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TITLE: Intraocular Microdisplay Projection for Vision Restoration After Corneal Blindness

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13. SUPPLEMENTARY NOTES

14. **ABSTRACT: The cornea is the front clear window into the eye through which light must pass in order for the eye to see. Because of its location at the front of the eye it is the most exposed structure to military relevant trauma such as blast, chemical, and thermal injury. About 36% of eye injuries in Operation Iraqi and Enduring Freedom involved the cornea. Future beam weapons such as infrared and UV lasers, and microwaves will be primarily absorbed by the cornea when hitting the eye. When the cornea is injured and blood vessels grow onto the cornea, there is currently no effective treatment because corneal transplantation (replacing the cornea with a cornea from a deceased donor) does not work in this situation due to high risk of rejection. Plastic buttons placed into the cornea have been performed but these are exposed to the external environment and are at high risk of infection and other complications such as falling out. In addition to disease, there are thousands of patients who suffer corneal injuries in work related accidents. Due to the industrial nature of many ocular chemical and thermal burns, corneal injury disproportionately affects those in the prime of their life. Lastly, 12.7 million people around the world are unable to obtain corneas for transplantation due to a shortage of donors. Building on the most recent developments in state-of-the-art high-resolution small display technology we have created a tiny projector (like a movie projector) that can be implanted into the eye (intraocular) of these patients. The device can wirelessly receive video data and power from a camera and processor positioned upon the frame of a pair of glasses. A lens focuses the image onto the retina. This in effect will place a miniature movie projector inside the eye, so that the patient will be able to see a projected image even with a completely scarred cornea or even if the eyes are closed. This design is superior to currently used devices because it is completely covered and not exposed to infection and it does not require cornea tissue to be collected from donors. The risks of our implant are that it may become dislocated or there may be leakage of liquid around the cable. Both of these can be fixed with further surgery. We have demonstrated prototypes of this device and discussed our published findings that this is a feasible technology. In this study we propose to test this type of device in animals.**

15. SUBJECT TERMS NONE LISTED

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			USAMRDC
Unclassified	Unclassified	Unclassified	Unclassified	14	19b. TELEPHONE NUMBER *(include area code)*

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1. **INTRODUCTION:** *Narrative that briefly (one paragraph) describes the subject, purpose and scope of the research.*

This project seeks to build and test 15 intraocular projection devices, then perform their implantation and observe their function in living rabbits. This device is the basis of a new way of treating corneal blindness and is free from the limitations of traditional methods. It also forms the basis of possible vision enhancing technology with military applications. Successful demonstration in rabbits validates the technology.

2. **KEYWORDS:** *Provide a brief list of keywords (limit to 20 words).*

Cornea, blindness, display, transplant, vision, wireless, projection, LED, LCD, keratoprosthesis

3. **ACCOMPLISHMENTS:** *The PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency grants official whenever there are significant changes in the project or its direction.*

What were the major goals of the project?
List the major goals of the project as stated in the approved SOW. If the application listed milestones/target dates for important activities or phases of the project, identify these dates and show actual completion dates or the percentage of completion.

Year 3 of this project is completion of implantation in 15 rabbits. It is covered by

Mile Stone 5: implantation of 15 animals	Month 25	Dr. Yu
Subtask 2: Weekly examination and monthly VEP vision testing	Months 13-31	Dr. Yu Dr. Palanker
Major Task 2: Histology		
Subtask 1: Eye removal and histological examination	Months 30 to end	Dr. Yu
Milestone 6: histologic analysis of 30 eyes (15 test, 15 control).	Month 34	Dr. Yu

Due to delays related to pandemic restrictions and design changes, we obtained a 1 year no cost extension to complete with this project.
Thus, we completed milestone 5 May 11 or Month 30 vs planned month 25 in the original schedule.
Subtask 2 is ongoing.
Mile stone 6 remains to be completed later this year.

What was accomplished under these goals?
For this reporting period describe: 1) major activities; 2) specific objectives; 3) significant results or key outcomes, including major findings, developments, or conclusions (both positive and negative); and/or 4) other achievements. Include a discussion of stated goals not met. Description shall include pertinent data and graphs in sufficient detail to explain any significant results achieved. A succinct description of the methodology used shall be provided. As the project progresses to completion, the emphasis in reporting in this section should shift from reporting activities to reporting accomplishments.

In this third year of the project:

1) Major activities are implantation of animals and observing them during the trial. Also, there is sacrifice and histology analysis after completing their 6 months trial periods.
2) Specific activities: rabbit surgeries and projector implantation of last 6 animals, now 15 total. Now 11 of 15 rabbits have completed trial and been sacrificed. Their eyes are undergoing histologic study. 4 remain in the in vivo study.
3) Significant results: are successful implantation of remaining 6 animals thus far with limited complications (1 case of lens opacification in this batch). Histology study shows normal appearance of intraocular structures such as retina, optic nerve, and cornea.
4) Other accomplishments: nothing to report

Figures demonstrating work this year are below.

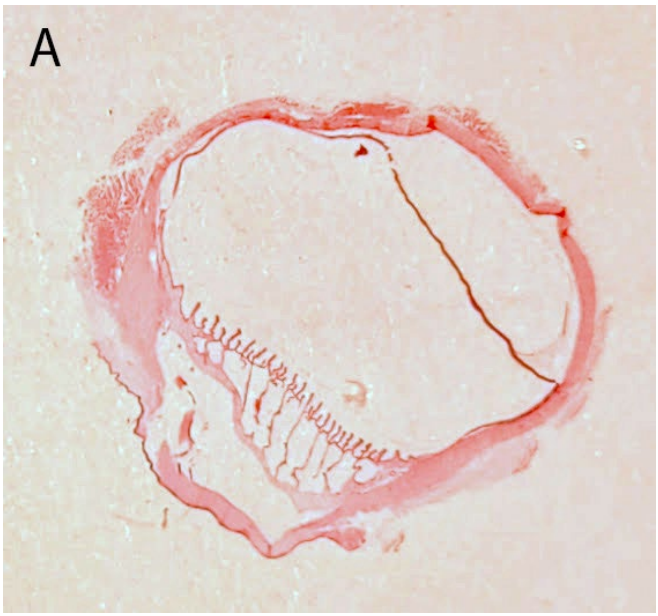

Figure A. Histology of implanted rabbit eye after excision demonstrating intact and normal appearing intraocular structures.

Figure B. Rabbit with implant at approximately 3 months. Iris irregularity is demonstrated.

What opportunities for training and professional development has the project provided?
If the project was not intended to provide training and professional development opportunities or there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe opportunities for training and professional development provided to anyone who worked on the project or anyone who was involved in the activities supported by the project. "Training" activities are those in which individuals with advanced professional skills and experience assist others in attaining greater proficiency. Training activities may include, for example, courses or one-on-one work with a mentor. "Professional development" activities result in increased knowledge or skill in one's area of expertise and may include workshops, conferences, seminars, study groups, and individual study. Include participation in conferences, workshops, and seminars not listed under major activities.

Nothing to report

How were the results disseminated to communities of interest?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe how the results were disseminated to communities of interest. Include any outreach activities that were undertaken to reach members of communities who are not usually aware of these project activities, for the purpose of enhancing public understanding and increasing interest in learning and careers in science, technology, and the humanities.

We have been accepted for an abstract for presentation at the MHSRS, pending presentation next month

What do you plan to do during the next reporting period to accomplish the goals?
If this is the final report, state "Nothing to Report."

Describe briefly what you plan to do during the next reporting period to accomplish the goals and objectives.

We will complete implantation and analysis of implants and eyes.

4. **IMPACT:** D*escribe distinctive contributions, major accomplishments, innovations, successes, or any change in practice or behavior that has come about as a result of the project relative to:*

What was the impact on the development of the principal discipline(s) of the project?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe how findings, results, techniques that were developed or extended, or other products from the project made an impact or are likely to make an impact on the base of knowledge, theory, and research in the principal disciplinary field(s) of the project. Summarize using language that an intelligent lay audience can understand (Scientific American style).

Nothing to report

What was the impact on other disciplines?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe how the findings, results, or techniques that were developed or improved, or other products from the project made an impact or are likely to make an impact on other disciplines.

Nothing to report

What was the impact on technology transfer?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe ways in which the project made an impact, or is likely to make an impact, on commercial technology or public use, including:

- *transfer of results to entities in government or industry;*
- *instances where the research has led to the initiation of a start-up company; or*
- *adoption of new practices.*

Nothing to report

What was the impact on society beyond science and technology?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe how results from the project made an impact, or are likely to make an impact, beyond the bounds of science, engineering, and the academic world on areas such as:

- *improving public knowledge, attitudes, skills, and abilities;*
- *changing behavior, practices, decision making, policies (including regulatory policies), or social actions; or*
- *improving social, economic, civic, or environmental conditions.*

Nothing to report

5. CHANGES/PROBLEMS: *The PD/PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency grants official whenever there are significant changes in the project or its direction. If not previously reported in writing, provide the following additional information or state, "Nothing to Report," if applicable:*

As described above we have received 1 year extension with written approval due to delay in surgeries.

Actual or anticipated problems or delays and actions or plans to resolve them
Describe problems or delays encountered during the reporting period and actions or plans to resolve them.

Nothing to report.

Changes that had a significant impact on expenditures

Describe changes during the reporting period that may have had a significant impact on expenditures, for example, delays in hiring staff or favorable developments that enable meeting objectives at less cost than anticipated.

Nothing to report

Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Describe significant deviations, unexpected outcomes, or changes in approved protocols for the use or care of human subjects, vertebrate animals, biohazards, and/or select agents during the reporting period. If required, were these changes approved by the applicable institution committee (or equivalent) and reported to the agency? Also specify the applicable Institutional Review Board/Institutional Animal Care and Use Committee approval dates.

Significant changes in use or care of human subjects

None

Significant changes in use of biohazards and/or select agents

None

6. **PRODUCTS:** *List any products resulting from the project during the reporting period. If there is nothing to report under a particular item, state "Nothing to Report."*

- **Publications, conference papers, and presentations**
  Report only the major publication(s) resulting from the work under this award.

  Journal publications. *List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Identify for each publication: Author(s); title; journal; volume: year; page numbers; status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

  None

  h, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like. Identify for each one-time publication: author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (e.g., book, thesis or dissertation); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

  None

  Other publications, conference papers and presentations. *Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication as noted above. List presentations made during the last year (international, national, local societies, military meetings, etc.). Use an asterisk (*) if presentation produced a manuscript.*

  Yu CQ. Long Term Stability of Intraocular Implanted Electronics. MHSRS 2022

- **Website(s) or other Internet site(s)**
  List the URL for any Internet site(s) that disseminates the results of the research activities. A short description of each site should be provided. It is not necessary to include the publications already specified above in this section.

  https://yulab-stanford.github.io/people/ - github lab website for PI

- **Technologies or techniques**
  Identify technologies or techniques that resulted from the research activities. Describe the technologies or techniques were shared.

  None

- **Inventions, patent applications, and/or licenses**
  Identify inventions, patent applications with date, and/or licenses that have resulted from the research. Submission of this information as part of an interim research performance progress report is not a substitute for any other invention reporting required under the terms and conditions of an award.

  None

- **Other Products**
  Identify any other reportable outcomes that were developed under this project. Reportable outcomes are defined as a research result that is or relates to a product, scientific advance, or research tool that makes a meaningful contribution toward the understanding, prevention, diagnosis, prognosis, treatment and /or rehabilitation of a disease, injury or condition, or to improve the quality of life. Examples include:
  - *data or databases;*
  - *physical collections;*
  - *audio or video products;*
  - *software;*
  - *models;*
  - *educational aids or curricula;*

- *instruments or equipment;*
- *research material (e.g., Germplasm; cell lines, DNA probes, animal models);*
- *clinical interventions;*
- *new business creation; and*
- *other.*

None

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Provide the following information for: (1) PDs/PIs; and (2) each person who has worked at least one person month per year on the project during the reporting period, regardless of the source of compensation (a person month equals approximately 160 hours of effort). If information is unchanged from a previous submission, provide the name only and indicate "no change".

Name: Daniel Palanker
Research Role: Co Investigator
Research ID: 2-0480-3025 ORCID
Person Months worked – 1.20 calendar months
Contribution to Project: advising on rabbit electrophysiology

Name: Charles Yu
Research Role: PI
Research ID: 1-8095-2930 ORCID
Person Months worked – 3.00 calendar months

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

If the active support has changed for the PD/PI(s) or senior/key personnel, then describe what the change has been. Changes may occur, for example, if a previously active grant has closed and/or if a previously pending grant is now active. Annotate this information so it is clear what has changed from the previous submission. Submission of other support information is not necessary for pending changes or for changes in the level of effort for active support reported previously. The awarding agency may require prior written approval if a change in active other support significantly impacts the effort on the project that is the subject of the project report.

None

What other organizations were involved as partners?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe partner organizations – academic institutions, other nonprofits, industrial or commercial firms, state or local governments, schools or school systems, or other organizations (foreign or domestic) – that were involved with the project. Partner organizations may have provided financial or in-kind support, supplied facilities or equipment, collaborated in the research, exchanged personnel, or otherwise contributed.

Provide the following information for each partnership:
<u>Organization Name:</u>
<u>Location of Organization: (if foreign location list country)</u>
<u>Partner's contribution to the project</u> (identify one or more)

- *Financial support;*
- *In-kind support (e.g., partner makes software, computers, equipment, etc., available to project staff);*
- *Facilities (e.g., project staff use the partner's facilities for project activities);*
- *Collaboration (e.g., partner's staff work with project staff on the project);*
- *Personnel exchanges (e.g., project staff and/or partner's staff use each other's facilities, work at each other's site); and*
- *Other.*

Nothing to report

8. SPECIAL REPORTING REQUIREMENTS

COLLABORATIVE AWARDS: *For collaborative awards, independent reports are required from BOTH the Initiating Principal Investigator (PI) and the Collaborating/Partnering PI. A duplicative report is acceptable; however, tasks shall be clearly marked with the responsible PI and research site. A report shall be submitted to* ***https://ers.amedd.army.mil*** *for each unique award.*

QUAD CHARTS: *If applicable, the Quad Chart (available on https://www.usamraa.army.mil) should be updated and submitted with attachments.*

9. APPENDICES: *Attach all appendices that contain information that supplements, clarifies or supports the text. Examples include original copies of journal articles, reprints of manuscripts and abstracts, a curriculum vitae, patent applications, study questionnaires, and surveys, etc.*