Characteristics of Suture Materials Used in Oral Surgery: Systematic Review

Abdullah Farisa, Lian Khalida, Mohammed Hashima, Sara Yaghia, Taif Magde, Ward Bouresly, Zaid Hamdoona, Asmaa T. Uthman, Hesham Marei, Natheer Al-Rawi

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ABSTRACT

Background: The aim of this review was to evaluate the most used suture materials with regards to their inflammatory response, their bacterial adhesion, and their physical properties when used to close oral wounds.

Methods: Four databases (PubMed, Scopus, Dentistry & Oral Sciences, and OVID) were searched to retrieve relevant studies from January 1, 2000, to January 31, 2020.

Results: Out of the 269 articles, only 13 studies were selected as they were relevant and met the systematic review’s protocol. These studies showed that almost all suture materials (catgut, polyglycolic acid [PGA] sutures, nylon, expanded polytetrafluoroethylene, and silk sutures) caused bacterial adherence and tissue reaction. In nylon and chromic catgut, the number of bacteria accumulated was lowest. Silk and nylon were found to be more impacted than catgut and PGA in terms of physical characteristics such as tensile strength. PGA, on the other hand, was said to be the most susceptible to knot unwinding.

Conclusions: Following an oral surgical operation, all sutures revealed varied degrees of irritation and microbial accumulation. Nonresorbable monofilament synthetic sutures, however, exhibited less tissue response and less microbial accumulation.

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suture material is made of a single strand which provides less tissue resistance and less likely to harbour microorganisms than multifilament sutures. However, crushing of the suture can lead to undesirable and premature suture failure. As reported, silk is one of the most cost-effective suture materials currently used. However, the primary drawback of this type of suture is the patient’s discomfort in having sutures removed and the hassle of an additional visit to the clinic. Adhesives are being offered as a replacement for traditional suturing procedures as health care advances. Cyanoacrylates are powerful adhesives that are biocompatible, are biodegradable, and do not interfere with the healing process. It does, however, have minor stiffness and a variety of toxic effects that are still being investigated.

Nonetheless, there were not enough articles comparing the different suture materials of interest together; however, the primary goal of this systematic review is to compare the physical strength and susceptibility to microbial accumulation of the most common types of sutures, including catgut, PGA, nylon, and silk. This evaluation will also offer some insight on the tissue reaction following an oral procedure.

Materials and methods

Study design and the focused question

This systematic review followed criteria stated in the updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The research question for this review was formulated according to the Population, Intervention, Comparison, Outcomes (PICO) criteria: “Which suture materials produce lesser tissue reaction and lower bacterial accumulation when used in oral surgical procedure. The primary outcome was the bacterial accumulation on suture materials whilst the secondary outcome was the oral tissue reaction after placement of these sutures.”

Search strategy and eligibility criteria

Using selected Medical Subject Headings (MeSH), relevant papers were retrieved from four databases (PubMed, Dentistry & Oral Sciences, Ovid, and Scopus). The search terms used were as follows: (Sutures AND tissue reaction) AND (sutures AND bacterial accumulation) AND (sutures AND knot security) AND (Threaded OR Multifilament sutures) AND (silk OR catgut OR Nylon OR PGA sutures). All research published through July 30, 2021, was included in the search. The following were the eligibility criteria: published from January 1, 2000, to January 31, 2020, in the dental literature.

Publications were taken into consideration if all of the following criteria were met: (1) clinical trials, in vitro, or experimental studies, (2) sutures done in oral surgery, (3) articles published in the English language only, (4) full-text articles, (5) articles published after the year 2000, and (6) articles about silk, PGA, nylon, catgut, and n-butyl cyanoacrylate suture materials.

Exclusion criteria

All case reports and case series studies, review papers, as well as animal studies were excluded.

Literature screening and data extraction

The retrieved articles went through a 3-phase screening procedure based on the eligibility criteria after a preliminary search in the specified databases. This included title and abstract screening as well as a thorough full-text reading.

Screening was done by 2 authors (A.F. and L.K.), and any disagreements were addressed by discussion with a third reviewer (M.H.). Cohen’s Kappa was used to measure the level of inter-examiner agreement. Published articles that met the qualifying criteria were included. Data including the author’s name/year, study design, sample types and numbers, and follow-up periods were retrieved.

Data extraction and method of analysis

The process of study selection is documented in the PRISMA flowchart presented in the Figure, and the search was run in 4 phases:

Identification phase

The total numbers of recorded extracted articles from those 4 search engines were 269. After skimming the article’s titles, 117 articles were eliminated as they were duplicates.

Screening phase

The titles and the abstracts of the remaining 152 records were examined based on predefined eligibility criteria. One hundred nineteen articles were excluded and only 33 articles remained.

Eligibility phase

After full text reading, 20 articles were found to be not eligible due to different reasons, as seen in the supplementary table.

Inclusion phase

The remaining 13 articles were checked, the full text of the relevant papers were separately examined by 3 reviewers, and any disagreements were resolved by consensus.

Quality assessment and risk of bias

Two authors performed the quality appraisal of the included papers (Z.H. and N.A.).

For randomised clinical trials (RCTs), the quality of the included studies was assessed using the Cochrane Risk of Bias tool (RoB2). A total of 5 domains are examined for the RoB2 test, with judgments ranging from minimal risk of bias to some concerns and to high risk of bias. The overall risk of bias usually corresponds to the worst risk of bias in any of the domains.

For nonrandomised clinical trials (NRCTs), 2 authors (H.M. and Z.H.) used ROBINS-I instrument to assesses a total of 7 domains, with low risk, moderate risk, severe risk, and critical risk of bias being the judgments. The low risk of ROBINS-I corresponds to a high-quality nonrandomised study. Overall,
for low risk, the study is judged to be at low risk of bias for all domains; for moderate risk, the study is judged to be at low/moderate risk of bias for all domains; for serious or high risk, the study is judged to be at high risk of bias in at least one domain, but not at critical risk of bias in any domain; and for critical risk, the study is judged to be at critical risk of bias in at least one domain.

In vitro studies included in this review were assessed with the tool developed by the United States national toxicology programme. The tool consists of 7 criteria: (1) experimental condition bias; (2) blinding during study; (3) incomplete data; (4) exposure characterisation; (5) outcome assessment; (6) reporting bias; and (7) other.

The interpretation for fulfilling a “high,” “moderate,” and “low” risk of bias score of the 3 study designs is depicted in Table 1.

Results

The kappa value was 0.85, so the agreement amongst the 3 investigators was almost perfect.

Risk of bias

Using the RoB2 and ROBINS-1 checklists and in vitro studies checklist, 5 studies were assessed as having a low risk of bias, and 7 studies were rated as having a moderate risk of bias. Four studies were rated as having high or serious risk of bias (Table 1). The characteristics and the main findings of the included studies are depicted in Tables 2 and 3.

Bacterial accumulation

Six studies (4 RCTs, 1 NRCT, and 1 in vitro study) investigated bacterial accumulation on different suture materials under different conditions.

Sortino et al found that silk sutures exhibited a higher degree of aerobic bacteria. In particular, Streptococcus viridans, Neisseria saporifera, Corynebacterium, and Staphylococci than poly glycolic acid sutures. Pathogenic bacteria were also found such as Pseudomonas aeruginosa, Klebsiella pneumoniae, Staphylococcus aureus, Streptococcus pyogenes, and Enterobacterium. It was also reported that fungi, in particular, Candida albicans was observed on silk sutures and not on PGA sutures. On the contrary, PGA sutures did not show significant differences in
Table 1 – Risk of bias of the included studies.

| Author/year | Bias arising from the randomisation process | Bias due to deviation from intended intervention | Bias due to missing outcome data | Bias in measurement of the outcome | Bias in selection of the reported results | Overall bias |
|-------------|---------------------------------------------|-----------------------------------------------|--------------------------------|-------------------------------------|-----------------------------------------|-------------|
|             | D1                                         | D2                                            | D3                             | D4                                  | D5                                      |             |
| Randomised clinical trials |                |                                              |                                |                                     |                                         |             |
| Perez et al 2015 | High                                         | Some concern                                  | Low                            | Some concern                        | Low                                     | Moderate    |
| Sortino et al 2007 | Some concern                                 | Low                                           | Low                            | Some concern                        | Low                                     | Moderate    |
| Mahesh et al 2019 | Some concern                                 | Low                                           | Low                            | Some concern                        | Low                                     | High        |
| Balamurugan et al 2012 | High                                         | Low                                           | High                           | Some concern                        | High                                    | High        |
| Asher et al 2018 | Low                                         | Low                                           | Low                            | Low                                 | Low                                     | Low         |
| Non Randomised clinical trials |                |                                              |                                |                                     |                                         |             |
| Kumar et al 2013 | Low                                         | Critical                                      | Low                            | Low                                 | Serious                                 | Serious     |
| Syafilda et al 2019 | Low                                         | Low                                           | Low                            | Low                                 | Low                                     | Low         |
| Lekens et al 2019 | Moderate                                     | Moderate                                      | Moderate                        | Low                                 | Bias due to deviation                    | Low         |
| Author/year | Same experimental condition | Blinding during study | Incomplete data | Exposure characterisation | Outcome assessment | Reporting | Other | Overall bias |
|             | D1                                         | D2                                            | D3                             | D4                                  | D5                                      | D6          | D7    |             |
| In vitro studies |                |                                              |                                |                                     |                                         |             |
| Vasanthan et al 2009 | Serious                                      | Low                                           | Low                            | Low                                 | Low                                     | Low         | Moderate |
| Arce et al 2019 | Low                                         | Critical                                      | Low                            | Low                                 | Moderate                                | Moderate    |
| Abellan 2016 | Low                                         | Low                                           | Low                            | Low                                 | Low                                     | Low         |
| Kumar et al 2013 | Low                                         | Critical                                      | Low                            | Low                                 | Low                                     | Low         |
| Sudhairy et al 2018 | Low                                         | Serious                                      | Low                            | Low                                 | Low                                     | Low         |
| Syafilda et al 2019 | Low                                         | Low                                           | Low                            | Low                                 | Low                                     | Low         |
| Kim et al 2007 | Low                                         | Low                                           | Low                            | Low                                 | Low                                     | Low         |
| Lekens et al 2019 | Moderate                                     | Moderate                                      | Moderate                        | Low                                 | Low                                     | Moderate    |
| Author/year | Aim of the study | Surgical setting | Suture materials | Follow-up | Main findings | Weakness |
|-------------|-----------------|------------------|-----------------|-----------|---------------|----------|
| Perez et al 201510 | Compare the antibacterial effect of Monocryl® Plus suture with silk suture | RCT | Surgical extraction of upper right third molar | • SS | Silk suture showed significantly higher values for both aerobes and anaerobes. Monocryl® Plus yielded a lower count for almost all the isolated species. However, the differences were only statistically significant after 3 days (125 CFU/cm/mL, SD of 179 for silk suture and 28 CFU/cm/mL, SD of 42 for Monocryl® Plus suture) ($P = .013$). The presence of pathogenic microorganisms was also less evident in this suture after 72 hours and 7 days, though not statistically significant. | Small sample size (10 males and 10 females). |
| Sortino et al 200711 | Compare bacterial contamination of black silk and polyglycolic acid sutures that had been in the oral cavity for 8 days | RCT | Surgery at mandibular angle | • SS • PGA | Black silk sutures exhibited a high degree of aerobic bacteria. Both kinds of sutures had a similar degree of anaerobic bacteria. Polyglycolic acid sutures did not show significant differences for the presence of saprophyte bacteria if compared to black silk sutures. However, pathogenic bacteria as well as fungi were missing in polyglycolic acid sutures. The use of a 0.2% chlorhexidine solution did not significantly affect the pattern of bacterial contamination detected in both suture materials. | Confounding factors not mentioned in the study. |
| Mahesh et al 201912 | To study the microbial recovery from sutures explanted from noninfected or infected clinical specimens | RCT | Implant surgery with GBR | • SS • PG • Gut • PTFE • Polyamide | Two types of sutures, one monofilament (polyamide) and one braided (Vicryl), were found to harbour the maximum number of anaerobic bacteria. Aerobic bacteria grown around gut sutures showed minimum CFUs ($< 10^3$) per suture. However, Vicryl and polyamide sutures harbour the maximum number of anaerobic bacteria. | |
| Balamurugan et al 201213 | To assess histologically the tissue reaction of 2 suture materials | RCT | Minor oral surgical procedure | • SS • PG | Inflammatory cells detected in all samples. The intensity varied from mild (68% vs 64%) to moderate (16% vs 20%) to severe (16% vs 16%) in Vicryl group and BSS group, respectively. | Selection bias. |
| Asher et al 201814 | To compare bacterial accumulation on different suture materials following oral surgery | RCT | Implant and periodontal surgery | • SS • PGA • Nylon • Polyester | Nylon sutures showed significantly lower CFU levels compared to silk, coated polyglactin, and polyester sutures. The type of surgery (implant vs periodontal surgery) did not significantly influence bacterial accumulation. No significant differences were observed between antibiotic consumption and antibiotic-free groups for all the tested parameters. | |
| Kumar et al 201315 | To compare effectiveness of the black silk sutures with cyanoacrylate adhesives in closing the surgical incisions | NRCT | Bilateral apicoectomy | • SS • Cyanoacrylate adhesives | On the 3rd and 7th postoperative days epithelialisation was better on the sides treated with n-butyl-2 cyanoacrylate. However, the sites closed with black silk suture showed significant inflammation and scar formation. | Small sample size (10 patients only). |
| Syafilda et al 201916 | To compare post-odontectomy wound healing time using silk and catgut sutures | NRCT | Third molar impaction surgery | • SS • Catgut | On day 1 and day 7 of the surgery, the catgut sutures have a mean score of wound healing time that is better than silk sutures. However, the time needed to perform suture of cat gut is longer. | Posttest design with short follow-up (1st and 7th day postoperatively). Results were highly subjective. |
| Leknes et al 200517 | To evaluate clinically and histologically tissue reactions to silk and expanded polytetrafluoroethylene (ePTFE) suture materials placed in human oral tissues | NRCT | Periodontal surgery | • SS • ePTFE | Bacterial plaque was detected in 10 of 11 silk and four of 11 ePTFE suture channels at 7 days, and 8 of 10 and 4 of 11 suture channels at 10 days. Braided silk sutures apparently cause a more extensive inflammatory tissue reaction than ePTFE. Silk sutures present a higher risk of slack of the suture loop than does ePTFE. | The examiner could not be masked with regards to suture material under study. |

(continued on next page)
| Author/year | Aim of the study | Study design | Surgical setting | Suture materials | Follow-up period | Main findings | Weakness |
|-------------|-----------------|--------------|------------------|------------------|-----------------|--------------|----------|
| Vasanthan et al 2009 | To compare the tensile strength of commonly used sutures over a 2-week period under simulated oral conditions | In vitro | A biologic simulation was created in vitro. All samples were tested pre-immersion and 1 hour and 1, 3, 7, 10, and 14 days post immersion. The tensile strength was assessed using a micro tensile tester, and the maximum load required to cause suture breakage was determined. The point of breakage in the samples and the samples themselves were also assessed. | • Chromic gut  
• PG  
• PG-FA | 14 days | 4-0 sutures are stronger and have greater tensile strength than 5-0 sutures. CG seems to sustain its strength better than PG and PG-FA after 2 weeks. PG-FA may not be a desirable suture if tensile strength is required after 10 days. | The controlled aseptic in vitro environment in this study, without the influence of bacterial proteolytic enzymes, might affect the results. |
| Arce et al 2019 | To compare the in vitro tensile strength of sutures used in implant surgery according to the type of thread and the immersion time in artificial saliva | In vitro | A universal test machine was used to measure the tensile strength. The failure point of the samples was evaluated at 10 x increase using a stereomicroscope. | • SS  
• PG  
• PTFE | 21 days | When comparing the in vitro tensile strength of PG, BS, and PTFE sutures at baseline and 3, 7, 14, and 21 days, there was no statistically significant difference. | Suture technique, type of saliva, diet, and hygiene habits could be confounding factors and were not measured. |
| Abellan et al 2016 | To compare the mechanical properties of 5 suture materials on 3 knot configurations when subjected to different physical conditions | In vitro | Three knot configurations were compared A.2=1=1 (forward-forward-reverse), B.2=1=1 (forward-reverse-forward), and C.1=2=1 (forward-forward-reverse). Mechanical properties (failure load, elongation, knot slippage/breakage) were measured using a universal testing machine. | • SS  
• PV  
• PGA  
• GC  
• PTFE | 14 days | Polyglycolic acid followed by glycolide-e-caprolactone copolymer showed the most knot failure load, whilst polytetrafluoroethylene showed the lowest. Physical conditions, such as pH concentration and thermal cycle process, have no influence on suture mechanical properties. | |
| Sudhair et al 2018 | To evaluate the presence of Staphylococcus aureus and Escherichia coli, in polyglycolic acid (PGA) 4-0 and silk sutures, with or without hyaluronic acid (HA) treatment | In vitro | This in vitro study measured S aureus and E coli growth on PGA and silk sutures, through incubation in agar media for 24 h. | • SS W/WO HA  
• PGA W/WO HA | The mean S aureus colony-forming units (CFUs) differed at each time point between non-HA and HA-PGA sutures, with a greater number of CFUs on non-HA-PGA. The mean S aureus CFUs were significantly higher on non-HA silk than on HA-silk sutures. There was a significant increase in E coli CFUs on non-HA silk than on HA-silk sutures. E coli CFUs were higher on non-HA-PGA than on HA-PGA sutures. | Compared 2 types of suture material with different filament synthesis. |
| Kim et al 2007 | Tensile properties such as maximum tensile load, elongation rate, stiffness, and energy absorbed before breakage of 7 kinds of surgical sutures were measured | In vitro | Tensile properties were measured for 6 sutures (3 absorbable and 3 non-absorbable) using a universal testing machine. | • SS  
• Nylon polypropylene  
• Catgut chronic catgut PGA | The tensile maximum load after tensile loading decreased, which was significant in chronic catgut. Type of non-absorbable suture influenced knot security and the synthetic monofilament materials showed a tendency to be untied easily. | One knotting method used. |

CFU, colony-forming unit; ePTFE, expanded polytetrafluoroethylene; GC7, glycolide-e-caprolactone copolymer; HA, hyaluronic acid; PGA, polyglycolic acid; PG, polyglactin; PTFE, fluoropolymer of tetra-fluoroethylene; PG-FA, polyglactin-fast absorbing; PV, polyamide; RCT, randomised clinical trial; SS, silk suture.
the presence of saprophyte bacterial accumulation when compared with silk sutures; however, both sutures had a similar degree of anaerobic bacterial accumulation like Fusobacterium nucleatum, Peptococcus anaerobes, and Bacteroides melaninogenicus. Bacterial accumulation was not affected when sutures were treated with 0.2% chlorhexidine solution. Perez et al.\textsuperscript{10} found that silk sutures showed significantly higher values for both aerobes and anaerobes. However, Monocryl\textsuperscript{10}/C210 yielded a lower count for almost all the isolated species. However, the presence of pathogenic microorganisms was also less evident in this suture after 72 hours and 7 days—though not statistically significant. Mahesh et al.\textsuperscript{12} conducted a study on suture segments (silk, gut, polyglactin [PG], polytetrafluoroethylene [PTFE], and polyamide sutures) that were extracted 14 days postoperatively; they were inoculated on culture media of blood agar plates. They found that aerobic bacteria were minimal around gut suture, showing CFU (≤10\(^4\)/suture) in comparison to silk 10\(^2\)–10\(^4\)/suture. Nylon (polyamide) sutures had equal amounts of aerobes and anaerobes showing CFUs (≤300 sutures × 10\(^4\)/suture). Correspondingly, the effectiveness of hyaluronic acid (HA) at reducing bacterial accumulation in silk and PGA sutures (PGA) was examined in vitro by Sudhair et al.\textsuperscript{16} and results showed that the mean S aureus and E coli CFUs were significantly higher on non-HA-treated silk than on HA-treated silk sutures. E coli CFUs were significantly higher on non-HA-treated PGA sutures than on HA-treated PGA sutures. Thus, HA reduced bacterial accumulation in both PGA and silk sutures.\textsuperscript{16} Asher et al concluded that neither the type of surgery (implant vs periodontal surgery) nor antibiotic taking significantly influence bacterial accumulation. However, nylon sutures showed significantly lower CFU levels compared to silk, coated polyglactin, and polyester sutures.\textsuperscript{13} Leknes et al found that bacterial plaque was detected in 10 of 11 silk and 4 of 11 expanded polytetrafluoroethylene (ePTFE) suture channels at 7 days and 8 of 10 and 4 of 11 suture channels at 10 days.\textsuperscript{14}

### Tissue reaction

Four clinical trials assessed the tissue reaction. A clinical study was conducted by Lekens et al.\textsuperscript{14} to assess the inflammatory response against 2 sutures (braided silk suture and ePTFE sutures) in histological sections. They concluded that braided silk sutures cause more extensive inflammatory

| Type of suturing material | Number of studies | Level of evidence | Strength of evidence | Main findings |
|--------------------------|-------------------|-------------------|----------------------|--------------|
| Silk                     | Sortino et al.\textsuperscript{11} | RCT              | Medium              | - Biocompatible and good handling characteristics |
|                          | Perez et al.\textsuperscript{10} | RCT              | High                | - High amounts of bacterial and fungal accumulation (both aerobes and anaerobes) |
|                          | Mahesh et al.\textsuperscript{12} | RCT              | Medium              | - Extensive inflammatory tissue reaction |
|                          | Sudhair et al.\textsuperscript{11} | In vitro study   | High                | - More scar formation and longer wound healing |
|                          | Asher et al.\textsuperscript{14} | RCT              | High                | - Most susceptible to knot unwinding |
|                          | Leknes et al.\textsuperscript{17} | NRCT             | Medium              | - No significant difference in saprophyte bacterial accumulation when compared with silk |
| PGA                      | Sortino et al.\textsuperscript{11} | RCT              | Medium              | - Most susceptible to knot unwinding |
|                          | Abellan et al.\textsuperscript{19} | In vitro study   | High                | - No significant difference in saprophyte bacterial accumulation when compared with silk |
|                          | Sudhair et al.\textsuperscript{11} | RCT              | High                | - Most susceptible to knot unwinding |
| Nylon                    | Asher et al.\textsuperscript{14} | RCT              | High                | - Significantly lower CFU and bacterial accumulation levels when compared to other suture materials (silk, coated PG, and polyester) |
|                          | Kim et al\textsuperscript{22} | In vitro study   | High                | - Significantly lower CFU and bacterial accumulation levels when compared to other suture materials (silk, coated PG, and polyester) |
| PTFE                     | Mahesh et al.\textsuperscript{12} | RCT              | Medium              | - No significant difference in terms of tensile strength to PG and SS |
|                          | Leknes et al.\textsuperscript{17} | NRCT             | Medium              | - Lowest knot failure |
|                          | Arce et al.\textsuperscript{19} | In vitro study   | Medium              | - Better wound healing time than silk sutures |
|                          | Abellan et al.\textsuperscript{19} | In vitro study   | High                | - Longer time required to perform the sutures |
| Catgut                   | Mahesh et al.\textsuperscript{19} | RCT              | Medium              | - Better strength than PG and PG-FA sutures after 2 weeks (chromic gut) |
|                          | Syafilda et al.\textsuperscript{16} | NRCT             | High                | - Better wound healing time than silk sutures |
|                          | Vasanthan et al.\textsuperscript{18} | In vitro study   | Medium              | - Longer time required to perform the sutures |

CFU, colony forming unit; NRCT, non randomized clinical trial; PG, polyglactin; PGA, polyglycolic acid; PGFA, polyglactin-fast absorbing; PTFE, polymer of tetrafluoroethylene; RCT, randomised clinical trial; SS, silk suture.
tissue reaction than ePTFE sutures. Syafilda et al. in their clinical trials, tested wound healing with 2 suture materials (silk and catgut). They found that on day 1 and day 7 of the surgery, the catgut sutures had a better score of wound healing time than silk. However, the healing time needed to perform suturing with catgut is longer. Balamurugan et al. found that inflammatory cells are detected in both silk and PGA suture samples. However, the intensity varied from mild (68% vs 64%) to moderate (16% vs 20%) to severe (16% vs 15%) in the PGA group and the silk suture group, respectively. Kumar et al. concluded that surgical sites closed with silk sutures showed significantly more inflammation and scar formation than those closed with n-butyl cyanoacrylate adhesives. Moreover, n-butyl-2-cyanoacrylate also showed dense inflammatory infiltrate and more uniform distribution of neutrophils, lymphocytes, and histocytes, unlike silk which had infiltrates on the margins of the gap.

**Knot security and tensile strength**

Four in vitro studies evaluated tensile strength and knot security. Vasanthan et al. measured the tensile strength of 3 suture materials (chronic gut, PG, and glycolide-e-caprolactone copolymer [PG-FA]) after immersing the sutures with serum saliva mixture using a microtensile tester, the maximum load required to cause suture breakage and the point of breakage were assessed. They found that 4-0 sutures have greater tensile strength than 5-0 sutures. Chromic Gut seems to sustain its strength better than PolyGlyactin and PG-FA after 2 weeks. Arce et al. used a stereomicroscope to compare the tensile strengths of sutures used in implant surgery according to the type of thread and immersion time in serum saliva mixture. They used 3 suture materials (silk, PG, and PTFE). They found no statistically significant differences in tensile strengths of PG, silk, and PTFE sutures at baseline and after 3, 7, 14, and 21 days. Abellan et al. compared the mechanical properties of 5 suture materials on 3 knot configurations. They assessed the mechanical properties (failure load, elongation, knot slippage/breakage) of the following sutures: silk, polyamide, PGA, glycolide-e-caprolactone copolymer, PTFE. Three knot configurations were compared. They observed that polyglycolic acid followed by glycolide-e-caprolactone copolymer showed the most knot failure load, whilst PTFE showed the lowest. Kim et al. evaluated the tensile properties of 6 different surgical sutures, including maximum tensile load, elongation rate, stiffness, and energy absorbed before breakage. They found that in non-absorbable sutures, the type of suture material significantly influenced the tensile properties. However, in absorbable sutures, the maximum tensile load after tensile loading decreased, which was significant in chronic catgut. Moreover, the type of non-absorbable suture influenced knot security, and the synthetic monofilament materials showed a tendency to be untied easily.

**Discussion**

**Bacterial accumulation**

Bacterial aggregation on catgut sutures were observed to be less than other materials, but since all sutures harbour bacteria contributing to delay in healing, it is recommended to limit suture usage in surgery. There was a higher number of bacteria found in non-absorbable sutures compared to absorbable sutures. Sutures should be removed as soon as possible (6-10 days), according to recent research, because systemic illnesses can have oral origins, such as how bacteremia can occur after suture removal. Nylon’s bacterial adhesion was comparatively lower than silk, indicating that nylon should be the first target of sutures for microbial adhesion whenever possible. In one study, the bacterial colonisation was 83% and 65% lower than silk after 3 and 7 days, respectively. Streptococci were the most abundant organisms in both sutures, followed by Neisseria spp and coagulase-negative Staphylococcus. Silk and PGA sutures were also evaluated. Silk exhibited a high level of aerobic bacteria, pathogenic bacteria, and fungi. PGA did not display a substantial difference in the presence of aerobes, with no pathogenic bacteria or fungi. Although multifilaments are simple to handle, they harbour more bacteria than monofilaments; multifilament sutures may be treated with HA due to the anti-inflammatory, anti-edematous, and anti-bacterial properties. Every suture serves as a point of entry for an infection that might impede the wound’s healing. Due to the greater surface area on which microorganisms can adhere, multifilament sutures have a higher bacterial adhesion index than monofilament sutures. That is why sutures should not be left for long durations.

**Tissue reaction**

A study of Sudhairy et al. found that silk is known to cause inflammation due to its structure that acts as a great bacterial receptor; however, PGA had a more restricted inflammatory reaction. The clinical parameters included in the study by Lekens et al. were the variation in the slack of the suture loop and “bite” of the suture in the tissue, which were significant variables in the assessment of immobolisation and healing of the wound margins. Slack of suture is assessed by manual probing from the top of the interdental papilla to the suture level. Tissue bite is the amount of suture embedded inside the oral tissue determined by measuring its length by a caliper. The less tightness the suture receives, the less compact contact is between the suture thread and the underlying tissue, creating gaps. Those potential spaces can prevent the optimal epithelial healing through direct contact inhibition mechanism. Findings showed that the durability and integrity of the wound cannot be properly preserved by silk sutures. A separate study by Syafilda et al. revealed that although catgut sutures have a faster average wound healing time than silk, their stiff nature makes them more susceptible to injury to the oral tissues during treatment and makes them more difficult to tie than silk. Meanwhile, silk sutures outperform catgut in terms of biocompatibility and handling characteristics, making them more appealing to practitioners. Tissue reactions linked to the physical properties of the sutures can be correlated to the capillary and fluid absorption profile of the suture, and PGA was assessed in the Balamurugan et al study as demonstrating superior results to silk, which were also attributed to the fact that monofilaments had a lower friction coefficient resulting in less tissue
injury. Another study found that areas sealed with silk sutures took longer to heal and had more inflammation than those sealed with cyanoacrylate. The attachment of the 2 ends of the wound with cyanoacrylate leaves no room for moisture to enter during the healing process. Accordingly, this study advocated the usage of cyanoacrylate as an effective tool for sealing the incision margins and decreasing the inflammatory reactions along with the antimicrobial activity.

**Knot security and tensile strength**

Sutures break quickly when twisted into a knot because they are weak, and their tensile strength is less than the knotting strength. Suture gauge length is inversely related to tensile strength, since smaller volumes have less dispersed defects, resulting in less possibility of breakage. In one study, nylon had the highest tensile load due to its high elongation rate; however, due to the smaller diameter when elongated at the suture site, this resulted in displacement, gap formation, and tissue rupture, which is considered a clinical failure. Another property that inversely affected the tensile load of all studied suture materials was the caliber of the suture; when it increased, the maximum tensile loads of sutures decreased. In addition, knotting sutures decreases the mechanical properties, and when faced with a higher load, failure happens in 2 ways: slippage or breakage, which disrupts the healing process. Kim et al showed that the tensile load decreased for all sutures except silk, concluding that monofilament absorbable sutures have a higher knot slippage incidence in a salt solution. In another study, the tensile strength of silk declined unstably over the time when soaked in serum-saliva mixture. The study found that the force needed to affect slippage was highest at baseline and lowest after 7 days, confirming that monofilaments had a higher resistance to forces than multifilament. In yet another study, the monofilament catgut had a uniform strength that was distributed throughout the suture and the presence of chronic coating, which prevents slippage and delays the loss of tensile strength, increased the knot stability of the suture. An in vitro study was conducted to check the physical and mechanical properties of silk and PGA, using 3 different knot configurations. They concluded that suture resistance hinges mainly on 2 things: the type of material and the configuration of the knot used, where silk was more resistant with knot B, and a satisfactory result with the use of knot A for PGA. It is also noted that the physical contact to biodegradable agents did not affect the quality or knot resistance of sutures.

The current study includes a few limitations, including a wide range of inclusion criteria, such as RCTs and NRCTs, as well as in vitro investigations, which were all examined together in this review, which could be a source of bias due to the diversity of study designs. Furthermore, clinical studies with fewer patients (both randomised and non-randomised) may not have enough power to detect the primary and secondary outcomes. For these reasons, before advocating the use of resorbable/non-resorbable sutures for oral wound closure, a large, multicentre, and high-quality randomised clinical research is required to validate these findings.

**Conclusions**

In comparison to polyfilament sutures, nonresorbable monofilament synthetic sutures showed less tissue reaction and microbial accumulation. Of all the suture materials evaluated, nylon and chromic gut sutures had the least degree of bacterial aggregation.

**Conflict of interest**

None disclosed.

**Supplementary materials**

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.identj.2022.02.005.

**REFERENCES**

1. Kakoei S, Baghaei F, Dabiri S, Parirokh M, Kakoei S. A comparative in vivo study of tissue reactions to four suturing materials. Iran Endod J 2010;5(2):69.
2. Srinivasulu K, Dhiraj Kumar N. A review on properties of surgical sutures and applications in medical field. International J Res Eng Technol 2014;2(2):85–96.
3. Minozzi F, Boliero P, Unfer V, Dolci A GM. The sutures in dentistry. Eur Rev Med Pharmacol Sci 2009;13(3):217–26.
4. Javed F, Al-Askar M, Almas K, Romanos GE, Al-Hezaimi K. Tissue reactions to various suture materials used in oral surgical interventions. ISRN Dent 2012:1–6.
5. Petrie EM. Cyanoacrylate adhesives in surgical applications. Rev Adhes 2014;2(3):253–310.
6. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71.
7. McGugh ML. Interrater reliability: the kappa statistic. Biochem Medica 2012;22(3):276–82.
8. Sterne JAC, Savovic J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ 2019;366:14898.
9. Roony A. Extending a risk-of-bias approach to address in vitro studies. OHAT editor. Washington, DC: National Toxicology Program Office of Health Assessment and Translation; 2015.
10. Sala-Pérez S, Lopez-Ramirez M, Quinteros-Borgarello M, Valmaseda-Castellón E, Gay-Escoda C. Antibacterial suture vs silk for the surgical removal of impacted lower third molars. A randomized clinical study. Med Oral Patol Oral Cir Bucal 2016;21(1):e95–e102.
11. Sortino F, Lombardo C, Sciacca A. Silk and polyglycolic acid in oral surgery: a comparative study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105(3):e15–8.
12. Balamurugan R, Mohamed M, Pandey V, Katikaneni HKR, Kumar KA. Clinical and histological comparison of polyglycolic acid suture with black silk suture after minor oral surgical procedure. J Contemp Dent Pract 2012;13(4):521–7.
13. Asher R, Chacartchi T, Tandlich M, Shapira L, Polak D. Microbial accumulation on different suture materials following oral surgery: a randomized controlled study. Clin Oral Investig 2019;23(2):559–65.
14. Leknes KN, Reýnstrand IT, Selvig KA. Human gingival tissue reactions to silk and expanded polytetrafluoroethylene sutures. J Periodontol 2005;76(1):34–42.
15. Abellan D, Nart J, Fascula A, Cohen RE, Sanz-Moliner JD. Physical and mechanical evaluation of five suture materials on...
three knot configurations: an in vitro study. Polymers (Basel) 2016;8(4):147.

16. Sudhir VR, Biju T, Ramesh A, et al. Effect of hyaluronic acid added to suture material and its relationship with bacterial colonization: an in vitro study. J Int Soc Prev Community Dent 2018;8(5):391.

17. Syafilda R, Rusdy H, Riza A. Sitorus M. Comparison of wound healing time post odontectomy surgery using silk and catgut sutures in Pirngadi Hospital. J Dentomaxillofacial Sci 2019;4(1):32.

18. Suresh Kumar M, Natta S, Shankar G, et al. Comparison between silk sutures and cyanoacrylate adhesive in human mucosa- a clinical and histological study. J Int Oral Heal JIOH 2013;5(5):95.

19. Vasanthan A, Satheesh K, Hoopes W, Lucaci P, Williams K, Rapley J. Comparing suture strengths for clinical applications: a novel in vitro study. J Periodontol 2009;80(4):618–24.

20. Arce J, Palacios A, Alvitez-Temoche D, Mendoza-Azpur G, Romero-Tapia P, Mayta-Tovalino F. Tensile strength of novel nonabsorbable PTFE (Teflon®) versus other suture materials: an in vitro study. Int J Dent 2019;7419708.

21. Kim JC, Lee YK, Lim BS, Rhee SH, Yang HC. Comparison of tensile and knot security properties of surgical sutures. J Mater Sci Mater Med 2007;18(12):2363–9.

22. Mahesh L, Kumar VR, Jain A, et al. Bacterial adherence around sutures of different material at grafted site: a microbiological analysis. Mater (Basel, Switzerland) 2019;12(18):2848.