversial in the literature [15].

1.3. Needles

Many suture needles are available today. The primary choice for oral surgeons is reverse-cutting suture needles, which are triangular in cross-section, where the triangle's base faces the inner part of the circle created by the needle. This shape prevents oral mucosa from tearing as tension is applied during knot tying. Therefore, the 3/8-circle needle is most often used in dentoalveolar settings. However, the 1/2-circle needle is sometimes preferred where working space is restricted, such as in the maxillary posterior region [16,17].

Four types of cutting edges are presented for needles. (1) Conventional cutting has three cutting edges, the third being on the inside of the needle's curvature. It may be prone to cutting out tissue because the inside cutting edge cuts toward the edges of the incision. (2) Reverse cutting was created for tough, difficult-to-penetrate tissue such as skin and oral mucosa. It is as sharp as conventional cutting, but its design is slightly different. The third edge is located on the outer convex curvature of the needle, offering advantages such as (a) greater strength than conventional cutting needles, (b) the risk of tissue tearing is greatly reduced, and (c) the hole left in the tissue by the needle leaves a wide wall of tissue for the suture to rest against while the suture is tied. (3) Taper-point needles pierce and spread tissue without cutting it (sharp point). The needle body flattens to an oval or rectangular shape. They are preferred when the smallest possible hole in the tissue and minimum tissue cutting is desired. (4) Taper-cutting needles combine the features of the reverse cutting edge tip and taper point needles. The cutting edge extends slightly from the point and then blends into a round body. All three cutting edges are typically sharp to provide a uniform cutting action. The point (aka trocar) readily penetrates tough tissues.

1.4. Objective

In order to obtain an answer to the question mentioned above, this systematic review was carried out with the primary objective of verifying which suture (polyamide or silk) of two non-resorbable suture materials with different structures had better/greater tensile strength/resistance to tension and superior mechanical behavior. The second goal was to verify which one had greater performance. The null hypothesis was that both types of sutures had the same behavior.

2. Materials and Methods

2.1. Protocol and Focus Question

This systematic study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards. The focused clinical question was formulated based on the P.I.C.O. (Population, Intervention, Comparison, and Outcome) strategy (Table 2): "In patients that underwent oral surgery treatment (P), is there significantly higher tensile strength/resistance for silk sutures (I) or for polyamide sutures (C) when comparing the outcomes (O)?". The systematic literature review was registered in the PROSPERO database (The International Prospective Register of Systematic Reviews, CRD42023462728).

Table 2. PICO strategy for formulating the clinical question.

Population (P)	Individuals in oral surgery treatment who received sutures after surgical intervention
Intervention (I)	Tensile strength/resistance of silk suture used at the end of the surgical intervention
Comparison (C)	Tensile strength/resistance of polyamide suture used at the end of the oral surgical procedure
Outcome (O)	Higher tensile strength/resistance to traction and factors that can interfere with the resistance; plaque accumulation

2.2. Search Strategy

The bibliographic search was carried out using three electronic databases, ScienceDirect, B-On, and PubMed/MedLine, between March and May 2023. The following MeSH terms were defined: sutures, breaking strength, tensile strength, oral surgery, and dentistry. They were articulated and combined using Boolean operators. There were restrictions, such as articles published in Portuguese, Spanish, or English between 1 January 2018 and 3 April 2023. The references in the included papers were crosschecked for possible additional studies, and the authors were contacted to clarify any doubts about the data.

2.3. Eligibility Criteria

The inclusion criteria were: (1) clinical trials, randomized controlled trials (RCTs), cohort studies, case-control studies, cross-sectional studies, in vitro, and in vivo (animal) tests; (2) studies that presented tensile strength/resistance to traction for silk and/or polyamide sutures; (3) studies that presented clinical outcomes for silk and/or polyamide sutures; (4) articles that reported about the knot setting for surgical wound closing.

The exclusion criteria were: (1) articles that evaluated the tension resistance of resorbable sutures; (2) articles that evaluated the tension resistance of non-resorbable sutures, other than those made of silk or polyamide; (3) articles with incomplete reports/data for the analyses performed; (4) books/e-books; (5) book chapters; (6) no access to the full text; (7) any type of review.

2.4. Selection of Articles and Information Extraction

Two researchers (M.A.O. and F.C.) initially screened all articles manually and independently by reading the title and abstract; in case of divergence, a third author was consulted (G.V.O.F.). Then, the studies that met the inclusion criteria or those with insufficient data in the abstract to make a clear decision were selected to evaluate the entire manuscript. Duplicate articles were removed. The same researchers and process were involved in reading the full texts. The following information was extracted from the articles and recorded in Excel (Microsoft Office v. 16.83): (i) author and year of publication; (ii) type of study; (iii) country; (iv) suture used; (v) clinical characteristics and details reported; (vi) general results; and (vii) statistical results.

2.5. Risk of Bias

Two independent investigators (M.A.O. and F.C.) performed the quality assessment. In cases of divergence, a third researcher was consulted (G.V.O.F.). The methodological quality of the articles selected for this systematic review was assessed using the Joanna Briggs Institute (JBI) checklist for RCTs [18] and the QUIN tool (Quality Assessment Tool For In Vitro Studies) for in vitro assays [19].

The JBI evaluates 13 parameters using questions grouped into five categories; each of these questions was classified and scored as "yes", "no", "unclear", or "not applicable" [13]. The QUIN tool was developed to classify the reliability and validity of in vitro assays. This tool involved 12 questions (12 criteria). Each of the questions has four possible answers: "adequately specified", "inadequately specified", "not specified", or "not applicable". For each of the 12 items on the QUIN checklist, a score is obtained, being "2" if the answer was "adequately specified", "1" if the answer was "inadequately specified", and "0" if the parameter was "not specified". In cases of "not applicable", no points are assigned. The QUIN tool summary score is obtained using the following formula: QUIN score = (total score/2 x criteria numbers) x 100.

The result was obtained as a percentage, serving to classify the in vitro assay as having a low risk of bias (>70%); medium risk of bias (50–70%); or high risk of bias (<50%) [19].

3. Results

3.1. Selection and Characteristics of Studies

The search strategy is presented in Table 3. Of the 6020 potentially relevant articles obtained from the databases, 3218 remained after eliminating duplicates. Subsequently, screening was carried out where 3182 articles were eliminated after reading the title and abstract. Three articles were also excluded because they were published in other languages. Therefore, for full-text reading and assessment of the eligibility of the articles, 33 articles remained. After an individual analysis and evaluation and applying the exclusion criteria, 23 articles were eliminated (justification in Figure 1). Then, 10 articles were finally included.

Regarding the typology of the 10 articles included, 8 were in vitro studies [1,4,5,10,14,15,20,21] and 2 were RCTs [22,23]. The articles' main topics were related to the tensile strength of polyamide and/or silk thread; some articles also made references to some factors inherent to the oral cavity or the suture thread and whether they interfere with tensile strength. The content and characteristics of the studies included in this systematic review are summarized in Table 4.

Table 3. Search strategy for each database and results.

Electronic Database	Search Terms	Articulation	Number of Articles Found
ScienceDirect	Breaking strength;	Sutures AND Breaking strength AND Oral surgery	644
	Sutures;	Sutures AND Breaking strength AND Dentistry	254
	Oral surgery; Dentistry;	Sutures AND Tensile strength AND Oral surgery	781
	Tensile strength;	Sutures AND Tensile strength AND Dentistry	413
	Breaking strength;	Sutures AND Breaking strength AND Oral surgery	670
B-On	Sutures;	Sutures AND Breaking strength AND Dentistry	260
	Oral surgery; Dentistry;	Sutures AND Tensile strength AND Oral surgery	2163
	Tensile strength;	Sutures AND Tensile strength AND Dentistry	783
	Breaking strength;	Sutures AND Breaking strength AND Oral surgery	4
PubMed	Sutures;	Sutures AND Breaking strength AND Dentistry	3
	Oral surgery; Dentistry;	Sutures AND Tensile strength AND Oral surgery	23
	Tensile strength;	Sutures AND Tensile strength AND Dentistry	22

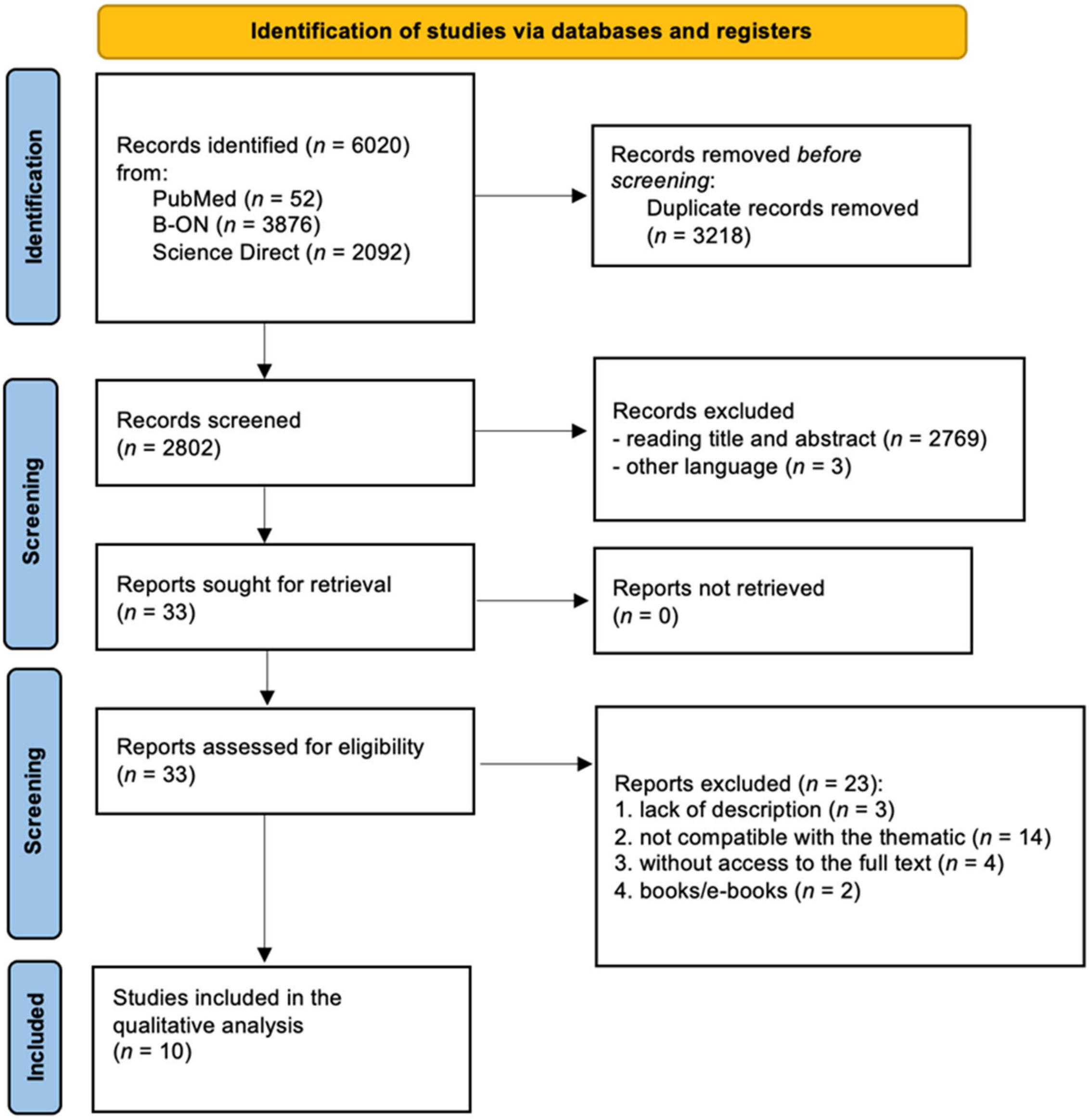

Figure 1. PRISMA flowchart used for the selection and inclusion of the articles.

Table 4. Characteristics of the studies included.

Author/Year	Country	Typology	Suture Type	Topic Covered	Statistics	Interpretation
Asher et al., 2019 [22]	Germany	RCT	Silk and polyamide	Comparison of accumulation and bacterial retention	ANOVA $p < 0.05$	Polyamide had the best results
Dragovic et al., 2020 [23]	Germany	RCT	Silk	Influence of suture configuration on bacterial accumulation, healing, handling, and physical properties	T and x^2 test Friedman test Kolmogorov–Smirnov test Wilcoxon test $p < 0.05$	Synthetic monofilament sutures had better results
Gaukroger et al., 2020 [15]	U.K.	In vitro	Polyamide	Role of CHX and isopropyl alcohol in the suture strength of polyamide	ANOVA $p < 0.05$	CHX and isopropyl alcohol did not alter the mechanical properties

Table 4. *Cont.*

Author/Year	Country	Typology	Suture Type	Topic Covered	Statistics	Interpretation
Varma et al., 2020 [14]	U.S.A.	In vitro	Silk and polyamide	Effect of HA and CHX on tensile strength in silk and polyamide sutures	Kolmogorov–Smirnov test, Wilcoxon test, Mann–Whitney U test $p \leq 0.05$	Polyamide showed greater stability; HA did not negatively alter the mechanical properties, whereas CHX did
Kuzu, 2021 [5]	Turkey	In vitro	Silk and polyamide	Comparison of tensile strength in silk and polyamide sutures	One Way ANOVA Tukey HSD tests $p < 0.05$	Polyamide had the best results
Taysi et al., 2021 [20]	Turkey	In vitro	Silk	Evaluation of tensile strength and elongation in various sutures, including silk sutures	ANOVA Tukey HSD tests $p < 0.05$	The tensile strength of silk decreases slightly over time (days)
Anushya et al., 2022 [21]	India	In vitro	Silk	Role of grape and lemon juice in suture strength	*t*-test $p < 0.05$	Juices changed the mechanical properties
Manfredini et al., 2022 [4]	Italy	In vitro	Silk and polyamide	Comparison of tensile strength in silk and polyamide sutures	ANOVA Tukey HSD tests $p < 0.05$	Silk had the best results
Wang et al., 2022 [1]	China	In vitro	Silk	Tension resistance in straight lines and at suture knots	ANOVA Tukey HSD tests $p < 0.05$	Silk had the worst mechanical results in both variables tests
Taysi et al., 2023 [10]	Turkey	In vitro	Polyamide	Evaluation of tensile strength in knots and suture elongation	Tukey HSD tests $p < 0.05$	Configuration different from that recommended by the manufacturer obtained better results

CHX = Chlorhexidine; U.K. = United Kingdom; U.S.A. = United States of America; HSD = honestly significant difference; S.D. = standard deviation; RCT = randomized controlled trial; HA = hyaluronic acid.

3.2. Main Results Found

3.2.1. RCTs

Two RCT studies were included in this systematic review. Asher et al. [22] aimed to compare the bacterial accumulation of different suture materials, comparing silk and polyamide. They enrolled 50 healthy non-smoker patients (mean age of 54 years, 26 female/24 male) who were scheduled for implant or periodontal surgery with a surgical incision site large enough to include at least four stitches with 5 mm between them. The bacterial retention was compared by incubating the sutures removed in the postoperative period using aerobic and anaerobic culture media, with the number of colony units formed (CFUs) being counted at the end of the incubation time. The authors concluded that polyamide demonstrated significantly fewer CFUs than silk sutures, and even though all participants used CHX mouthwash, it did not prevent the accumulation of bacteria on the suture.

The second RCT [23] included 32 individuals aged between 18 and 25. They were referred for impacted third molar extraction, and the site received simple stitches after extraction using different types of sutures. The authors stated that silk-type sutures had the strongest inflammatory reactions, similar to resorbable-type sutures, and owing to the phenomenon of high capillarity, they absorb liquid from saliva, leading to the disintegration of the filaments. In addition, they reported that the suture configuration, and not their chemical composition, played an important role in the inflammatory reaction. One of the most important aspects was flexibility; it permitted easy handling through the tissues and manipulation. The authors highlighted that sutures with a multifilament structure absorbed oral fluids and blood clots, making them difficult to handle in the oral cavity. The loss of tensile strength was the second most important factor influencing the clinical choice of suture; the authors reported that it was significantly higher in the multifilament-type suture. Another feature reported was the elongation rate of multifilamentary sutures, which was 10–15%, whereas for monofilamentary sutures, it was around 20–25%. This explains why multifilamentary sutures are prone to irreversible changes in their structure due to postoperative edema. Hence, according to the authors, a synthetic and monofilament suture should be used whenever possible.

3.2.2. In Vitro Studies

Eight in vitro studies were found. Gaukroger et al.'s [15] study focused on four suture types (Coated Vicryl, 2-0 Monocryl, 3-0 Ethilon, and 3-0 Vicryl Rapide) that were soaked for 5 min in either 2% chlorhexidine (CHX) and 70% isopropyl alcohol (test group), or Hartmann's solution (control group) to verify whether any alteration occurred in their mechanical properties, leading to possible complications during wound healing. Each suture was left to dry for 11 days before the tensile strength test. The results revealed significant differences in failure load, tensile strength, and Young's modulus between suture types ($p < 0.05$). Therefore, no significant differences were observed in failure load, tensile stress, or Young's modulus for the same suture type. Then, the authors concluded that the solutions tested did not significantly change the mechanical properties of suture materials.

Varma et al. [14] evaluated whether hyaluronic acid (HA) and CHX influence the tensile strength (before and after immersion) of silk and polyamide sutures. The polyamide suture, before and after immersion in CHX, presented tensile strengths of 354.0 N/mm^2 and 289.0 N/mm^2, respectively, whereas the silk suture showed results of 1035.2 N/mm^2 and 458.0 N/mm^2. The polyamide suture was observed to have greater stability than the silk suture. Regarding immersion in the HA solution, the polyamide exhibited tensile strength of 354.0 N/mm^2 before immersion and 331.0 N/mm^2 after ($p > 0.05$); likewise, the silk suture exhibited non-significant differences in pre- and post-immersion tensile strength values at 1035.2 N/mm^2 and 916 N/mm^2, respectively. Monofilament sutures had lower tissue resistance and a lower risk of infection when compared with multifilament sutures. The authors presented the silk suture as easy to handle, flexible, and with high tissue slippage; however, it has a huge disadvantage—the ability to retain bacteria, perpetuating a longer tissue inflammatory reaction. Polyamide had lesser resistance when tying the stitches, lesser tissue drag, and greater flexibility compared with multifilament materials. Tensile strength was lost with a 10–90% variation between 10 and 90 days. The authors stated that the use of HA as a chemical adjuvant, unlike CHX, did not negatively alter the mechanical properties of the sutures, possibly owing to the HA's viscous nature. As observed in this in vitro study, suture materials coated with HA can stabilize tensile strength to a certain extent.

Kuzu [5] evaluated 4/0 sutures, 10 of which were polyamide and 10 were silk (20 others were included but were made of other materials). Silk yielded a value of 14.250 N.cm for tensile strength and polyamide 17.446 N.cm, with a statistically significant result. This study also concluded that the sutures used in this investigation can be used safely for up to 2 weeks. Another reason for the drop in tension resistance was the stitches, given that tying the suture can reduce approximately 1/3 of the tension resistance, mainly at the same location.

Taysi et al. [20] presented a study comparing the tensile strength and elongation required until the failure of various types of 3-0 sutures, including silk sutures, after immersion in artificial saliva. Silk sutures were mentioned as the most used in dentistry owing to their economical cost and ease of handling. However, the prominent inflammatory reaction means they are not the best choice. The evaluation before immersion in artificial saliva (64.8 N.cm) and after 3 (51.9 N.cm), 7 (54.1 N.cm), and 14 days submerged (58.1 N.cm) demonstrated a slight decrease in the tension resistance of the silk suture, with the most noticeable reduction on the 3rd day. Another factor mentioned is that increasing tensile load did not result in greater elongation failure. Therefore, greater stretching can cause gaps at the surgical site's edges, leading to possible clinical failure. The crucial point of this article is that silk sutures lose tensile strength when submerged in saliva.

Anushya et al. (2022) [21] mentioned that sutures with lower tensile strength are more susceptible to breaking during the healing process due to postoperative edema. A sample size of eight sutures of resorbable material (polyglycolic acid) and non-resorbable material (silk) was used. The control group measured intact sutures, while the test group evaluated the tension of the sutures after immersion in grape juice and lemon juice for one week (twice/day for 10 min). After this period, a surgeon's stitch was tied, and tension resistance was measured. The results showed that the perception of silk's tensile strength was slightly lower than that of resorbable sutures but statistically non-significant ($p > 0.05$). After immersion, it was observed that the traction of the resorbable material significantly increased when immersed in grape and lemon juices compared with the non-resorbable silk suture. The authors concluded that certain chemical substances could alter sutures' physical and mechanical characteristics, such as those observed in the resorbable material after immersion in fruit juices, which had superior tensile strength and excellent stitch retention capacity compared with silk.

Manfredini et al. [4] studied eight materials, including silk and polyamide, which varied among 3-0, 4-0, and 5-0. All sutures were subjected to tension measuring after immersion in artificial saliva at 37 °C, mimicking the oral cavity's conditions. The 3-0 gauge presented the highest tensile strength values for all types of sutures compared with the others. Thus, the silk suture for 3-0, 4-0, and 5-0 yielded tensile strength values of 13.75 N.cm, 13.13 N, and 6.57 N, respectively. Regarding calibers 3-0 vs. 4-0, there was no statistically significant result; however, for 3-0 vs. 5-0 and 4-0 vs. 5-0, the difference was statistically significant. Concerning polyamide sutures, for 3-0, 4-0, and 5-0, the respective tensile strengths were 13.32 N, 10.17 N, and 3.25 N. Therefore, unlike silk sutures, all tensile strength comparisons between gauges (3-0 vs. 4-0, 3-0 vs. 5-0, and 4-0 vs. 5-0) were statistically significant. These data corroborate that as the caliber of the sutures decreases, the tensile strength also decreases correspondingly. Moreover, the authors evaluated the tension resistance of knots. For both sutures of interest, the results demonstrated that the tension resistance also decreases as the gauge decreases. The silk suture had great variability between the three calibers, with statistically significant values. The tensile strength values in the silk suture knot in gauges 3-0, 4-0, and 5-0 were 12 N, 8.23 N, and 0.31 N, respectively. Regarding the tensile strength values of the polyamide suture knot, for gauges 3-0, 4-0, and 5-0, these were 8 N.cm, 6 N, and 3 N. Thus, the authors concluded that tensile strength plays a fundamental role in the ability to resist the stress generated in the knot and in the protection of the surgical wound; the resorbable sutures immersed in saliva tended to lose tensile strength, probably owing to the biodegradation mechanism that is accelerated by the local fluid.

Wang et al. [1] measured the tension resistance of sutures 5-0 (the knot) using seven types of sutures (four resorbable and three non-resorbable)—two of them were silk sutures with different knot techniques (surgeon's knot and the square knot) and numbers of semi-knots (three, four, or five). Node security was classified as "stable" or "unstable". After tying the knot, the tip was cut to 3 mm, and the loop was cut to the middle perimeter of the knot. To measure tensile properties, for each suture type, a total of 20 sutures were used in two configurations: a. ten sutures for straight-line tensile testing; and b. ten sutures for knot traction testing. After the comparisons, the two silk sutures were the materials that exhibited the lowest resistance to the tension of both the straight lines (6.53 N) and nodes (6.40 N). When comparing both silk sutures, it was shown that despite having the same chemical composition, they presented different knot retention capabilities, unlike tensile strength, where there were no significant differences. The greatest resistance to tension in a straight line was found in monofilament sutures. The tension required to break the suture was always greater than that needed to untie the knot. The authors concluded that, besides the surgeon's knot being safer, the number of semi-knots necessary to obtain security did not depend on the number but rather on certain specific combinations of knotting techniques. This statement was supported by the fact that the greatest security in a silk thread with the square knot technique required four semi-knots, whereas the surgeon's knot technique, using the same suture, only needed three semi-knots.

Taysi et al.'s study [10] investigated the mechanics of monofilament non-resorbable sutures, including 4-0-gauge polyamide, under different knot configurations. A total of 120 sutures from three different materials were evaluated. Four-knot configurations were tested: a. Surgeon's knot + square knot (2 = 1 = 1); b. Cross surgeon's knot + square knot (2 x 1 = 1); c. Cross reverse surgeon's knot + square knot (1 x 2 = 1); and d. Reverse surgeon's knot + square knot (1 = 2 = 1) (the symbol "=" corresponds to a semi-knot given in the opposite direction to the previous one, and "x" corresponds to a semi-knot in the same direction). The tensile strengths of the polyamide suture knots according to configurations a–d were 28.6 N, 26.1 N, 23.3 N, and 24.3 N, respectively. The statistical analysis revealed that polyamide had the greatest resistance to tension with configuration (a), corresponding to 28.6 N. Regarding elongation, the polyamide exhibited deformation in lengths of 5540 µm, 5163 µm, 4013 µm, and 5161 µm, respectively, for configurations a–d. It was possible to conclude that the type of knot configuration appears to cause a considerable difference in elongation. In particular, suture elongation in configuration (c) was statistically and significantly lower than in other configurations. Through this study, the authors verified that different knot configurations can improve the mechanical profile of monofilament-type sutures. The ideal configuration the manufacturer gave for the polyamide suture was configuration (c), although the researchers identified that configuration (a) obtained significantly better mechanical results. Therefore, configuration (a) (surgeon's knot + square knot), defined in the article as the gold standard, proved the most beneficial regarding knot tension resistance. However, the authors recognized that a likely explanation for configuration (c) suggested by manufacturers was that it provided significantly less elongation, possibly avoiding a clinical failure regarding the formation of gaps at the edges of the surgical site due to postoperative edema.

3.3. Risk of Bias Assessment

Table 5 shows the methodological evaluation of clinical trials consisting of 13 questions relating to selection and allocation, administration of the intervention/exposure, assessment, detection and measurement of results, patient retention, and the general statistical validity of the randomized clinical trial.

Table 5. Methodological evaluation of randomized controlled clinical trials according to the Joanna Briggs Institute (JBI) critical appraisal tool [18].

	Selection and Allocation			Intervention Administration/ Exhibition			Assessment, Detection, and Measurement of Results			Retention of Participants	Statistical Validity		
Author/Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Asher et al., 2019 [22]	N	Y	U	Y	U	Y	U	Y	Y	Y	Y	Y	Y
Dragovic et al., 2020 [23]	U	N	U	Y	U	Y	U	Y	Y	Y	Y	Y	Y

Y = Yes; N = No; U = unclear.

Regarding the clinical trial by Asher et al. [22] for the selection and allocation group, there was a moderate risk of bias, as the sutures used by the researchers in this RCT were not selected randomly; they were chosen completely independently, solely based on the choice of the most used sutures clinically. Furthermore, it is not clear whether the included patients were in the same baseline in terms of age, sex, gender, type of surgery, postoperative care, or absence/existence or status of periodontal disease. Regarding the administration of the intervention, there was a moderate risk of bias because, although the allocation of each suture was concealed by being placed in a coded and sealed opaque envelope containing the suture sequence for the surgery/patient, the envelope with the schematic design of the suture was opened when creating the flap; however, it is not possible to understand whether the surgeon was aware of which suture they were using. In the group referring to evaluation, detection, and measurement of the result, despite there being a parameter classified as "unclear", there was a moderate risk of bias because it is not clear whether or not the results evaluators were aware of which sutures were used and in which patients. In the remaining two parameters, there was a low risk of bias.

In the clinical trial by Dragovic et al. [23], the selection and allocation category had a high risk of bias, given that the selection of sutures used in the investigation was made only based on those most used clinically, without any randomization process. No blind patient allocation process was reported, nor was any means of comparing the proportion of participants with specific relevant characteristics in the compared groups described. The intervention administration group was classified as having a moderate risk of bias because it was not mentioned in the investigation that the surgeon was not aware of the suture being used. This leads us to believe that there was knowledge regarding this fact. The moderate risk of bias regarding the evaluation, detection, and measurement group of the results is due to the fact that it is not mentioned in the article whether the evaluators of the study results were unaware of the allocation of sutures to patients. Regarding the other two remaining parameters, the risk of bias was low.

For in vitro tests, as presented in Table 6, the methodological assessment is carried out based on the response to twelve items to assess whether each article is classified as having a high or medium risk of bias using the equation previously mentioned. Thus, the following articles were classified as having a high risk of bias: Anushya et al. [21], Kuzu [5], and Varma et al. [14]. The following articles were classified as having a moderate risk of bias: Gaukroger et al. [15]; Manfredini et al. [4]; Taysi et al. [20]; Taysi et al. [10]; and Wang et al. [1].

Table 6. Methodological evaluation of in vitro assays according to the Quality Assessment Tool for In Vitro Studies (QUIN).

Author/Year	Criteria												Total Score
	1	2	3	4	5	6	7	8	9	10	11	12	
Anushya et al., 2022 [21]	2	0	0	1	2	0	0	2	0	0	1	2	10
Gaukroger et al., 2020 [15]	2	0	0	2	2	2	0	2	2	0	1	2	15
Kuzu, 2021 [5]	2	0	0	1	2	0	0	2	0	0	2	2	11
Manfredini et al., 2022 [4]	2	1	0	1	2	0	0	2	0	0	2	2	12
Taysi et al., 2023 [10]	2	0	0	1	2	2	0	2	0	0	2	2	13
Taysi et al., 2021 [20]	2	0	0	1	2	2	1	2	0	0	1	2	13
Varma et al., 2020 [14]	2	0	0	1	2	0	0	2	0	0	2	2	11
Wang et al., 2022 [1]	2	0	0	1	2	2	0	2	0	0	2	2	13

0: Not specified; 1: Inadequately specified; 2: Properly specified.

These scores were obtained essentially due to all articles obtaining unfavorable scores, mainly in five of the categories, and numbers 2 and 3 refer to the calculation of the sample size and the sampling technique. In these parameters, it was assumed by the authors, or it was not adequately specified whether the researchers included or calculated a sample size capable of obtaining statistically significant results or whether the sample was representative of the applied population. Groups 7, 9, and 10 also obtained relatively low scores, essentially because few articles detailed the number, training/practice, calibration, inter- and intra-rater reliability, randomization, or blind or double-blind evaluation of the results.

4. Discussion

Based on the scientific literature in this systematic review, there was a common consensus among the majority of researchers that there is no single ideal suture for all types of procedures in dentistry. However, Kuzu [5] stated that sutures with a gauge of 7-0 or thinner are recommended for microsurgeries; 5-0 or 6-0 are indicated for esthetic surgeries; and 3-0 and 4-0 sutures are usually the most used in mucous membranes, being the most applied in routine clinical dentistry.

It is collectively agreed that the choice of an appropriate suture can influence the healing of surgical wounds, mainly owing to the conditions and functions inherent to the oral cavity and, above all, the presence of saliva. Regardless of the origin of the material, the primary role of suture threads is to support the tissue until mucosal continuity and tensile strength are re-established. Primarily, the factors taken into consideration by surgeons at the time of selection are related to the surgical site, the number of layers of tissue involved, duration until removal of the suture thread, resistance to tension, capillarity, 3D configuration, ease of handling, characteristics of security of the knot, and presence of edema expected post-operatively, with it being extremely important that the suture is free of irritating, carcinogenic, or infectious substances [22–25].

Indhumathi and Kumar [25] considered several factors for selecting a suture material, mainly with regard to its physical and mechanical properties (filament structure, gauge, degradation conditions, tension force, surface texture, and rigidity [level of flexibility]). Regarding the tensile strength, the authors reported that it must be equivalent to the soft tissue's tensile strength to obtain better results. This characteristic depends on whether the suture's macrostructure is multifilamentary or monofilamentary. Sutures with a multifilamentary structure contained high mechanical properties and significantly greater flexibility and malleability than monofilament sutures. Moreover, it was reported that resorbable sutures underwent degradation of around 50% of their tensile strength after around 60 days in the tissues, whereas non-resorbable sutures can sustain their tensile strength for a period longer than 60 days (not easily broken down by proteolytic enzymes like resorbable sutures). Furthermore, they stated there was still little consensus in the literature for the submersion of sutures in antimicrobials (e.g., CHX and triclosan) before surgery. In another narrative review [26], the authors stated that silk sutures have a high level of bacterial adherence, which can impair healing, whereas polyamide sutures were the least reactive and had fewer postoperative complications.

4.1. Bacterial Retention

The oral cavity and mucosa are not sterile territory, and they are colonized by bacteria that, together with food debris, form a biofilm and facilitate surgical site infection. In order to avoid exacerbation of postoperative edema and foreign body reaction to the suture, it is crucial to reduce retention, bacterial colonization, and the Wicking phenomenon (transmission of oral fluids and bacteria from the suture to the surgical wound) as much as possible. This fact is recognized as being superior in multifilament sutures [23].

Asher et al. [22], Dragovic et al. [23], and Shah et al. [25] are in agreement when considering the dichotomy between silk and polyamide sutures; the latter presents a very significant reduction in bacterial accumulation and a more minor tissue reaction, having a notable advantage in terms of healing and postoperative complications. The results of these researchers, when comparing both sutures mentioned above with other suture types, suggested that the macrostructure configuration of the suture plays a relevant role in bacterial retention, unlike the chemical composition. This fact was based on multifilament sutures absorbing oral fluids, including blood, saliva, crevicular fluid, and others, which make the sutures more viscous and difficult to handle after clotting. Dragovic et al. [18] added that the type of surgery and periodontal diagnosis did not significantly increase bacterial incidence.

Therefore, owing to the inevitable bacterial accumulation in sutures, Asher et al. [22] and Dragovic et al. [23] advised that the duration of the presence of sutures in the oral cavity should be minimized and that they should be removed, essentially according to the specific and individual healing conditions. However, the authors argued that the minimum period of sutures within the oral cavity should correspond to 7 days, avoiding their early removal so that they fulfill their function of compressing the mucoperiosteal flap against the tissues and not just closing the gap caused by the incision.

Regarding the use of antimicrobial solutions in sutures, Indhumathi and Kumar [24] reported that the use of the bacteriostatic triclosan (2,4,4′-trichloro-2′-hydroxydiphenyl ether) did not affect the tissue or healing response; however, the documented benefits referred to the reduction or prevention of bacterial plaque formation owing to inhibition of the growth of microorganisms by interfering with cell membranes. Moreover, regarding the use of CHX, Asher et al. [22] found that this chemical substance did not prevent bacterial accumulation or completely prevent infectious processes.

Another relevant association evidenced by Dragovic et al. [23] was the greater bacterial load present in sutures, and the number of inflammatory cells consequently recruited was significantly associated with the pain felt by patients when removing the suture, highlighting the better choice of polyamide compared with silk sutures.

4.2. Mechanical Properties

Adequate suture tension resistance is extremely important for adapting the flaps until complete healing. Therefore, this mechanical property needs to be as stable as possible, especially in the first two postoperative weeks, when suture materials tend to lose between 70 and 80% of their initial strength [4]. Regarding this characteristic, no consensus was found in the literature included in this systematic literature review, and despite Kuzu [5] demonstrating polyamide has greater resistance to tension than silk, Manfredini et al. [4] found the opposite.

Thus, the tensile strength is affected by several factors, which, in addition to the material itself, include caliber, flexibility, knot technique chosen, number of semi-knots, elongation, and structure [1,5,10,20]. Regarding diameter, sutures with larger calibers show better results in resistance to tension [4]. Several researchers corroborate that the physical structure of multifilamentary sutures offered greater resistance to traction and abrasion, flexibility, elasticity, and reliability in the knot [4,5,10,20].

As far as nodes are concerned, Kuzu [5], Wang et al. [1], and Taysi et al. [10] agreed that mechanical interweaving was the most fragile element of the suture. Then, when a suture reaches its breaking point, it always happens at or close to the knot. After evaluating the tensile strength of the knot, Manfredini et al. [4] confirmed that even though silk sutures presented significant variability in knot tension resistance with different calibers, they continued to contribute more favorable values compared with polyamide. Evaluating the work of Wang et al. [1], it was mentioned that the type of suture affects the security of the knot because silk and polyamide have different structural properties and, therefore, different memories and friction coefficients. Multifilament sutures are generally considered safer. Although monofilament sutures have a lower coefficient of friction than multifilament sutures, they can be associated with superior memory, which is attributed to a better knot retention capacity.

The security of the knots also assumes considerable importance in the tension resistance of a suture material. When creating a node, one of the objectives is to use the minimum number of semi-nodes to obtain a safe configuration. A smaller number of semi-knots may cause greater slippage; however, it reduces the risk of pathological reactions and has the advantage of reducing surgery time. Therefore, the knot configuration, the tension applied, the suture material, and the caliber influence the safety. Different knot configurations can improve the mechanical profile of the suture threads; in other words, the security and reliability of the knot depends not on its number but on certain specific combinations of knots [1,10].

Regarding the configuration of the knots, in agreement with some articles in the literature, the surgeon's knot was referred to as the most robust and stable compared with the square knot. This is probably because the surgeon's knot is tied twice initially unlike the square knot, which is tied only once. However, it is important to note that the tension must be applied equally and parallel to both ends of the thread and perpendicular to the axis of the knot [1,10]. The knot configuration suggested by the manufacturers showed lower resistance to tension when compared with the surgeon's knot. However, the elongation suffered with the configuration proposed by the manufacturer was significantly lower, which is why the researcher believed this is the recommended configuration [10].

Stretching a suture, despite allowing better handling, may be responsible for creating postoperative gaps, which is considered a clinical failure. However, stretching becomes an advantage for healing when exponential edema is predicted. Multifilamentary sutures have a lower elongation rate than monofilament sutures, making the latter less prone to irreversible changes. Another condition to consider is that increased tensile loads do not necessarily imply greater elongation at failure [1,20,23].

4.3. Chemical Substances

Usually, in dentistry, specifically, periodontics and oral surgery, several chemical adjuvants are added to sutures to either reduce bacterial accumulation or stabilize their mechanical properties. Furthermore, sutures are subject to a wide range of adverse environments, and it has not been widely studied whether chemical agents in contact with sutures modify these properties.

The antimicrobial properties of CHX are quite well documented. CHX for wound irrigation or application to the edges of the surgical wound at the time of closure is widely used to reduce bacterial contamination and suture failure. However, this procedure is often carried out without knowledge of the changes that this chemical solution can cause in mechanical properties, thereby causing complications in healing [15].

Some authors have controversial opinions on this subject. Gaukroger et al. [15] stated that isopropyl alcohol and CHX are unlikely to compromise mechanical properties, as there were no significant differences in tensile strength, Young's modulus, or final tensile stress in the silk and polyamide sutures after 11 days of immersion in CHX. In contrast, Varma et al. [14] demonstrated that the tensile strength of silk and polyamide sutures significantly reduced when exposed to CHX.

Chemical adjuvants were also used as a complement, not only for antibacterial purposes but also to improve the biomechanical properties of the suture. HA has biocompatibility, antibacterial, anti-inflammatory, and non-immunogenic properties; therefore, mouthwashes with HA are increasingly used to close wounds and promote healing. After immersing sutures in HA, regardless of the suture material used, polyamide and silk sutures did not significantly reduce tensile strength. In this way, HA did not interfere with the mechanical property of tensile strength after 24h (there was stability). However, although polyamide has shown greater stability of mechanical characteristics compared with silk, the exact mechanism by which this occurs is not fully understood and requires further investigation [14].

4.4. Study Limitations

A limited number of studies were included, with various and diverse study designs, methodological designs, types of sutures, and environmental conditions. Moreover, after many in vitro experiments, more in vivo studies are necessary, given that there are factors intrinsic to the individual that can cause variability in response to sutures, such as general systemic health, eating habits, malnutrition, chemotherapy agents, alcoholism, smoking, level of oral hygiene, level of inflammatory reaction, postoperative edema, or movements inherent to the oral cavity and parafunctions. In addition, the short monitoring periods of in vitro tests, the small sample size, the lack of tests with cyclic load (repetitive tension exerted on the suture), or the force exerted by the knots were some of the obstacles mentioned or not evaluated. Only three databases (ScienceDirect, B-ON, and PubMed) were used, which may limit the number of articles found; it is suggested in new systematic studies that others should be used, such as EMBASE, Global Health, The Cochrane Library Database, and/or Web of Science. Furthermore, due to the heterogeneity design and type of studies included, it was not possible to draw any type of statistical analysis.

5. Conclusions

In light of the results of this systematic review and within the limitations observed, it was possible to reject the null hypothesis that both types of sutures had the same behavior and results/performance. Sutures with a monofilament polyamide physical structure caused less inflammatory reaction owing to less bacterial retention and capillarity, while multifilament sutures (silk) had superior mechanical characteristics. The loss of tensile strength was significantly higher in the multifilament-type suture. The elongation rate for the multifilament-type suture was between 10 and 15%, whereas for monofilament sutures it was between 20 and 25%; multifilamentary sutures were prone to irreversible changes in their structure, which is a problem connected with postoperative edema. When using sutures hydrated with CHX, the evidence demonstrated in the preservation and stability of mechanical properties lacks uniformity and congruence. However, HA seems to present a promising option with regard to its characteristics and antibacterial capabilities.

Even though the mechanical properties of sutures are well documented in the literature, further investigations with high-quality methodological design to obtain the best scientific evidence are necessary to better answer the clinical question placed, mainly in vivo, to analyze the many variables inherent to the oral cavity and the human body.

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