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Lesion Sterilization and Tissue Repair (LSTR) in Primary Teeth: A Narrative Review

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Abstract

Lesion sterilization and tissue repair (LSTR) is a minimally invasive endodontic technique that can help eliminate infection and promote natural healing in the dental and periapical tissues. This technique is based on the premise that polymicrobial root canal infections require broad-spectrum antimicrobial control, which is particularly important in primary teeth and anatomically challenging cases where traditional root canal instrumentation may be inadequate. The biological basis, evolution, antimicrobial agents, clinical procedures, outcomes, limitations, controversies, and future directions of LSTR are discussed. Current evidence suggests that LSTR may achieve good clinical and radiographic success in selected cases. However, antibiotic resistance, tooth discoloration, variations in protocols, and a lack of long-term data remain pertinent concerns. LSTR is a treatment option in pediatric endodontics; however, further studies are needed to standardize the protocol and establish its long-term benefits and safety.

Categories: Dentistry
Keywords: antimicrobial agents, clinical outcomes, lesion sterilization and tissue repair, lstr technique, pediatric endodontics

Introduction And Background

The objective of endodontic treatment of infected primary teeth is to control infection while maintaining tooth function until natural exfoliation [1]. The biologically based approach involving the local application of antibacterial medicaments is called lesion sterilization and tissue repair (LSTR). This approach requires minimal or no mechanical instrumentation to disinfect infected root canal tissues [2]. LSTR has recently been reported to yield good clinical and radiographic outcomes. However, variations in protocols and medicaments, as well as uncertainty regarding long-term outcomes, warrant further evaluation. Therefore, the biological basis, clinical applications, outcomes, limitations, controversies, and future directions of LSTR in primary teeth are of interest [3].

LSTR is fundamentally based on the biological principle that the body can repair its own damaged tissues if the infection can be effectively eradicated [4]. Root canal infections are polymicrobial, involving several bacterial species organized into complex and resilient biofilms. This microbial complexity contributes to the failure of antimicrobial therapy using a single agent in many cases [5].

To address this, LSTR uses a combination of antibiotics, usually metronidazole, ciprofloxacin, and minocycline [6]. Each antibiotic has an individual role, and their combination may provide a synergistic antimicrobial effect greater than that of any single drug alone [7]. This approach does not rely primarily on mechanical instrumentation but aims to reduce the microbial load to a level at which healing can occur [8].

Once the microbes have been controlled, the host response to the infection becomes a key factor influencing tissue repair [9]. Blood flow increases, inflammation decreases, and cells responsible for tissue repair, such as fibroblasts and osteoblasts, contribute to the regeneration of damaged tissues [10]. Bone regeneration and the healing of periapical lesions may occur naturally in a favorable healing environment [11].

This paradigm shift in endodontic philosophy is summarized by the principle that successful canal instrumentation is only part of the overall treatment process, whereas creating an environment conducive to healing is of greater importance [12].

With the accumulation of clinical evidence in recent years, the biological rationale for LSTR therapy and its effectiveness have been further substantiated [13].

Review

Antimicrobial agents used in LSTR

Endodontic infections are polymicrobial in nature and difficult to disinfect because microorganisms form complex biofilms and may persist within dentinal tubules, anatomical irregularities, and accessory canals, where they are less accessible to conventional chemomechanical procedures. Conventional chemomechanical preparation may not be sufficient to eliminate bacteria from dentinal tubules and anatomical irregularities. For this reason, LSTR is based on the local application of antimicrobial agents to reduce the microbial load while minimizing mechanical instrumentation. The composition of the antimicrobial combination, its formulation, and its method of application are crucial factors in determining the biological and clinical efficacy of the treatment [14].

Ciprofloxacin, a fluoroquinolone used in triple-antibiotic formulations for LSTR, is associated with musculoskeletal and other adverse effects when administered systemically to children. However, these risks cannot be directly extrapolated to local intracanal application because systemic exposure may differ. Evidence regarding the long-term safety of ciprofloxacin-containing LSTR formulations in primary teeth remains limited, warranting cautious use and further research.

The classic triple-antibiotic combination, known as 3-Mix, consists of metronidazole, ciprofloxacin, and minocycline. These agents were selected based on their complementary antimicrobial properties and their ability to combat a broad spectrum of microorganisms involved in endodontic infections. Metronidazole acts against anaerobic microorganisms by producing free radicals that damage microbial DNA. Ciprofloxacin inhibits bacterial DNA gyrase and topoisomerase IV, thereby interfering with bacterial DNA replication. Minocycline, a tetracycline derivative, inhibits bacterial protein synthesis by binding to the 30S ribosomal subunit. The combination therefore provides activity against a variety of bacterial groups that may coexist in infected primary teeth [15].

Other formulations are also being investigated. Clindamycin has been suggested as an alternative to minocycline because minocycline may cause intrinsic tooth discoloration. Ornidazole has also been suggested as an alternative to metronidazole. However, the use of these alternatives should be assessed based on their antimicrobial activity, drug compatibility, potential adverse effects, and the clinical characteristics of the tooth to be treated [16].

Composition and pharmacological characteristics of commonly used agents

The antimicrobial agents used in LSTR differ in their mechanisms of action and spectra of activity. Their principal characteristics are summarized in Table *1*.

Antimicrobial agent	Pharmacological class	Principal mechanism of action	Role in LSTR
Metronidazole	Nitroimidazole	Formation of reactive metabolites that damage bacterial DNA under suitable reducing conditions	Provides activity against susceptible anaerobic microorganisms
Ciprofloxacin	Fluoroquinolone	Inhibition of bacterial DNA gyrase and topoisomerase IV	Contributes activity against susceptible Gram-negative and other sensitive bacteria
Minocycline	Tetracycline derivative	Inhibition of protein synthesis through binding to the 30S ribosomal subunit	Provides broad antibacterial activity against susceptible microorganisms
Clindamycin	Lincosamide	Inhibition of protein synthesis through binding to the 50S ribosomal subunit	Alternative to minocycline in formulations intended to reduce the risk of discoloration
Ornidazole	Nitroimidazole	DNA damage following intracellular drug activation	Potential alternative to metronidazole for susceptible anaerobic microorganisms

TABLE 1: Principal antimicrobial agents used in LSTR

LSTR: lesion sterilization and tissue repair.

Preparation of the antibiotic paste

The composition of LSTR antibiotic pastes varies across published protocols. Some clinical studies have used ciprofloxacin, metronidazole, and minocycline in a 1:3:3 weight ratio, respectively, mixed with propylene glycol and polyethylene glycol to form a paste. Other protocols have used macrogol and propylene glycol as the vehicle (3Mix-MP). The exact vehicle volume and final drug concentrations should be reported for each

study when available, as these parameters cannot be assumed to be identical across formulations [17,18].

When preparing antibiotic paste, the physical properties of the antibiotics and the stability of the individual components must be taken into consideration. In the conventional preparation method, the tablets are crushed, and the contents of capsules, if any, are removed. Each antibiotic is then ground separately in a clean mortar and pestle. The powders are combined on a clean glass slab or mixing pad to obtain a uniform mixture. To prevent changes in the consistency of the components and facilitate mixing, the components should be kept dry during the preparation process [19].

An appropriate vehicle is then added to the antibiotic powder to form a paste. The physical properties of macrogol and propylene glycol make them suitable vehicles, as they facilitate paste formation and help distribute the medicament throughout the treated area. The choice of vehicle can influence the uniformity, handling characteristics, diffusion, and local availability of the antibiotics [20].

The medicament should be prepared using a controlled and reproducible technique. The formulation may vary according to the particle size of the powder, antibiotic dosage, vehicle, and mixing method. These parameters should therefore be reported in clinical research to improve reproducibility and facilitate comparisons between clinical treatment protocols [21].

Emerging single-agent alternatives

Growing concerns about antibiotic overuse have encouraged the investigation of alternative intracanal medicaments. Conventional antibiotic combinations have been studied, and single-agent therapies using moxifloxacin and nitrofurantoin are being investigated as alternatives. These strategies aim to simplify the formulation of the medicaments and may help reduce exposure to multiple antibiotics. However, these agents require evaluation in well-designed clinical studies to establish their efficacy and safety in LSTR. Currently, there is insufficient evidence to conclude that a single agent is equivalent to triple-antibiotic paste in all cases [22].

Clinical procedure and treatment protocols

The primary indications for LSTR are selected primary teeth with pulpal necrosis and associated infection in which tooth preservation is desired. The use of LSTR should be guided by the degree of tooth destruction, restorability, periradicular or furcal pathology, physiological stage of root resorption, and expected duration of function of the primary tooth [23]. Clinical procedures generally include local anesthesia, isolation using a rubber dam, caries removal, and access to the pulp chamber. Necrotic or infected coronal tissue is removed, and mechanical instrumentation of the canals is minimized or avoided, depending on the protocol. Irrigation may be performed using saline, sodium hypochlorite, or chlorhexidine. The antimicrobial properties, tissue effects, and compatibility with the treatment should all be considered when selecting the irrigant [24].

The antibiotic medicament is then placed in the pulp chamber or at the canal orifices, according to the protocol, after the infected tissue has been removed and the operative field has been appropriately managed. The cavity is then filled with a restorative material to minimize microleakage and prevent reinfection. A stainless steel crown may be used as the definitive restoration in molars with substantial structural requirements [25].

The clinical protocols reported in the literature vary among studies. Differences exist in the choice of medicament and irrigation solution, degree of instrumentation, and restorative technique [26]. Some protocols use a mixture of metronidazole, ciprofloxacin, and minocycline, with propylene glycol and/or macrogol as vehicles. After access preparation and removal of infected tissue, the medicament is placed on the pulp floor or in the pulp chamber. The cavity is then sealed with a suitable restorative material. Follow-up examinations are required to assess the symptomatic response, radiographic changes, and maintenance of function of the treated tooth [27].

Variations in Reported Clinical Protocols

In pediatric dental treatment, the treatment protocol must also be adapted to the child's age, cooperation, and behavior. Treatment can be facilitated through behavior guidance approaches, such as tell-show-do, and other appropriate nonpharmacological techniques. Patient comfort and infection control remain essential, particularly with regard to local anesthesia and effective isolation. After medicament placement, an adequate coronal seal is essential to prevent reinfection and help maintain the tooth over the long term [28].

General Steps in LSTR

Single-visit versus multiple-visit protocols: LSTR may be performed using single-visit or multiple-visit protocols, depending on the treatment approach and clinical presentation. In a single-visit approach, the

medicament is placed in the prepared pulp chamber or root canals, followed by an appropriate coronal restoration. Multiple-visit approaches may involve temporary sealing and reassessment before definitive restoration, depending on the selected protocol and clinical findings. However, the number of visits is not universally standardized, and the treatment duration should be reported according to the protocol used in each study. Long-term clinical and radiographic follow-up remains essential for evaluating treatment success.

The principal stages of a typical LSTR procedure are summarized in Table 2. The precise sequence may vary according to the selected medicament and clinical protocol.

Stage	Clinical consideration
Case selection	Assess restorability, pulpal status, infection, root resorption, and the expected lifespan of the primary tooth
Anesthesia and isolation	Administer local anesthesia and establish rubber dam isolation
Access and caries removal	Remove carious tissue and gain access to the pulp chamber
Removal of infected tissue	Remove accessible necrotic or infected coronal tissue while preserving sound tooth structure
Irrigation	Use the irrigant specified by the treatment protocol, considering antimicrobial efficacy and tissue safety
Limited instrumentation	Minimize or omit mechanical canal instrumentation when indicated by the LSTR approach
Medicament placement	Place the selected antibiotic formulation in the pulp chamber or at the canal orifices
Coronal sealing	Seal the access cavity with an appropriate restorative material to limit microleakage
Definitive restoration	Restore the tooth to provide structural protection and maintain function
Follow-up	Conduct clinical and radiographic assessments to evaluate treatment response

TABLE 2: General clinical stages of lesion sterilization and tissue repair (LSTR)

Clinical outcomes and success of LSTR in pediatric dentistry

The physiological, anatomical, and behavioral differences between children and adults affect the management of infected primary teeth. Primary molars undergo physiological root resorption and have complex root canal anatomy, which can make conventional instrumentation and irrigation difficult. The challenges associated with prolonged endodontic treatment may be further compounded by fear, anxiety, short attention spans, and limited cooperation. Preserving an infected primary tooth until its natural exfoliation is essential for maintaining mastication, arch integrity, and normal dentition development [29].

LSTR has been proposed as a minimally invasive alternative to conventional pulpectomy in selected pediatric cases. Clinical effectiveness is generally assessed based on both clinical and radiographic outcomes. Clinically, the treated tooth should be free of pain, swelling, abscess, sinus tract, and pathological mobility. Radiographic evaluation may include the resolution or reduction of furcal and periradicular radiolucency and, when appropriate, continued root development or physiological resorption of the treated tooth [30].

Clinical and radiographical outcomes of LSTR

Systematic reviews have reported good short-term outcomes for LSTR, with some demonstrating favorable clinical and radiographic results at follow-up periods of 6-18 months. Some reviews have also suggested that LSTR may achieve outcomes comparable to those of conventional pulpectomy in selected cases. However, comparisons among studies are challenging because of differences in case selection, antibiotic formulations, restorative techniques, follow-up periods, and outcome definitions [31].

The reported clinical effectiveness of LSTR has also been attributed to the antimicrobial action of the medicament, which may help reduce the bacterial load in infected primary teeth. However, the relationship between antimicrobial activity and clinical healing is complex. Tooth restorability, the stage of root resorption, the quality of the coronal seal, and the severity of the pre-existing infection may all influence the final outcome [32].

Factors influencing treatment success

The clinical outcomes of LSTR may be influenced by patient-related, tooth-related, procedural, and restorative factors. A retrospective investigation using the Frankl Behavior Scale reported that treatment

success was not significantly associated with the child's level of cooperation. This finding suggests that the minimally invasive nature of LSTR may be beneficial for pediatric patients who are difficult to manage during lengthy procedures. However, behavior should still be considered during case selection and treatment planning [33]. The major factors that may influence LSTR outcomes are summarized in Table *3*.

Factor	Potential influence on treatment outcome
Case selection	Restorability, extent of infection, and physiological root resorption may affect prognosis
Tooth anatomy	Complex canal morphology may limit access to infected tissues and influence disinfection
Medicament formulation	Antibiotic selection, concentration, ratio, and vehicle may affect antimicrobial performance
Preoperative infection	The severity and distribution of infection may influence the likelihood of healing
Irrigation and tissue removal	Appropriate removal of accessible infected tissue and use of an appropriate irrigant may reduce microbial burden
Coronal seal	Inadequate sealing may permit microleakage and reinfection
Definitive restoration	Structural protection and restoration quality may influence tooth retention
Patient cooperation	Cooperation may affect treatment delivery, although minimally invasive protocols may reduce procedural burden
Follow-up duration	Short-term improvement may not predict long-term tooth survival or radiographic healing
Outcome definition	Differences in clinical and radiographic success criteria may affect comparisons across studies

TABLE 3: Factors potentially influencing the clinical and radiographic outcomes of lesion sterilization and tissue repair (LSTR)

Strengths and weaknesses of LSTR

There are several potential benefits of LSTR in pediatric endodontics. The reduced need for instrumentation may help preserve tooth structure and decrease the procedural burden associated with conventional pulpectomy. The technique may also be beneficial in cases involving complex root canal morphology, thin dentinal walls, or anatomical features that hinder instrumentation in primary molars. Additionally, some LSTR procedures may be shorter or less technically demanding, potentially making them beneficial for treating younger or anxious children [34].

However, LSTR has several important limitations. The evidence base comprises studies with varying treatment protocols, antimicrobial combinations, restorative methods, and follow-up periods. These differences make it difficult to determine whether observed variations in success rates are attributable to the medicament, clinical technique, tooth characteristics, or differences in study design [35].

Concerns associated with antibiotic use also apply to LSTR. The use of multiple antibiotics may contribute to antimicrobial resistance, and adverse effects, such as tooth discoloration associated with minocycline-containing formulations, remain concerns. Alternative medicaments have been proposed, but their efficacy and safety require evaluation in clinical trials. Furthermore, reduced mechanical instrumentation does not eliminate the need for appropriate case selection, effective infection control, and an adequate coronal seal [36].

Table *4* summarizes the main benefits and limitations of LSTR.

Potential advantages	Important limitations
Minimizes or avoids extensive mechanical instrumentation	Does not guarantee complete elimination of microorganisms
May preserve tooth structure	Effectiveness may vary with anatomy, infection severity, and case selection
May reduce treatment complexity and procedural burden	Protocols differ in medicament composition, preparation, and placement
May be useful for selected primary teeth with complex canal anatomy	Long-term comparative evidence remains limited
May be suitable for selected patients with limited cooperation	Antibiotic exposure raises concerns regarding resistance and adverse effects
May support preservation of a restorable primary tooth	Adequate coronal sealing and definitive restoration remain essential
May provide favorable short-term clinical outcomes	Heterogeneous outcome definitions limit comparisons between studies

TABLE 4: Potential advantages and limitations of lesion sterilization and tissue repair (LSTR) in pediatric dentistry

Contraindications and case selection

LSTR may be unsuitable for non-restorable teeth, teeth with extensive pathological root resorption, or cases in which the infection cannot be adequately controlled. Other considerations include extensive supporting-tissue destruction, an unfavorable prognosis, and the inability to achieve an adequate coronal seal or ensure appropriate follow-up. Careful clinical and radiographic assessment is therefore essential, and alternative treatment options should be considered when the tooth cannot be predictably retained. These considerations should be evaluated in accordance with established pediatric dental guidelines and the individual clinical presentation.

Evidence gaps and future research

LSTR has demonstrated favorable clinical outcomes in selected pediatric patients; however, several questions remain unanswered. Further research is warranted, particularly well-designed randomized controlled trials comparing standardized LSTR protocols with conventional pulpectomy and other established treatment options. Such studies should clearly describe the inclusion criteria, antimicrobial formulations, irrigation protocols, restorative procedures, and clinical and radiographic outcome measures.

The importance of long-term follow-up should also be emphasized, as short-term symptom resolution does not necessarily indicate complete radiographic healing or long-term tooth retention. Future investigations should also assess the effects of different antibiotic combinations, single-agent alternatives, drug concentrations, and vehicles on treatment outcomes. In addition to clinical effectiveness, the potential for antimicrobial resistance, adverse effects, and tooth discoloration should be evaluated.

Standardization of treatment protocols and outcome definitions would improve comparability among studies and strengthen the evidence base. Until more robust evidence becomes available, LSTR should be considered an alternative to conventional pulpectomy only in carefully selected cases.

Conclusions

LSTR is a conservative treatment approach for selected teeth with infection. It is based on the biological principle of using locally applied antimicrobial agents to help control infection while minimizing mechanical instrumentation. The available literature has reported favorable short-term clinical and radiographic outcomes, and comparative data suggest that LSTR may be a viable alternative to conventional treatment in appropriately selected patients. However, the evidence remains inconclusive in some areas because of variations in antimicrobial formulations, treatment protocols, case selection, and follow-up periods. Further standardized, high-quality clinical research is needed to better establish its long-term efficacy, safety, and role in pediatric endodontic treatment.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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