Accessible materials for simulating cataract surgery: Development of a sustainable phacoemulsification training module using agarose and gelatin

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Background:

- Cataracts are the leading cause of blindness worldwide
- Cataract surgery is challenging and difficult to simulate
- Training models are largely restricted to cadaveric eyes (wet lab) and virtual reality, access to which are limited by both cost and available facilities

Table 1. Comparison of Current Simulation Strategies

Strategy	Pros	Cons
Virtual Reality Total Studies: 36	• Performance metrics • Repeatable & engaging	• Cost limits access • Physical side effects
Wet Lab Total Studies: 19	• Easily accessible • Provides physical feedback	• Long set-up time • Limited Shelf-life
Dry Lab Total Studies: 2	• Lower cost & easy access • Easy set-up for practice	• Challenging to design • Fidelity may be variable

Purpose:

- Support underfunded training programs through development of a low-cost, accessible and sustainable lens and eye module for simulation of cataract surgery

Materials and Methods:

- Literature search (PubMed, Embase, Metadex) of lens mechanical properties (Young's/Elastic Modulus, Shear Modulus, Bulk Modulus, Hardness, Toughness)
- Evaluate novel materials for lens simulation using the following criteria: (1) Cost < 1$/lens; (2) access in-store or online (3) total preparation time < 10 minutes
- Materials meeting criteria were tested for content validity
- The compatible cataract simulator prototype was designed in Fusion 360 and 3D printed using the Anycubic i3 Mega X

Results:

Based on published literature, a total of 10 research articles were identified which provided the Young's modulus of the lens. The value ranged between 0.8×10^{-6} GPa and 5×10^{-1} GPa based on the age and extent of the cataract formation

Table 2. Materials Evaluation For Lens (N = 20)

Material	Cost per Lens	Accessibility	Prep Time < 10 mins	Biodegradable*
Gelatin	$0.08	Online & Retail	✓	Yes
Agarose	$0.24	Online - General	✓	Yes
Calcium Alginate	$0.06	Online - General	✗	Yes
Silicone Resin	$0.06	Online - General	✗	No
Polypropylene Pellet	$0.01	Online - General	✗	No
Fluorinated Ethylene Propylene	$0.02	Online - Specialty	✗	No
Ultra High Molecular Weight Polyethylene	$0.04	Online - General	✗	No
Polycaprolactone	$0.55	Online - Specialty	✗	Yes
High Density Polyethylene	$0.02	Online - General	✗	No
Low-Density Polyethylene	$0.03	Online - Specialty	✗	No
Polyvinyl Alcohol	$0.15	Online - General	✗	Yes
Polyvinyl Chloride, Powder	$0.24	Online - Specialty	✗	No
Polymethylpentene	$0.20	Online - Specialty	✗	No
Ethylene Vinyl Acetate	$0.02	Online - General	✗	No
PDMS Silicone	$0.05	Online - General	✗	No
Encapso-k	$0.06	Online - Specialty	✗	No
Polyacrylamide Resin	$0.25	Online - Specialty	✗	No
Cellulose Acetate Butyrate	$0.40	Online - Specialty	✗	Yes
Polytetrafluoroethylene	$0.26	Online - Specialty	✗	No
Cellulose Propionate	$1.20	Online - Specialty	✗	Yes

*Biodegradability does not necessarily mean that the material will completely disappear in the environment or that the degradation products will not have any negative impacts.


Fig 1. Agarose Lens


Fig 2. Gelatin Lens


Fig 3. Fusion 360 Model

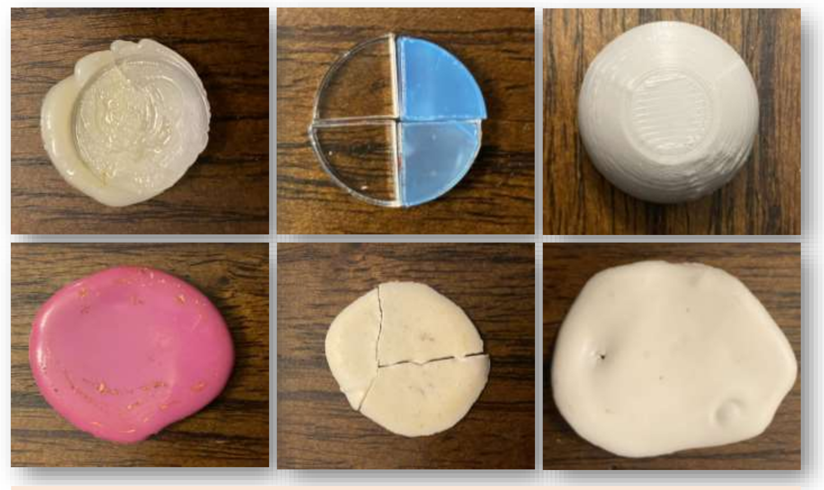
Fig 4. Other Lens Material

Conclusions:

- This work identified agarose and gelatin as low-cost and accessible materials to simulate cataract surgery
- Both materials are reusable and biodegradable
- Future analysis will include broader testing by Ophthalmology trainees across Canada

References