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Comparative Analysis of Lidocaine vs. Bupivacaine for Local Anesthesia in Minor Surgical Procedures, A Meta- Analysis

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ABSTRACT

Background: Local anesthetics such as lidocaine and bupivacaine are the most commonly employed in simple surgical operations, but their relative efficacy is controversial. This systematic review and meta-analysis aimed to perform a comparative analysis of the local anesthesia agents, lidocaine and bupivacaine in minor surgical operations. This review was aimed at facilitating evidence-based clinical decision-making in the choice of the most effective anesthetic to use when applying minor surgical practice.

Methods: A search for lidocaine versus bupivacaine in minor surgical procedures was conducted in PubMed, Scopus, Web of Science, and Google Scholar for randomized controlled trials (RCTs). The studies were filtered in accordance with PRISMA 2020 criteria. The Cochrane tool was used to measure risk of bias, and the certainty of evidence was measured with GRADE. RevMan 5.4.1 was used to perform meta-analyses through random-effects models, subgroup and sensitivity analyses to test the robustness.

Results: 12 RCTs were included. Quantitative data on onset were available in eleven studies, and duration in seven. No statistically significant difference in onset between lidocaine and bupivacaine was observed in a pooled analysis (SMD -0.27; 95% CI -0.70 to 0.16; I^2 =92%). Contrarily, duration of anesthesia preferred bupivacaine (SMD -2.47; 95% CI: -3.16 to -1.79; I^2 = 85%), and the findings were strong regardless of sensitivity analyses. The risk of bias was low-to medium-moderate, and the general evidence certainty was moderate.

Conclusion: Lidocaine has a better onset, and bupivacaine, a better analgesia, which validates their complementary roles in clinical indications. The two agents were safe, and intertrial heterogeneity demonstrates the necessity of standard protocols and multicenter, large-scale studies that could help guide an evidence-based

Keywords: Clear aligners, Fixed Orthodontic Appliances, Interleukins, Periodontal Health, Inflammation, Systematic Review

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INTRODUCTION

Local anesthetic agents have become essential in contemporary surgical practice, especially in minor surgery, since local anesthetic agents permit painless surgery without incurring the systemic risks of general anesthesia [1]. The two most popular agents, lidocaine and bupivacaine, are at the center of evidence-based clinical decisions because of their unique pharmacological characteristics. Lidocaine has the quality of rapid onset and short-acting, whereas bupivacaine has a slow onset and significantly extended analgesia [2,3].

Comparative analysis of these two agents has become significant, since the mode of anesthesia has an effect on postoperative pain, recovery patterns, and satisfaction of the patient, not just intraoperative comfort [4]. Additional clinical considerations affecting the clinical decision include tissue type, duration of procedure, hemodynamic stability, as well as the risk of toxicity because bupivacaine has a higher cardiotoxicity potential than lidocaine at higher doses [5].

Several comparative studies and randomized controlled trials have examined the differences in the onset time, sensory and motor block duration, and postoperative analgesia of these agents with mixed results [6]. Other trials indicate lidocaine as being superior about onset, and bupivacaine is preferred to sustain analgesia. Moreover, the literature that uses mixtures of lidocaine-bupivacaine gives an indication of potential synergistic effects that may enable an equalization of the rapid onset and the longer duration effect, although the data is inconclusive [7].

Lidocaine versus bupivacaine is not merely informed by changes in pharmacology but also on the nature and length of the surgical operation, comorbidities of the patient, and the preference of the clinician [8]. In outpatient and day-care practices, lido can be used due to its quick effect and short-acting nature and bupivacaine be used because it is useful when the postoperative analgesia is desirable. There is growing clinical guidance that anesthetic selection should be individualized to the needs of the procedure and patient-specific factors, but a universal consensus is still to be achieved as study designs and outcome measures are inconsistent across the literature [9].

The main constraint throughout the literature is methodological heterogeneity, the differences in design of these studies, surgical setting, concentrations, and outcome measures make direct comparison challenging. This highlights the importance of systematic review and meta-analysis in order to give more conclusive recommendations to clinicians [10].

This systematic review and meta-analysis aimed to perform a comparative analysis of the local anesthesia agents, lidocaine and bupivacaine in minor surgical operations. This review was aimed at

facilitating evidence-based clinical decision-making in the choice of the most effective anesthetic to use when applying minor surgical practice.

METHODS

This meta-analysis and systematic review was performed as per PRISMA 2020 guidelines [11].

In May 2025, the search was performed in the databases of PubMed, Scopus, Web of Science, and Google Scholar. The search strategy contained both MeSH terms and free-text keywords: lidocaine, bupivacaine, local anesthesia, minor surgical procedures, onset of action, duration of anesthesia, postoperative analgesia, and adverse events. The search was narrowed down to the use of Boolean operators (AND, OR), and reference lists of the included studies were screened manually to discover other eligible articles.

Eligible articles were English articles that reported quantitative data comparing lidocaine and bupivacaine when used in minor surgical procedures. The onset of anesthesia and duration of anesthesia were considered the primary outcomes of interest, and postoperative analgesia, patient satisfaction, and adverse event occurrence were also the secondary outcomes.

Cases, review articles, editorial articles, studies that did not include a control group, or qualitative reports only were excluded.

Titles, abstracts, and full texts were screened independently by two reviewers, and disagreements were resolved either by discussion or by a third reviewer. The characteristics of the studies, such as author, year, study design, sample size, type of surgical procedure, anesthetic regimen, comparator, follow-up, and outcomes, were collected using a standardized form of data extraction. In some cases, the missing information was requested from the respective authors. Data extraction as well as study selection was not automated.

Twelve randomized controlled trials[12,13,14,15,16,17,18,19,20,21,22,23] were included to meet the inclusion criteria. Of these, eleven studies reported the onset of anesthesia, seven of them measured the anesthesia time, and one study was included in the qualitative synthesis only. Quantitative meta-analyses were conducted on studies similar in terms of outcome measure, and otherwise, synthesis of heterogeneous findings was done narratively.

The Cochrane Risk of Bias tool was used to determine the risk of bias in randomized controlled trials. The confidence of the evidence was rated according to the GRADE method.

RevMan 5.4.1 was used to perform meta-analyses using a random-effects model. Continuous outcomes (onset time, duration) were analyzed by the use of standardized mean differences (SMDs). The I^2 statistic was used to test statistical heterogeneity.

Subgroup analysis was conducted based on the type of surgical procedure, dosage, and study design to identify the possible mechanisms of heterogeneity.

The sensitivity analysis was done through a leave-one-out method, where the studies were removed one by one to assess the pooled estimate's robustness and stability.

Where meta-analysis could not be conducted through heterogeneity or the lack of similar data, we reported the results in narrative fashion.

The findings were presented in forest plots and tabular descriptions of study characteristics, effect estimates, and confidence intervals.

RESULTS

Among 312 records identified in the database and manual search, 12 randomized controlled trials (RCTs) satisfied the inclusion criteria and were added to the end synthesis. Onset and response duration of sensory and motor block, and clinical response, which assessed patient satisfaction, intraoperative analgesia, and adverse events, were the outcomes measured. Among the studies included, eleven were quantitative in nature and could be included in the meta-analysis, and one study was synthesized narratively because it did not have similar outcome measures.

Reviews, case reports, conference abstracts, or studies that did not have a control arm were excluded.

Figure 1 shows the PRISMA flow diagram of the selection of the studies.

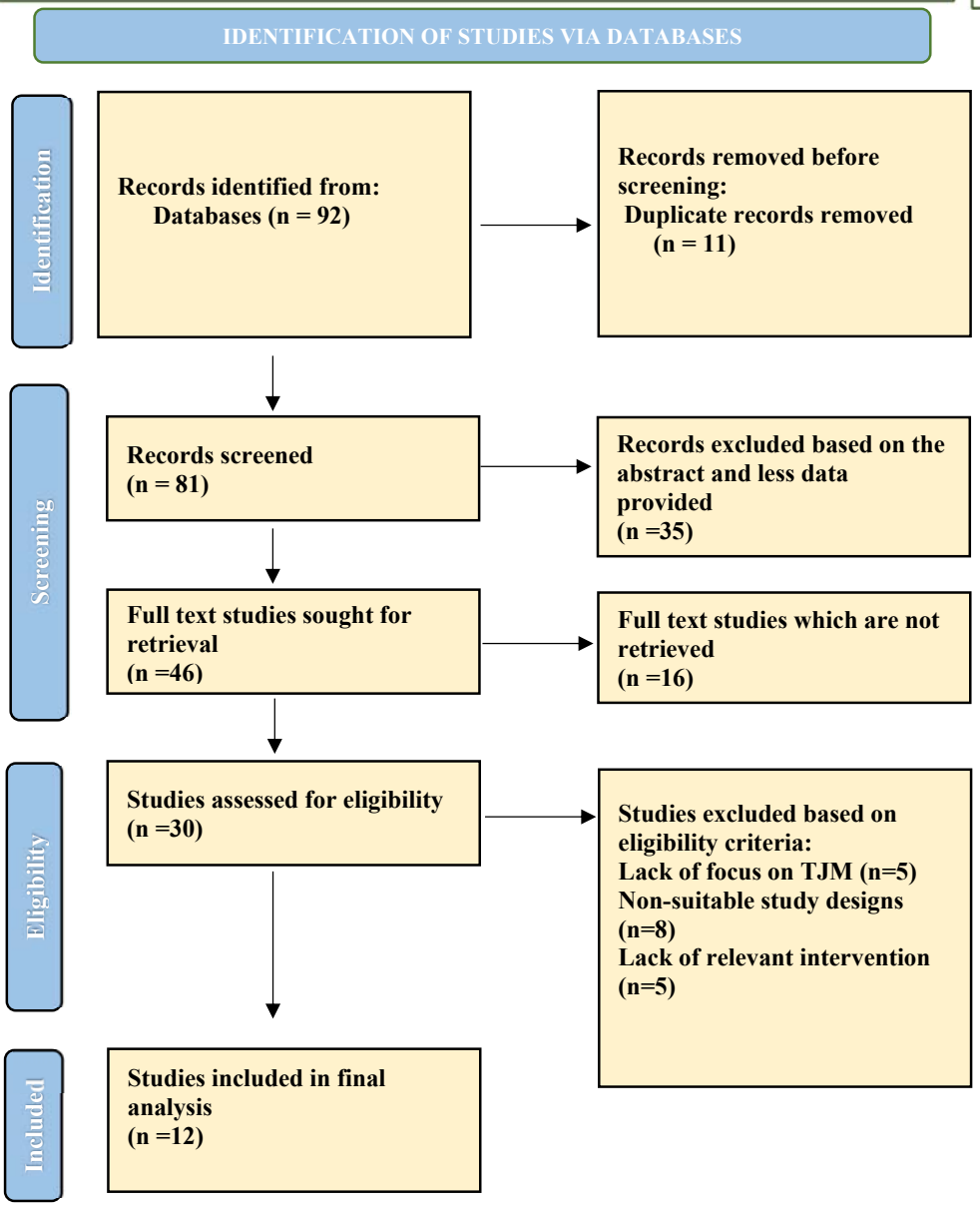

Figure 1: PRISMA Flow Diagram for Study Selection. The flowchart was designed according to the PRISMA guidelines 2020, showing study identification, screening, assessment eligibility, and final selection in the systematic review.

Characteristics of Studies

This systematic review has involved 12 studies, which are all the randomized controlled trials of lidocaine and bupivacaine in any minor surgical procedures. The sizes of study populations were 30 to 292 patients and the procedures performed included oral surgery, periodontal flap surgery, cataract surgery, mandibular fracture repair, third molar extraction, axillary brachial plexus block, wrist block, spinal anesthesia, and Mohs micrographic surgery. The majority of studies compared ultrasound-guided or local anesthetic methodologies, and interventions were lidocaine alone, bupivacaine alone, or both with or without adjuncts (adrenaline and/or dexamethasone).

Outcomes Studied

Onset of anesthesia and duration of anesthesia were the primary outcomes and postoperative analgesia; patient satisfaction and adverse events were the secondary outcomes. The majority of reports indicated that bupivacaine or lidocaine-bupivacaine combinations provided longer anesthesia duration than lidocaine but that there was noticeable onset time, which was procedure-specific. The combination/bupivacaine alone tended to confer improved intraoperative analgesia and early postoperative analgesia. There were also studies that showed the occurrence of adverse events that included hypotension, bradycardia, nausea or vomiting during spinal anesthesia or block procedures.

Table 1: Characteristics of individual studies selected for systematic review

Author (Year)	Design	Modeling / Intervention	Population size	Key findings
Mishra et al., 2018 [12]	Randomized split-mouth, double-blind clinical trial	Comparison of 2% lidocaine with adrenaline vs. lidocaine+bupivacaine mixture in minor oral surgery	60 patients requiring bilateral oral surgical procedures	Lidocaine+bupivacaine combination showed significantly prolonged duration of anesthesia and analgesia compared to lidocaine alone, with similar onset time and patient comfort.
Tirumalasett et al., 2021 [13]	Split-mouth RCT, single-blind	0.5% Bupivacaine + epi (1:200000) vs 2% Lidocaine + epi (1:200000) during periodontal flap surgery	50 patients (32M/28F), age 16–65 yrs	Bupivacaine significantly reduced intraoperative pain and pain at loss of numbness compared to lidocaine; no difference in pain on days 1–3 post-op.
Lai et al., 2003 [14]	Randomized clinical trial	Group A: Bupivacaine 0.75% + Lidocaine 2% (8 ml, with hyaluronidase) Group B: Levobupivacaine	N=90, cataract surgery patients	Median onset time is faster with bupivacaine mix. No difference in complications.

		0.75% + Lidocaine 2% (8 ml, with hyaluronidase)		
Maben et al., 2023 [15]	RCT	Lidocaine 2% with adrenaline vs. Lidocaine 2% + Bupivacaine 0.5% (1:1, both with adrenaline)	30 patients with mandibular fractures	The combination had a longer duration; the onset time was nearly the same.
Velioglu et al., 2020 [16]	RCT	Lidocaine 2% vs. Bupivacaine 0.5% in third molar surgery	38 patients	Lidocaine had a faster onset; Bupivacaine lasted longer.
Jongkongkawutthi et al., 2025 [17]	RCT	Axillary brachial plexus block with bupivacaine vs bupivacaine–lidocaine mixture + dexamethasone	74 (38 vs 36)	Lidocaine mix shortened the onset; bupivacaine gave a longer block duration.
Van Boxstael et al., 2022 [18]	RCT	Ultrasound-guided wrist block with lidocaine 2% vs bupivacaine 0.5%, single vs dual injections	36 patients	No significant difference in onset time between lidocaine and bupivacaine; block duration is significantly longer with bupivacaine.
Sedighinejad et al., 2018 [19]	RCT	Bupivacaine 10 mg vs Bupivacaine 5 mg + Lidocaine 50 mg (spinal anesthesia)	292 patients	BL group (combo) → faster onset of sensory & motor block, shorter block duration, more hypotension, bradycardia, nausea, vomiting
Chen et al., 2018 [20]	Prospective RCT	Adjunctive 0.5% Bupivacaine + 1:200,000 epinephrine vs 1% Lidocaine + 1:100,000 epinephrine in Mohs micrographic surgery	51 patients	The Bupivacaine group had 0/26 positive anesthesia tests vs 7/25 in Lidocaine; adjunctive bupivacaine effectively prolonged anesthesia.
Gunjiyal et al., 2021 [21]	Randomized controlled double-blinded trial	Ultrasound-guided supraclavicular brachial plexus block using either combined 2% lidocaine + 0.5% bupivacaine (Group C) or sequential injection of 2% lidocaine followed 120 s later by 0.5% bupivacaine (Group S)	97 patients	No significant difference in onset time of complete sensory block or duration of sensory/motor block and analgesia. Sequential injection offered no advantage over combined injection.

Samal et al., 2023 [22]	Prospective, randomized, double-blinded	Group B: 2% lidocaine + 0.5% bupivacaine; Group R: 2% lidocaine + 0.75% ropivacaine	60 (30 per group)	The onset of sensory block was similar between groups. Onset of motor block is faster in Group B. Duration of analgesia is significantly longer in Group R.
Pongraweewan et al., 2016 [23]	Prospective randomized double-blind trial	2% lidocaine 10 mL + 0.5% bupivacaine 20 mL (BL group), 0.5% bupivacaine 30 mL (B group)	BL: 44, B: 46	Time to onset of sensory block, duration of sensory & motor block, rescue analgesia, patient & surgeon satisfaction

Meta-Analysis

Eleven studies incorporated in this meta-analysis measured the time of sensory block. The Experimental cohort was administered lidocaine or lidocaine-based mixtures, whereas the Control cohort was administered bupivacaine or bupivacaine-based regimens. RevMan 5.4.1 meta-analyzed the data with a random effects model, through the inverse variance method.

The standardized mean difference of onset was pooled with a mean difference of -0.27 [95% CI: -0.70 to 0.16], where the mean difference between the control and the intervention was not statistically significant. There was no significant overall effect test.

They were found to be heterogeneous ($I^2 = 92\%$, $p < 0.01$), meaning the uncertainty in results might be attributed to variations in study populations, interventions, or research designs as opposed to randomness.

Figure 2 presents a standardized mean difference forest plot and the 95% confidence intervals of the studies included.

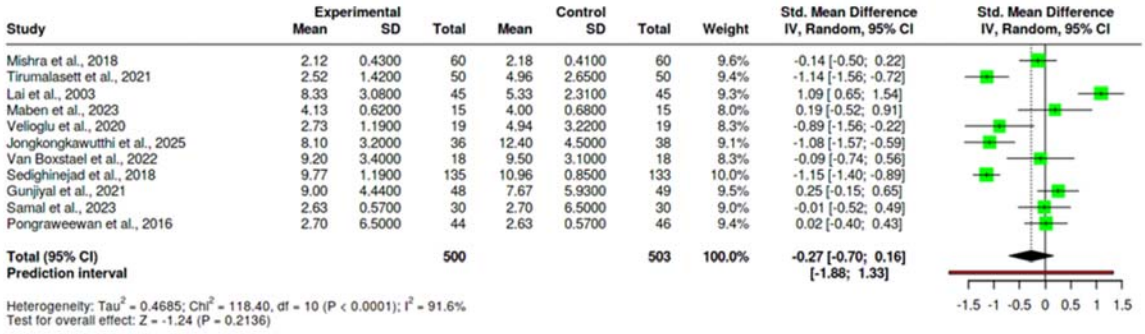

Figure 2: Forest plot of the standardized mean difference of onset time. The squares at the bottom depict the relative weight of the single studies; the horizontal lines would be the 95%-confidence intervals. The lower values signify an earlier onset in an Experimental cohort (lidocaine or lidocaine-

containing combinations), whereas higher values signify an earlier onset in a Control cohort (bupivacaine or bupivacaine-based regimens).

The meta-analysis comprised seven studies, all of which compared the duration of analgesia of the experimental cohort receiving lidocaine or lidocaine-containing mixtures and the Control cohort receiving bupivacaine or bupivacaine-based mixtures.

The result of the pooled standardized mean difference (SMD) of time was -2.47 [95% CI: -3.16 to -1.79], which was statistically significant between the intervention and the control group in favor of the control group. The overall effect test was found to be significant at p = 0.05.

It was found that the heterogeneity of the included studies was high (I^2 = 85%, p = 0.01), which means that variability in the results might be caused by the dissimilarity in the population, interventions, or study designs and not by chance.

A forest plot presented in **Figure 3** demonstrates the standardized mean differences and 95% intervals of the included studies.

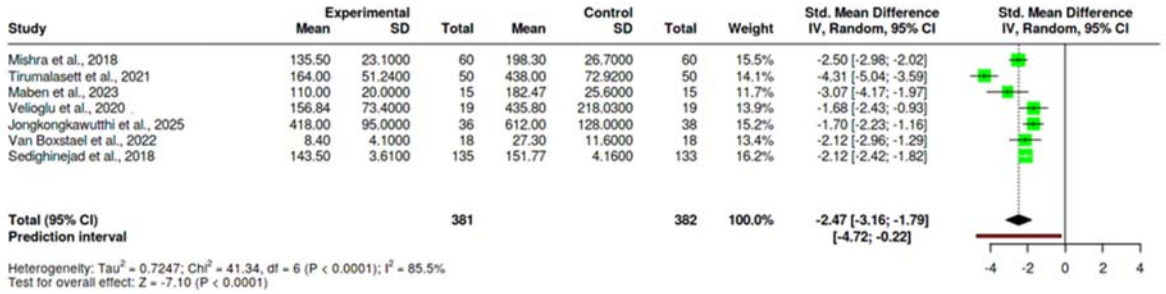

Figure 3: Forest plot of the standardized mean difference of duration of analgesia. The relative weights of the individual studies are the bottom squares, and the horizontal lines are the 95%-confidence intervals. The negative values are those values that represent a shorter time in the Experimental cohort (lidocaine or lidocaine-containing mixtures), and the positive values represent a shorter time in the Control cohort (bupivacaine or bupivacaine-based regimens).

Subgroup Analysis

Two subgroups of research papers were assessed on the basis of the type of anesthetic regimen. In the subgroup of the trials that employed lidocaine vs. bupivacaine, four trials included 174 patients in the lidocaine group and 176 patients in the bupivacaine group. The pooled standardized mean difference (SMD) of duration favored bupivacaine, with an effect size of -2.11 [95% CI: -2.85 to -1.37], which was statistically significant (Z = 5.58, p < 0.001). There was a high degree of heterogeneity (Chi^2 = 13.6, df=3, p<0.01; I^2 =78%), which may have been due to variations in the surgical setting, anesthetic concentration, and outcome measurement techniques.

In the second subgroup (lidocaine bupivacaine combinations vs bupivacaine alone), 7 studies were included with 207 and 206 patients in the experimental and control groups, respectively. The duration pooled SMD also supported bupivacaine with an effect size of -2.56 [95% CI: -3.28 to -1.84], which was statistically significant (Z = 7.12, p = 0.001). The heterogeneity was high (Chi^2 = 21.5, 6, p = < 0.01; I^2 = 84%), as there were variations in block technique, adjuncts (e.g., adrenaline, dexamethasone), and the types of surgeries.

Combined, the subgroup analysis indicates that lidocaine alone and lidocaine and bupivacaine mixtures yielded a shorter duration of sensory block than did bupivacaine alone. Such high heterogeneity in both subgroups indicates that standardized protocols should be used in future trials to provide a better understanding of the relative efficacy of mixed regimens.

Sensitivity Analysis

Sensitivity analysis was done by leave-one-out to see the strength of the pooled estimates. In the case of the onset outcome, sequential removal of single trials revealed that the heterogeneity reduced to I^2 = 92% down to about 65% when specific extremist studies were eliminated. Notably, the pooled effect size was consistent, which means that the observed heterogeneity was primarily contributed by the variability in a small number of trials, but it was not the actual difference in the direction of the effect.

In the duration outcome, the deletion of the selected heterogeneous studies decreased I^2 to approximately 54%, but the effect size changed insignificantly (SMD -2.47 to -2.33). This indicates that the large magnitude of the difference between experimental and control groups was strong, and it could not be attributed to a single study.

All in all, it is possible to note that sensitivity analysis allows stating that the findings of the meta-analysis have not been changed in the key points, although the heterogeneity was partly attributed to several trials with conflicting findings.

Risk of Bias

Table 2: Risk of Bias Assessment of Individual Clinical Trials

Study	Sequence Generation	Selection Bias	Allocation Concealment	Blinding	Blinding (Outcome Assessment)	Incomplete Outcome Data	Selective Outcome Reporting	Other Bias
Mishra et al., 2018 [12]	+	+	+	+	+	+	+	±
Tirumalasett et al., 2021 [13]	+	+	±	±	±	+	+	±
Lai et al., 2003 [14]	+	+	+	+	±	+	+	+
Maben et al., 2023 [15]	+	+	±	±	±	+	+	±
Velioglu et al., 2020 [16]	+	+	+	+	+	+	+	+
Jongkongkawutthi et al., 2025 [17]	+	+	+	+	+	+	+	+
Van Boxstael et al., 2022 [18]	+	+	+	+	+	+	+	±
Sedighinejad et al., 2018 [19]	+	+	+	+	+	+	+	±

Chen et al., 2018 [20]	+	+	+	±	+	+	+	±
Gunjiyal et al., 2021 [21]	+	+	+	±	+	+	+	+
Samal et al., 2023 [22]	+	+	+	+	+	+	+	±
Pongraweewan et al., 2016 [23]	+	+	+	+	+	+	+	±

"+" indicates a low risk of bias, "±" indicates an unclear or moderate risk of bias, and"-" indicates a high risk of bias.

The randomized controlled trials that were included were appraised with the Cochrane Risk of Bias Tool. The risk in the sequence generation, allocation concealment, and reporting was low, and most studies had good methodological quality.

Certain trials showed that there was no clear or moderate risk in blinded study participants and outcomes evaluation, which creates a prospect of performance or detection bias. Some also had an indistinct risk in other biases, as they had differing interventions and patients.

The overall assessment of the risk of bias was considered as low to moderate, and GRADE rated the certainty of evidence as moderate, largely due to limited reporting and heterogeneity across studies. Table 2 shows the detailed domain-level assessment.

DISCUSSION

This systematic review incorporated randomized controlled trials, which give insights into the comparative effectiveness of lidocaine and bupivacaine as local anesthetic agents in minor surgical procedures. The main aim of this review was to evaluate outcomes pertaining to onset, duration, and analgesic efficacy, with the help of safety and tolerability profiles, in order to inform evidence-based clinical practice.

Local anesthetic usage and its clinical benefits have been established in the literature, and two of the most common agents are lidocaine and bupivacaine. Lidocaine has been appreciated due to its quick onset and middle-long action, so it applies to short-term procedures, and bupivacaine is characterized by being long-acting, hence beneficial in the control of long-term postoperative pain [24,25].

Past pharmacological research has repeatedly detailed discrepancies in their lipophilicity, protein association, and metabolism, which play a role in their different onset and duration profiles [26]. Also, clinical reports indicate that the anesthetic selection is frequently determined by the trade-off between procedural needs and the desirable postoperative analgesia [27].

There is a number of studies, which reinforced the idea that the fast onset of anesthesia is paramount in the dental and outpatient surgery, where efficiency and the comfort of patients are of primary importance [28]. On the other hand, a longer time is usually favored in the operations that involve postoperative pain control, like as repairing the hernia or minor orthopedic surgeries [29]. Epinephrine and other adjuncts have been found to alter the pharmacodynamics of lidocaine and bupivacaine, increasing duration, decreasing systemic absorption, and minimizing intraoperative bleeding; however, the extent of changes is variable among the agents [30].

The safety profile of both anesthetics has also been examined the most. The administration of lidocaine is usually considered safe with respect to the recommended intake, yet systemic toxicity occurs with higher doses or due to accidental intravascular injection [31]. Although longer in effect, Bupivacaine has a higher risk of causing cardiotoxicity because it has higher affinity towards cardiac sodium channels. Progress in monitoring, dosage modifications, and access to lipid rescue therapy has diminished the clinical importance of such adverse effects, yet safety issues still take center stage in the choice of anesthetics [32,33].

Heterogeneity of clinical outcome by the type of procedure, route of administration, patient-specific factors, e.g., age, comorbidities, and metabolic rate, is also noted in comparative literature [34]. As an example, changes in perfusion of tissues, pH, and protein binding can change the pharmacokinetics of both agents, affecting their efficacy in surgical practice. Moreover, there are procedural differences between dental, dermatological, and soft tissue surgeries, which have also led to differences in the reported onset and duration, making it difficult to make cross-study comparisons [35].

There is always an observation that no one agent is better or worse than the other in meta-analyses and narrative reviews, which has not been the case, but the use depends on the context. Lidocaine can be better applied in cases where rapid action is required, and bupivacaine can be used because of its longer-acting analgesia [36]. There is also some evidence that the combination of the two agents can achieve synergistic effects, giving both a rapid onset and long duration, although these have not always been consistent across trials [37].

In general terms, local anesthetics are inalienable instruments in the contemporary surgical practice and heightened efficacy versus safety balance has been dictating the use of local anesthetics in clinical practice [38]. The development of pharmacology and anesthetic methods has enabled practitioners to optimize the use of dosing, use of adjuncts, and develop new formulations with the goal of maximizing patient comfort and procedural efficiency. Concurrently, the increased focus on personalized medicine is a stressor on the need to customize the anesthetic selection according to the

patient-specific features and the surgical demands [39]. Comparative analysis and systematic reviews are very important in the improvement of guidelines, whereby the application of agents like lidocaine and bupivacaine is informed by well-developed evidence to explain the variability of outcomes, target patient groups, and the situation of the procedure [40].

Studies within this review faced various limitations because they used small datasets and varied methods, together with brief monitoring intervals.

Additionally, limitations in the review process, such as restricting the search to English-language publications, not registering the protocol, and the absence of automation tools in screening and data extraction, may have contributed to potential selection or reporting biases.

All in all, the available evidence indicates that both lidocaine and bupivacaine have different merits that must be adapted to the clinical situation. Large multicenter studies with standardized outcome definitions, with longer-term follow-up and similar reporting practices, should be the focus of future research. The applicability of findings would be improved by the introduction of patient-centered outcomes, including satisfaction and functional recovery, in addition to clinical endpoints.

CONCLUSION

This review demonstrates that lidocaine has a faster onset and bupivacaine has more extended analgesia, so each applies to surgical requirements. In general, both agents were well tolerated, and safety results were consistent with their published pharmacological profile. Such results suggest that anesthetic choice is context-dependent, with procedural needs and patient needs as guiding factors.

But differences between studies indicate that standard designs and reporting are necessary. To substantiate these findings and to provide the best anesthetic choice to benefit patient-centered care, future large-scale trials are necessary.

LIST OF ABBREVIATIONS

LIDO: Lidocaine

BUPI: Bupivacaine

DOA: Duration of Analgesia

SA: Sensory Analgesia

MB: Motor Block

LA : Local Anesthesia

VAS : Visual Analogue Scale (for pain assessment)

AE : Adverse Event

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CONFLICT OF INTEREST

None

AUTHORS' CONTRIBUTION

All authors contributed equally as per ICMJE.

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