Flexible Laryngoscopy in Resource-Limited Settings: A Review and Low-Cost Prototype Proposal

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INTRODUCTION

Flexible laryngoscopes (FLs) are the standard of care for **visualization of the nose, throat and airway**, areas that are otherwise difficult to examine.

Limited access to FLs and other essential otolaryngologic resources in low-middle-income countries (LMICs) contributes to a notable global burden of unmet ENT care.

The availability of a **low-cost, durable, reusable** FL that meets cleaning standards, provides clear visualization and enables anesthesia-free diagnostics could improve access to ENT care in resource-limited settings.

METHODS

SYSTEMATIC REVIEW

A systematic review following PRISMA guidelines was conducted to assess current designs, materials, and availability of FLs used in low-resource settings.

PubMed and ScienceDirect were searched from January 2016 to December 2024. Inclusion criteria:
- Studies evaluating availability of otolaryngologic services, procedures, and laryngoscopes
- Low-middle-income countries as defined by the World Bank utilizing gross national income (GNI)

PROTOTYPE DEVELOPMENT

Findings from the review, market analysis and practicing otolaryngologist input informed design requirements emphasizing **affordability, usability, safety, ergonomics and disinfection compatibility.**

Components were designed using CAD, with selected components 3D-printed using PLA and others commercially sourced or custom manufactured. The prototype was iteratively refined through functionality testing and clinician feedback.



Figure 1: *CAD Exploded Assembly*

RESULTS

17
articles included in the systematic review

11
studies identified financial barriers to ENT care

$170
prototype material cost vs ~$2,000 to $10,000 commercial

SYSTEMATIC REVIEW: Included studies highlighted limited availability of affordable otolaryngologic visualization methods in LMICs, supporting the need for improved access to FL.

PROTOTYPE DEVELOPMENT: A fully functional, high-fidelity FL prototype was developed, prioritizing affordability, durability, visualization and flexibility.



Figure 2: *High-Fidelity Prototype*

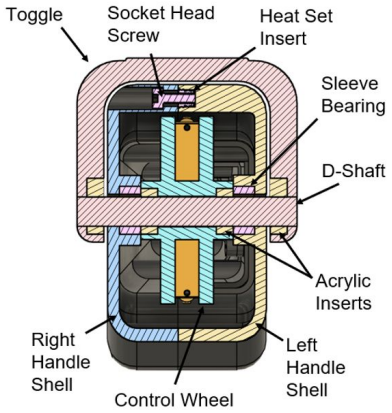


Figure 3: *Ergonomic Handle/Control Mechanism*

ERGONOMIC HANDLE: The 3D-printed PLA handle incorporates a **45° dual-directional toggle** that provides **110° dual-directional bending** of the distal tip. Sleeve bearings with a D-shaft support smooth rotation and improve mechanical durability.

BENDING MECHANISM: The distal tip consists of wire EDM-cut steel links, crimped together, and angulation wires to provide controlled 110° bending in two directions. The mechanism was designed to maintain user articulation and securely hold position during use.

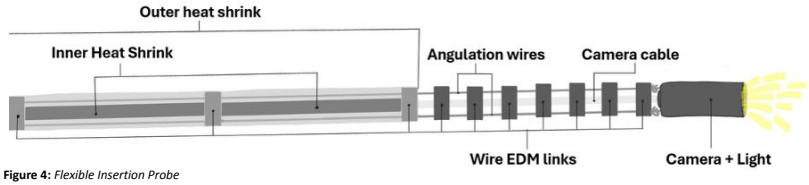


Figure 4: *Flexible Insertion Probe*

IMAGING SYSTEM: A **3.9mm waterproof CMOS camera** provides 1280✕720 resolution at 30 fps for real-time visualization and identification of pertinent anatomical structures.

DISCUSSION

The successful development of a high-fidelity, low-cost, flexible laryngoscope suggests feasibility of reducing a major barrier to ENT care in LMICs. With a material cost of approximately $170, the prototype represents a substantial reduction compared with commercial FLs, potentially improving access in resource-limited settings.

The prototype incorporates affordability, ergonomic design, visualization and durability while maintaining essential FL functionality. **Materials were selected for water and chemical resistance to support compatibility with standard high-level disinfection protocols.** Its modular design provides a foundation for continued refinement and scalability.

Clinical validation and further performance testing are needed. Future work should evaluate device reliability and clinical usability through structured feedback and testing, with a focus on optimizing the mechanical robustness of the distal bending tip.

Ultimately, continued refinement may support development of a **scalable, reusable FL platform** for resource-limited settings.

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