



GRIFFITH COLLEGE DUBLIN

Assignment Cover Sheet

Learner name(s): Reema Amin

Learner number(s): _____

Assignment Type: **Individual:** **Group:** _____

Course: MSc. in Digital Transformation **Stage/year:** Feb 2024

Module: Dissertation

Study Mode: Full time Part-time _____

Lecturer Name: Ankit Chaturvedi

Assignment Title: Final Research Proposal

No. of pages: 72

Uploaded to Moodle: Yes No _____

Additional Info: _____

Date due: 08/06/2025

Date submitted: 08/06/2025

Plagiarism disclaimer:

I/We understand that plagiarism is a serious offence and have read and understood the college policy on plagiarism. I/We also understand that I/We may receive a mark of zero if I/We have not identified and properly attributed sources which have been used, referred to, or have in any way influenced the preparation of this assignment, or if I/We have knowingly allowed others to plagiarise my/our work in this way.

I/We hereby certify that this assignment is my/our own work, based on my/our personal study and/or research, and that I/we have acknowledged all material and sources used in its preparation. I/we also certify that the assignment has not previously been submitted for assessment and that I/we have not copied in part or whole or otherwise plagiarised the work of anyone else, including other students.

Signed & dated: Reema Amin 08/06/25

Reema Amin

1.1 Please note: Students MUST retain a hard / soft copy of ALL assignments



Bioprinting Solutions for Diabetic Kidney Failure: The Future of Tissue-Engineered Organs

MSc. in Digital Transformation (Life Science)

Griffith College Dublin

Reema Amin

3127324

2025

Declaration

I hereby certify that the work contained in this dissertation which has been submitted to meet the set criteria for an MSc. in Digital Transformation (Life Science) have been all mine, my own research and reading. All sources of information, ideas and content from other scholars and authors have been properly credited. I further certify that the material in this dissertation is sincere and unique, a creation not copied or stolen from any source and has not been previously presented in an academic setting.

Author: Reema Amin

Author Signature: *Reema Amin*

Supervisor: Ankit Chaturvedi

Dated: 08 June 2025

Acknowledgement

I would like to say thank you wholeheartedly to all who supported me during the research and preparing this dissertation.

I am especially grateful to my supervisor for their guidance, constructive feedback, and encouragement throughout the project. Their support was instrumental in helping me shape and complete this work.

I am grateful to all the medical professionals, diabetic patients, and family members who volunteered to fill out the survey for the sake of necessary feedback for this study.

I am indebted to my peers and friends for their help in building contacts with respondents and support when working on this dissertation

Table of Content

1	Introduction.....	7
1.1	Background.....	7
1.2	Purpose.....	9
2	Literature Review	10
2.1	Research	11
2.2	Conceptual Framework.....	24
2.3	Conclusion	25
3	Research Methodology	26
3.1	Research Philosophy.....	26
3.2	Research Approach.....	27
3.3	Research Strategy	27
3.4	Time-Horizon	28
3.5	Techniques and Procedures.....	28
3.6	Pilot Testing.....	30
3.7	Final Implementation	30
3.8	Data Collection	30
3.9	Explanation	31
3.10	Ethical Implications.....	31
3.11	Research Limitations and Challenges	32
3.12	Justification of Methodological Choices	33
3.13	Thematic Analysis	33
3.14	Conclusion	36
4	Findings and Analysis	37
4.1	Analysis.....	37
4.2	Summary.....	48
4.3	Recommendations.....	49
4.4	Key Findings from Literature Review	50
4.5	Conclusion	54
5	Conclusion	55
	References.....	59
	Appendices.....	63

List of Figures

Figure 1: Survey Analysis 1 (Compiled by Author)	38
Figure 2: Survey Analysis 2 (compiled by author)	39
Figure 3: Survey Analysis 3 (compiled by Author).....	40
Figure 4: Survey Analysis 4 (compiled by Author).....	40
Figure 5: Survey Analysis 5 (compiled by author).....	41
Figure 6: Survey Analysis 6 (compiled by Author).....	42
Figure 7: Survey Analysis 7 (compiled by Author).....	43
Figure 8: Survey Analysis 8 (compiled by Author).....	44
Figure 9: Survey Analysis 9 (compiled by Author).....	45
Figure 10: Survey Analysis 10 (compiled by Author)	46
Figure 11: Survey Analysis 11 (compiled by Author)	48

In this study I determined the feasibility of 3D bioprinting for diabetic kidney failure management, discussing its suitability, economic pros and cons, and practical barriers when moving to a clinical setting with bioprinted kidneys. Insights were generated using a dual method of analysis, which involved a systematic review of literature and direct surveys with diabetic patients, their family members, and medical professionals.

The primary objective was to determine whether 3D bioprinting is a viable and acceptable alternative for kidney transplants, primarily to address the scarcity of available organs and to control diabetes associated with kidney complications. Though the participants' awareness of the bioprinting technology was low, the study identified potential for bioprinted kidneys when these were proven safe and effective. The rate of kidney-related hospitalizations in survey participants was associated with increased willingness to consider bioprinting for kidney replacement.

Analysis of the research and data showed that there are number of significant barriers to widespread implementation averaging safety concerns, excessive cost, unclear regulations and insufficient clinical preparation. However, the entry of superior biomaterials, stem cell-derived organoids, and cost-effective printing technologies is evidence that the technology is advancing fast to practicality. The research shows that bioprinted kidneys are not yet a clinical possibility for kidney replacement but the preparation for the incorporation of bioprinted kidneys in medical practice is developing rapidly. Patients who were afflicted by kidney failure expressed the greatest enthusiasm for this technology, showing the need for personal as well as cost-effective treatments.

In creating a readily accessible knowledge data bank, this dissertation advances the scholarly and clinical arguments about kidney bioprinting programs. To promote the incorporation of bioprinted kidneys into day-to-day healthcare, the study recommends increased public education, the development of ethical frameworks, and policy provisions in unethical provision

1 Introduction

1.1 Background

The technology known as three-dimensional (3D) bioprinting helps fabricate intricate biological constructs which include tissues and organs. Medical sciences can obtain major advantages from this technology because it strengthens personalized medicine applications and surgical planning procedures and organ transplantation methods (Murphy & Atala, 2014). Through 3D bioprinting regenerative medicine brings forth a promising result for addressing the worldwide organ shortage crisis by producing fabricated organs. Medical patients with end-stage organ failure need organ transplants as their final treatment option because kidney failure stands among these critical conditions. The scarcity of donor organs surpasses the available supply because of which patients endure extended waiting times and substantial mortality loss (Li et al., 2016)

The clinical solution of bioprinting enables medical professionals to create organ and tissue replicas using individual patient MRI or CT scan images (Aljohani et al., 2018). The recent progress in 3D bioprinting technology enabled scientists to create biomaterials starting from basic tissues like skin and cartilage all the way to elaborate structures of heart and kidneys (Yan et al., 2018). The massive potential of bioprinting exists in its capability to speed up organ making combined with the expansion of available donors and raised transplant success rates which together can radically reshape transplantation medicine. The research examines how 3D bioprinting affects kidney transplants for diabetic patients while discussing current issues and future possibilities in this field.

Uncontrolled diabetes leads to diabetic nephropathy which stands as a severe complication that produces kidney failure materializing as one of the primary reasons for kidney damage throughout the world. The microvasculature of the kidney suffers chronic damage from hyperglycemia making the organ unable to properly filter waste and manage fluid levels. End-stage renal disease (ESRD) develops from this damage until patients require either dialysis or kidney transplant (Liyanage et al., 2015). The insufficient availability of donor kidneys makes bioprinting techniques develop into a promising substitute for traditional organ transplant procedures.

Bioprinting technology supports the creation of organ-specific kidneys that match patient's unique structural and physical conditions. By using personalized techniques transplant efficiency would improve simultaneously with better patient quality of life while solving the donor organ shortage (Vijayavenkataraman et al., 2018). The manufacture of engineered kidney tissues promises to decrease substantially the number of people who need organ transplants while creating a resilient answer to the organ scarcity problem.

The main advantage of bioprinted kidneys involves cell sourcing from individual patients thus reducing the possibility of rejecting transplanted organs. The use of traditional organ transplants demands everlasting immunosuppressive therapy to fight rejection thus leading patients to experience major medical complications from infections and malignancies (Elalouf, 2021). Bioprinted kidneys created using a patient's own cells will not require immunosuppressants because such treatment becomes unnecessary thus delivering better healthcare along with reduced expenses.

Bioprinting technology enables valuable research potential regarding diabetic kidney disease investigation. Scientists can use engineered kidney models to create disease microenvironments that help them examine disease progression while conducting therapeutic drug assessments inside controlled environments. New treatment strategies together with personalized medicine options will emerge because of this development (Salybekov et al., 2024).

Bioprinting serves as a transformative method which enables effective treatment of diabetic kidney failure. Patient-specific kidney tissues produced through this technology together with limited organ supply reduction and enhanced disease research capability show tremendous promise for transforming transplantation medicine practice. The challenges of expanding tissue production and developing internal blood vessel systems and obtaining regulatory approval for bioprinted kidneys may become surmountable through continued investigation into new solutions.

1.2 Purpose

The proposed research establishes an extensive knowledge base designed to function as a single information hub for bioprinting experts studying kidney tissue engineering application to diabetic patients. Central resource collects and consolidates knowledge alongside challenges and cost information and stakeholder insights to support both decision-making and future research in this domain.

Achieving this objective requires the breakdown into specific objectives which the study presents. The research goal starts by evaluating the modern status of kidney bioprinting technology. Research shows that current advancements enable the production of renal structures from human-induced pluripotent stem cells into kidney organoids with natural tissue characteristics (Christou et al., 2023). The development of complete functional kidneys encounters ongoing hurdles when seeking to replicate their intricate vascular network and necessary tissue connectivity (Turunen et al., 2018). The research aims to map existing kidney bioprinting technologies through analysis of peer-reviewed studies and clinical trials alongside ongoing research projects through a full literature review.

The research will identify all obstacles that stand in the way of kidney bioprinting success. Numerous challenges exist that prevent the clinical adoption of bioprinted kidneys despite major development achievements. Adequate vascularization along with long-term functionality and suitable biomaterial selection remains a technical challenge in bioprinting (Turunen et al., 2018). The combination of ethical problems and regulatory standards alongside difficulties in scalability represents significant obstacles to advancing kidney bioprinting technologies (Christou et al., 2023). The research focuses on conducting an extensive examination of published studies to both groups and expanding our understanding of the numerous hurdles blocking kidney bioprinting success.

The research investigates how much it would cost to adopt kidney bioprinting technology. The successful clinical deployment of bioprinted kidneys relies heavily on economic viability. The long-term potential of bioprinting suggests cost reduction possibilities because it avoids donor procurement expenses and

immunosuppression requirements and postoperative care expenses (Christou et al., 2023). Bioprinted kidneys ready for diabetic patients require resilience against hyperglycemic stressors and related complications. Research reports about bioprinted renal tissue performance under experimental diabetes models allow researchers to evaluate their suitability for diabetic patient use.

The analysis examines both technical and clinical elements along with medical practitioner preparedness toward kidney bioprinting adoption. Clinical adoption of bioprinting technologies depends on how well healthcare professionals understand and prepare to work with this new technology. The adoption of modern technology depends on medical staff's familiarity with the machine alongside their perception of its advantages and the degree of institutional backing (Christou et al., 2023). A transformative objective requires professional medical surveys and interviews which measure physician responses about bioprinted kidney readiness for therapeutic protocols.

The research studies how both diabetic patients and their caregivers respond to bioprinted kidneys. The clinical success of bioprinted organs depends significantly on receiving patients' acceptance of technology. Patients and family members have concerns about the safety features and the effectiveness alongside ethical implications of receiving bioprinted tissues. The research goal investigates diabetic patients and their relatives' perspectives regarding bioprinted kidneys as a therapy through structured questionnaire administration with additional focus group dialogue for both qualitative and quantitative results.

The study will develop a publicly accessible information platform which will enable continued research into bioprinting applications and clinical implementations for stakeholders. The information repository presents integrated findings about technological progress along with difficulty assessments and economic estimation data and stakeholder position research. A single platform operated by the repository functions to guide researchers alongside clinicians and policymakers toward making knowledgeable choices while advancing the field of kidney bioprinting

2 Literature Review

The literature analysis reviews developments in 3D bioprinting technology as it applies to diabetic kidney failure prevention by manufacturing biological organs from the ground up. With the upsurge of diabetic

patients falling into the pattern of developing end-stage renal disease, significant hindrances are posed to traditional kidney transplantation because of the apparent lack of donor organs. A promising solution to tissue fabrication needs can be found along the lines of 3D bioprinting because it helps doctors to generate personalized kidney tissues through the blend of advanced biomaterials with living cells. The review presents an inspection of scholarly research that dives into bioprinting methods as well as ongoing development and research arguments on the topic of biomaterials. It explores various sources to highlight the knowledge gaps alongside pointing out the barriers of technological and medical aspects while also carrying out a readiness assessment for use of this innovation in practical healthcare that specifically concerns diabetic renal complication management. The reviewed findings will consist of a robust base for analysing bioprinted kidney feasibility along with the levels of its acceptability and potential of leaving an impact.

2.1 Research

Three-dimensional cell-printing of advanced renal tubular tissue analogue.

Though not specifically about diabetic kidney illness, the paper (Singh et al., 2020) provides insightful information that may greatly advance the studies on bioprinting tissues for diabetic patients who are having renal failure. It presents novel 3D cell printing methods designed especially to build intricate renal tubular tissue. The main use covered is not directly connected to diabetes, although the described process might be modified to create tissues unique to diabetic kidneys. This modification has promised to progress disease modelling and medication trials aimed at diabetic kidney problems.

Though the process described in the article is still in its infancy and unsuitable for transplantation, it is nevertheless a major advancement in the field of bioprinting for regenerative medicine. This development highlights the possibilities for next studies aiming at adapting this method to produce functioning kidney tissue appropriate for transplantation in diabetes patients. With more research and development, this strategy might have enormous promises for meeting the urgent requirements of diabetics who are in kidney failure.

Advancements in tissue and organ 3D bioprinting: Current techniques, applications, and future perspectives.

In-depth discussion of 3D cell printing methods and their possible uses in drug development is provided in this article (Mirshafiei et al., 2024). Its lessons, meantime, might go far farther than that, especially in relation to bioprinting kidneys for diabetics who are nearing kidney failure. Though the main goal is to find new drugs, the methods described in the paper provide a viable means to maybe bio print kidneys that are adapted to the requirements of diabetics.

The study describes a new technique for creating complex microfluidic tubes with endothelial and renal tubular epithelial cells. Advanced drug testing and disease modelling could be made possible by modifying this novel approach to create tissues unique to diabetic kidneys.

The article lays a vital foundation for future research in this field even though it doesn't go into the specifics of bioprinting whole kidneys for transplantation. Eventually, we might imagine producing functional kidney tissue appropriate for transplantation in diabetic patients by combining the techniques described in this paper with other developments in bioprinting technology. This is a major advancement in attending to the pressing requirements of those suffering from diabetic renal problems.

Applications, advancements, and challenges of 3D bioprinting in organ transplantation.

The article (Huang et al., 2024) introduces a new field of science, 3D Bioprinting, that may contribute to a global goal in organ transplantation by facilitating manufacturing of organs that are hard to replicate for critically ill patients. I want to say that this article is to address the capability of bioprinting to solve health problems that diabetic patients can have because of kidney failure.

Even though this paper gives a round overview of 3D bioprinting prospects for kidneys, it does not give any details of production of these organs. Yet it does not exempt that this technique may offer a chance to implement this technique for a kidney transplant operation at some point.

It is imperative to understand that creating bioprinting methods that can create intricate organs like kidneys would need more investigation and creativity. Still, this paper is a ray of optimism since it highlights how much 3D bioprinting has to offer to completely transform the field of organ transplantation and medicine.

Embedded 3D bioprinting – An emerging strategy to fabricate biomimetic & large, vascularized tissue constructs.

The paper (Budharaju et al., 2024) explores the intriguing field of embedded 3D bioprinting, a cutting-edge method that might completely transform organ transplantation. This is quite relevant to my research on bioprinting tissues for diabetic patients who are dealing with kidney failure because both sectors aim to use bioprinting to create functioning tissues for medical applications.

With the alluring possibility of producing huge, vascularized tissues—a critical need for organs like kidneys that depend on a sophisticated network of blood arteries for appropriate function—embedded bioprinting appears as a ray of hope in this scenario. In the middle of this promise, the paper also highlights the difficulties that need to be resolved before this approach may be smoothly included into clinical practice.

Main obstacles become ensuring the cells in the bio printed tissue survive and enabling appropriate integration into the recipient's body. Notwithstanding these obstacles, the paper presents a positive image of how embedded 3D bioprinting can open the door to transplantable organs.

To overcome the present barriers preventing the realization of this vision, further research and innovation are obviously necessary.

A critical review of current progress in 3D kidney biomanufacturing: advances, challenges, and recommendations.

The article (Wragg et al., 2019) delves into the fascinating field of 3D bioprinting as a possible kidney regeneration breakthrough. The goal aligns with my research of using bioprinting to construct functioning tissues for medical purposes, hence this connects well with my research title on bioprinting tissues for diabetes patients navigating kidney failure.

The paper carefully reviews the disadvantages of dialysis and transplantation, two of the existing kidney replacement treatments, and highlights the revolutionary possibilities of 3D bioprinting for producing artificial kidneys that more nearly resemble natural kidney function. Given the fact that diabetic patients suffering from renal failure frequently have restrictions with dialysis and run into obstacles to transplantation because of organ shortage, this realization is especially important for this research.

The difficulties are noted, such finding appropriate biomaterials and cells. Creating viable kidney tissue by bioprinting does, in fact, depend critically on the search for biocompatible materials and the best cell sources.

Basically, the paper presents a clear picture of the potential that 3D bioprinting must solve the drawbacks of the existing therapies for renal failure. Though challenges remain, following this research path gives

optimism for changing the diabetic kidney care landscape and improving the lives of individuals who require it.

Bioprinting of kidney in vitro models: cells, biomaterials, and manufacturing techniques.

The article (Fransen et al., 2021) focuses especially on the creation of bioinks, the necessary "ink" for bioprinting procedures. It talks about the tremendous promise bioprinting has been showing lately in areas like tissue engineering and regenerative medicine.

This article provides insightful information related to transplantable kidney bioprinting. It highlights how vitally important bioinks are to the feasibility of bioprinting kidneys. Consider bioinks, the components that allow living cells and biomaterials to be precisely layered to create complex kidney tissues. The importance of using bioinks that closely resemble the characteristics of real kidney tissues is emphasized in the article to guarantee the success of bioprinting for transplantation.

To enhance aspects like cell survival, tissue shape, and general functionality of bio printed kidney tissues, it also emphasizes continuous attempts to improve bioink formulations. Advancement of the field and the day when bio printed kidneys may be a practical transplantation option depending on this ongoing improvement.

Basically, this paper offers insightful information and research approaches that can direct my research and clarify the developments and difficulties in bioprinting methods and bioink creation.

3D Bioprinting tissue analogs: Current development and translational implications

This article (Liu, et al., 2023) puts a light on how 3D bioprinting tissue analogs is an upcoming field which has great prospects to be employed in the field of organ transplantation and the manufacture of functioning kidneys. However, the present state of technology yet to manufacture total operating systems for transplanting have not been replaced by other technologies. Instead, it is a channel of hope for medicine in the future.

The present article evokes the significance of the bioprinting of kidneys for placing them as an appropriate strategy for diabetic individuals who are troubled by the deterioration of kidneys in their health, because it places bioprinting in the context of a solution to diabetes condition that concerns kidney dysfunction. However, it also emphasizes the pressing need to surmount technical challenges before bioprinting can transition into clinical practice.

Kidney Engineering Technology for New Tissue Replacement Therapies.

The article (WYSS Institute, 2021) offers insightful information that is relevant bioprinting kidneys for diabetic individuals with renal failure. In this article, a novel bioprinting method using sacrificial writing is presented to create vascularized kidney tissue, a necessary step in creating working kidneys.

Though the article deals with kidney failure, the Wyss Institute essay takes a more general approach and does not specifically address diabetics. Furthermore, it appears that Wyss Institute research is at an earlier stage and focuses on establishing the foundation for useful building blocks like vascularized tissues.

In conclusion, the Wyss Institute article advances science considerably even though it does not address the details of bioprinting kidneys for diabetes patients. Their advances in vascularized tissue 3D bioprinting methods have promised the future creation of kidney transplants, particularly ones specifically designed for diabetics. The larger goals are well-aligned with this research, which also provides priceless insights into the technical nuances of bioprinting working kidney tissue.

3D Bioprinting

The article ("3D Bioprinting - NASA," 2023) clarifies ground-breaking 3D bioprinting studies carried out on the International Space Station (ISS), which are meant to progress the creation of bio printed tissues for possible medical transplants. One fascinating feature of space bioprinting is the use of living cells to build tissues, made possible by the microgravity environment, which promotes tissue development without the requirement for a scaffold. This NASA-led project has as its ultimate objective the bioprinting of organs for transplantation, such as hearts and kidneys, thereby launching a new chapter in regenerative medicine.

One significant development in the field is the NASA study on 3D bioprinting in space. Though it doesn't address the requirements of diabetics directly, its effects go well beyond that. This ground-breaking work may act as a spur for next uses in bioprinting organs for transplantation on Earth; kidneys are one such use. This research promises to illuminate novel strategies and promoting partnerships that could mutually benefit my research and the larger field of bioprinting for organ replacement, even though it might not immediately relate to the details of my research title.

ARPA-H launches a program to bio print organs on demand.

This article (ARPA-H, 2024) explains the potential of 3D bioprinting technology, this project produces organs—including kidneys—that can be made on demand for transplantation.

This program's common goal that aligns with my research, the creation of transplantable organs—makes it especially important. Though the PRINT program aims to produce a variety of organs to meet transplantation demands, my research focuses especially on bioprinting kidneys for diabetes patients.

Among other things, the ARPA-H program has a strong focus on doing away with the need for anti-rejection medications. It highlights the program's dedication to developing transplantation methods and enhancing patient outcomes.

For my research area, the PRINT program announcement is excellent news overall. It draws attention to the rapid progression in the 3D bioprinting technology advancement that leads to organ transplantation innovations and, thus, shows potential areas for cooperation that, on the other hand, may lead to faster development of technology for printing the 3D kidneys intended for diabetic patients.

Three-Dimensional Printing and Bioprinting in Renal Transplantation and Regenerative Medicine: Current Perspectives

The application of 3D printing and bioprinting technologies for renal transplantation and regenerative medicine by Christou et al. (2023) provides valuable information for diabetic kidney failure bioprinted solution development. The article demonstrates how 3D printing and bioprinting applications now generate customized medical models along with nephron-like structures that help surgeons plan procedures while offering potential individualized therapeutic options. Bioprinted solutions show promise for diabetic patients who have progressed to end-stage kidney disease because they address persistent issues with available organ supply and transplant rejection.

Bioprinting demonstrates its ability to create intricate kidney tissues by connecting cells, bioinks as well as vascular networks together. The application of bioprinting to medicine faces various hurdles that prevent clinical adoption due to technical limitations in replicating complete organ performance and difficulties in obtaining adequate vascularization and strict regulatory frameworks. Research shows these fundamental technological barriers to stand in the way of bioprinting's widespread application for organ failure management (Christou et al., 2023).

The article examines the financial return on investment by highlighting the high first costs despite potential long-term savings through decreased organ supply shortages and reduced need for immunosuppression.

Bioprinting advancement requires sustained cooperation among biomedical engineers with clinicians and policymakers to achieve its full potential. Medical system readiness for bioprinted organ implementation needs more study to ensure proper assessment of healthcare acceptance.

The article reinforces that bioprinting technologies show promise for becoming an advanced kidney replacement solution of the future. Research into medical biotechnology must continue with particular focus on diabetic patients because of current priorities in development. Current research builds from these discoveries to evaluate the effectiveness and acceptance rates and surmountable obstacles of using bioprinted kidneys to treat diabetic kidney failure.

Bioprinting technology and its applications

The article by (Seol et al., 2014) conducts an extensive review of modern surgical applications for three-dimensional (3D) printing in different medical specialties which demonstrates its wide-ranging transformative power. The authors identify three main applications of 3D printing technology: Through 3D printing surgeons achieve three key applications including anatomical model creation and personalised surgical instrument manufacture as well as customized implant production. The applications deliver key benefits to complex surgical operations through improved visualization and enhanced accuracy as well as individualized patient healthcare.

3D-printed anatomical models bring valuable benefits to preoperative planning by delivering precise graphics of individualized patient anatomies when used for renal transplantation procedures and diabetic kidney treatment. The advanced understanding of complex vascular structures and anomalies through these models helps to decrease surgical risks and leads to better patient results. 3D printing enables customized implant development which produces precise medical instruments matched to diverse anatomical specifications across patients.

Several obstacles exist in the way of 3D printing technology becoming widely used in surgical operations according to the article. The full implementation of 3D printing in surgery faces obstacles such as expensive start-up requirements and staff talent requirements and strict protocols for obtaining certification for printed medical products. The authors point to 3D printing's transformative power in surgery but recognize it requires further development for widespread adoption and cost-effectiveness.

3D printing technology makes significant improvements to surgical operations and patient-specific care according to (Seol et al., 2014). Their research supplies vital information regarding both potential benefits

and technical hurdles which need solving to achieve full clinical application of this tech in diabetic kidney failure treatment through bioprinting technology.

3D bioprinting of the kidney—hype or hope?

Turunen et al. (2018) reviews the development trajectory of kidney bioprinting by assessing whether existing research outcomes represent substantive contributions or hypothetical possibilities. The authors underline the requirement for new organ supply options because end-stage renal disease patients including diabetic kidney failure patients need immediate solutions. 3D bioprinting seems to provide a solution for organ-related gaps by showing potential to create functional renal tissues and organs.

Research demonstrates both successful kidney tissue printing of simpler structures and recognizes the technical hurdles that prevent precise duplication of kidney complexity. Technology faces three main difficulties which consist of developing sufficient blood vessel networks and maintaining functional printed tissues and achieving practical application at an industrial scale. The article reviews many bioinks alongside printing approaches while acknowledging that new research will be important to surpass present-day barriers.

The investigation by Turunen et al. (2018) shows potential uses for bioprinted kidney tissues for drug testing and disease modeling as the technology matures to provide instant advantages. The field development requires interested stakeholders from developmental biology, materials science and engineering to create a multidisciplinary structure of expertise.

The article presents an impartial viewpoint toward kidney bioprinting by acknowledging its existing capabilities as well as its present boundaries. The development of functional bioprinted kidneys requires sustained research alongside multidisciplinary collaboration to achieve this breakthrough that will benefit patients with diabetic kidney failure while reducing the organ shortage crisis.

Immune response against the biomaterials used in 3D bioprinting of organs

The article by (Amir Elalouf, 2021) presents a thorough review of immune responses of biomaterials utilized in the 3D printing of organs which is an important component in the process of advancing regenerative medicine. Elalouf stresses that although some hope arises for solving organ shortage problem in terms of organs replacement for such patients as patients with end-stage renal disease thanks to 3D bioprinting, the immunogenicity of the biomaterials is a limiting factor. The foreign body response (FBR)

of the body to implanted biomaterials may cause inflammation, fibrosis, and finally the rejection of the bioprinted organ.

The review assesses the mechanisms of FBR by highlighting the roles of several immune cells, for example B-cells, dendritic cells, macrophages, natural killer cells, neutrophils, and T-cells and the molecular signals as: antibodies, cytokines and reactive radical species. Elalouf notes that although the molecular signals regulate encapsulation of biomaterials in a fibrous form, it may hinder tissue integration and functionality for bioprinted tissues. This is especially significant in the case of diabetic kidney failure where the victims' immune system may be compromised thus exposing them to dangers from the implanted biomaterial that may trigger allergic reactions.

To restrain these said immune reactions, Elalouf explores various approaches like changes in bio-material surfaces, employing immunomodulating agents as well as patient-derived cells in the bioprinting of personal organs. The purpose intended for these approaches is to heighten biocompatibility of implants and minimize the risk of immune rejections. The reviews also focus on the extent of inter-relationship of material scientists, immunologists, and clinicians who come together in the line of work to rise above such challenges.

Finally, an (Amir Elalouf, 2021) review gives a lot of useful information about immunological difficulties related to the 3D bioprinting of organs. Through describing the complex blend of biomaterials with the immune system, the article focuses on the necessity of developing plans for modulation of the immune response that is supposedly aimed to better the viability of bioprinted organs. These are important for developing bioprinting remedies for diabetic kidney failure where matches must be ensured.

Natural Biomaterials and Their Use as Bioinks for Printing Tissues

The article by Benwood et al., (2021), offers an extensive review of corresponding natural biomaterials used for tissue engineering purposes as bioinks in 3D bioprinting. The authors describe a number of natural polymers that include agarose, alginate, cellulose, chitosan, collagen, decellularized extracellular matrix, dextran, fibrin, gelatin, gellan gum, hyaluronic acid, Matrigel, and silk, indicating their properties and how they are suited for extrusion-based bioprinting. These materials are relatively more favored primarily because of their biocompatibility and matrix-like character which sustains cell–viability and cell–function.

The choice of bioinks holds a crucial role in kidney tissue reconstruction for imitating kidney tissue complex architecture as well as the function in tissue engineering. According to the article, mechanical, rheological and cross-linking characteristics of bioinks, cytocompatibility and printability are of a particular

significance. To solve the predicaments of single biomaterial, multi-component bioinks are strongly suggested to do the course while also bettering the structural and functional constancy of bioprinted tissues.

The review explains about the problems connected to natural bioinks, for instance, the compositional variability, and its probable immunogenicity that may affect the bioprinted constructs consistency and safety. The authors strongly recommend in depth research in greater levels for curating standardized and optimized bioinks with an aim to increase efficiency as well as reliability of the concept and use of 3D bioprinting in clinical practices.

Overall, Benwood et al. (2021) outline some relevant information about the current condition of natural bioinks in 3D bioprinting and their possible applications in tissue engineering and regenerative medicine. The findings extracted by them prove to be fundamental in the process of fabrication of kidney tissues through bioprinting, which also can be employed to garner opinions on the material choices and well as strategy choices that will play into the formulation to derive results of functional and biocompatible constructs.

The Regulatory Challenge of 3D Bioprinting

The article by Mladenovska et al. (2023), focuses on the explanation of the in-depth regulatory environment with 3D bioprinting within regenerative medicine. The authors describe some of the complexities that result from the intersection of different domains, 3D Printing, cell therapy, and bespoke medical devices that are regulated by different sets of regulations. The merging cons equates unreliability in quality control, posing risks, and classifying, ultimately leading to making the process rather difficult for clinical use.

Classification of bioprinted goods is a major issue presented. It is comparatively harder to accommodate them into regulatory categories as opposed to the traditional medical devices, medications or bioprinted constructions. However, with this ambiguity one may experience delays when processes of approval are being undertaken and impediments to innovation. The authors are in favor of the invention of new regulatory pathways that are dedicated to specific uniqueness of bioprinted products.

Here, in the article, ample attention has been allocated to the need of standardized protocols in order to help the efficacy, reproducibility, and safety of the bioprinted organs and tissues. With the many personalized bioprinted constructions, it is very difficult to set up uniform quality control parameters. A common argument made here by the writers depicts that the need for united actions by regulatory bodies,

scientific community, and industry players is crucial to formulate all-inclusive guidelines that will support the speed of technological advancement.

Looking at diabetic kidney failure, these regulatory problems are rather of special significance. Bioprinted kidneys promise to be a revolutionary solution to the plight of end-stage renal disease-sufferers. However, factual practices are still questionable due to the lack of proper regulatory frameworks for such innovations to be implemented on a real-life basis. Mladenovska et al. (2023) also focuses on the significance of proactive reform of the frameworks to speed the introduction and use of bioprinted organs in clinical context.

3D bioprinting of human iPSC-Derived kidney organoids using a low-cost, high-throughput customizable 3D bioprinting system

The Research published by Chun et al. (2024) presents a novel, cost-effective, and easily accessible (in terms of price) automated 3D-bioprinting platform that can be used to create human-induced pluripotent stem cell (iPSC)-derived kidney organoids. Such development eliminates one of the major barriers in the field of regenerative medicine. the high prices and limited availability of bio printing technologies. By democratizing access to organoid construction, the platform shows potential to speed-up development of research and therapeutic applications surrounding organoids especially in diabetic kidney failure.

The authors describe the development and validation of the bioprinting system that they recommend, which can print kidney organoids with similar morphology and cellular composition. Its design utilizes parsimonious components and open-source software, thus justifying the use of this platform for smaller laboratories. Such access is vital while broadening the scope of kidney diseases research and searching for individual ways to treat the disorders.

One of the strengths of the study is that its focus is on reproducibility and scalability. The bioprinted organoids exhibited functional attributes like native kidney tissue such as expressing key nephron markers. This fidelity is important for disease modeling purposes, drug screening and maybe therapeutic interventions. However, the study also recognizes limitations including the requirement for organoids to mature further and incorporation of vascular structures to achieve full reproductive functions of the kidneys.

For diabetic kidney failure, this bioprinting platform provides an important piece of equipment to investigate mechanisms of diseases and test potential medicines. Its low cost and ease of operation can

help to achieve mass scale up and revolutionize joint research activities leading to rapid advancement in regenerative therapies.

Bioprinted 3D Bionic Scaffolds with Pancreatic Islets as a New Therapy for Type 1 Diabetes—Analysis of the Results of Preclinical Studies on a Mouse Model

Klak et al. (2023) inscribed an advanced position of type 1 diabetes treatment by applying bionic 3D bioprinted scaffolds with embodied pancreatic islets. A murine model was used by the researchers and later compared the efficacy of these bioprinted constructs to traditional islet transplantation under the renal capsule. Resultantly, both the methods were marked as efficient regarding limiting fasting glucose as opposed to untreated controls, with the bioprinted scaffolds showing outcomes of the same level if not better. Histological studies confirmed the appearance of tissue “islands” of insulin secretion creation of new vessels in the bioprinted scaffolds and recommended effective combination and performing of the transplanted tissue.

The prime force of this study is its distinctive use of decellularized extracellular matrix based bioink that almost imitates the native pancreatic environment, for example, rising potentiality and performance of islets. Established vascularization within the scaffolds is particularly notable as this is one of the key limiting issues in tissue engineering; accessibility of the implanted tissue to adequate blood supply has a direct effect on regenerating tissue viability. However, application of the study results to possible human applications requires caution since the study is based on a murine model. Further studies on big animal models and then clinical attempts are needed to confirm these findings and decide long-term usability and safety.

The implications of this research when it comes to diabetic kidney failure are not insignificant. The achievement of bioprinted pancreatic islets which integrate and function successfully, is indicative of alternative approaches for creating bioengineered tissues of the kidney for mitigation of lack of donor organs and for eliminating the requirement for lifelong immunosuppression. The study exhibits a base for potential progress in regenerative methods for endocrinopathy cases linked with diabetes by exhibiting the probability of employing bioprinted scaffolds for reinstating endocrine activity.

The application of 3D bioprinting in urological diseases

Xu et al. (2024) record an ideal automated 3D bioprinter in terms of affordability for the purpose of contriving human-induced pluripotent stem cells derived kidney organoids. This development removes one of the major obstacles of regenerative medicine. high cost and limited accessibility of the bioprinting

technologies. Modifying organoid fabrication with this platform directs to a possibility for expediting research and therapeutic use, particularly in the context of diabetic kidney failure.

The authors pose the idea of advancement and corroboration of their process of bioprinting, focusing on its potential of printing kidney organoids with conventional morphology and composition of cells. The application's architecture combines standard parts and free software, streamlining it as a useful lab tool for laboratories with low resources. Accessibility as such is considered integral to expand the research on kidney diseases and personalized treatment choices.

One of the strengths of the study is in terms of reproducibility and scalability. The bioprinted organoids showed functional properties like the native kidney tissue, such as expression of major organ-specific markers; such constancy is important in disease modelling application, drug screening, and even therapeutic interventions. Nonetheless, limitations are also noticed, such as factoring in the need for additional maturation of the organoids alongside the integration of vascular structures to make sure that the kidney remake is completely replicated.

In the case of diabetic kidney failure such a bioprinting platform may provide a useful tool for analysis of mechanisms of the disease and testing of possible treatments. The affordability and user-friendliness that it projects can be used for easy adoption by the majority, and it can also motivate collaborative research and speedy advancement of regenerative therapies.

Advancing organ and tissue repair through 3D bioprinting: a breakthrough solution to the global organ shortage crisis

The article (Sundaram et al., 2025) defines the potential of 3D bioprinting to remodel the world as was done by the global organ scarcity problem. The authors further focus on the ability of the technology to create complicated tissue constructs, along with its functional circulatory constructs, that is crucial for the viability and integration of bioprinted organs. This is especially pertinent for diseases such as diabetic kidney failure where the demand for organ transplants outruns supply.

One of the most notable strengths of the study is the focus on a combination of vascular networks in the printed tissues. The authors point out why the combination of these networks is important in the pursuit of keeping the potentiality of larger tissue constructs intact because it creates the pathway for oxygen and nutrient delivery all over the organ. They further convey that the drawbacks incurred in the attempt of replicating the complex architecture of native tissues and the necessity of appointing proper bioinks that imitate the extracellular matrix.

Nevertheless, the article mentions the limitations of existing bioprinting technologies as well. The authors note that despite the amount of progress made, there are still obstacles for overcoming, including ensuring mechanical strength and long-term functionality of bioprinted organ. They recommend sustained interdisciplinary research and collaboration to rise above the hindrances and proceed development in the field.

The pertinence of (Sundaram et al., 2025) insights are rather exemplary regarding diabetic kidney failure. The spoken revolution for patients suffering from end-stage renal disease might be found in the revolutions of the bioprinted kidneys in the face of shortage of donor organs. Providing a road map describing the situation of bioprinting technology and the routes to clinical translation, this article enhances this discussion with valuable information on the topic at hand, regenerative medicine.

2.2 Conceptual Framework

The conceptual framework in this research is aimed at bringing together the main themes in previous studies and guiding the assessment of bioprinting as a solution to diabetic kidney failure. Using its linear approach, this framework guarantees that the connections between main ideas are well delineated, and the research inquiry is moved forward. The conceptual framework aims at aligning the research question with prior concepts and empirical studies thus enabling an analysis of how the 3D bioprinting technology may be used in combating diabetic kidney failure. It will help us identify the areas which need further research due to lack of current knowledge.

Bioprinting technology, including 3D printing methodology, use of bioinks, and tissue-building processes, is the first focal point of the framework. This is at the core of the research, as it is vital in seeking possible solutions to diabetic kidney failure. With bioprinting, it is possible for researchers to print tissues that are specific to individual patients and hence sort out the shortage of donor kidneys. Transitioning to diabetic kidney failure, this represents the main medical problem being studied. For cases of kidney failure due to diabetic nephropathy, transplantation appears as a standard necessity, and here is where a groundbreaking intervention solution may come in the form of 3D bioprinting.

The imminent shortage of donor organs and the organ transplantation rejection challenge in dealing with diabetic kidney failure can only be resolved through bioprinting technology. Despite the promise of personalized, functional organ bioprinting, the issue involves numerous barriers and hindrances that hinder its effective application in this area. These barriers include issues such as creation of functional blood vessels, ethical maze and regulatory complexity. The third concept, challenges and barriers,

indicates these limitations, all of which must be addressed for bioprinted organs to replace conventional organ transplants successfully.

Financial viability of bioprinting is an important consideration which assesses the potential impact of application of bioprinting in the creation of kidneys on health expenditure. This region addresses the question of how bioprinting technologies can become affordable to finance and suggests if their deployment would reduce healthcare costs in a longer perspective thus reducing the dependence on dialysis resulting in improving organ transplants.

Appreciating the ways patients and healthcare personnel will welcome technology is an important idea in this framework. It is essential to have mass adoption of bioprinting by the patients and medical practitioners, to succeed on a long-term basis as a treatment. The connection between bioprinting and the willingness of patients to accept emphasizes the necessity to overcome barriers to the reception of new medical achievements that are influenced by various psychological, cultural, and social factors.

Furthermore, the framework highlights the importance of personalized medicine because bioprinted kidneys may be tailored especially for each patient, which could reduce transplant refusal cases and maximize the overall use of transplants. With bioprinting using a patient's cells, there is a marked improvement in tissue compatibility so there are positive and sustainable results for kidney transplants.

This conceptual landscape acts as the blueprint for presenting the study by explaining how those main ideas relate to one another. By examining such relationships, the framework guides research to respond to the most critical questions, test the already existing theories and point at possible hypotheses. Furthermore, this framework defines exact weaknesses which require further research, particularly when considering the obstacles that currently prevent bioprinting's ubiquitous use in kidney transplantation. With such framework in place, the investigation will determine the efficiency of 3D bioprinting in eradicating diabetic kidney failure and will broaden the understanding in tissue engineering and regenerative medicine.

2.3 Conclusion

The literature of the study presents that this area of 3D bioprinting has marked clear advancements, particularly in the sector of kidney tissue engineering and the ability to treat diabetic kidney failure. In various sources it is evident that the bioprinting presents a great hope for solving the worldwide problem of lack of kidney donors because it may offer the potential for the creation of the specific to a patient and

to be functional organ structures. The possibility to work with the patient-derived cells in the printing of kidney tissues provides a way to decrease transplant rejection and the as well dependence on immunosuppressive therapies, which is very applicable for diabetic patients who usually have serious medical problems (Murphy & Atala, 2014; Vijayavenkataraman et al., 2018).

Furthermore, this research analyses the advancement of the potential of bioprinting platforms by focusing on the transition from low-cost, comprehensible, devices to newer approaches with vascularization and complex tissue formations. To make sure of the progress of these technologies from just experimenting to taking it further for clinical utilization, a certain level of reproducibility, scalability, and biological performance is integral, all of which have been discussed in the studies (Turunan et al., 2018; Xu et al., 2024). Despite the anticipation of technical hindrances in the process of organ maturation, regulatory obstacles and ethical issues, literature depicts that rising above these barriers is important prior to making the bioprinted organs a regular medical practice (Aljohani et al., 2018; Salybekov et al., 2024).

In general, the findings of this body of literature strongly support the relevance and timeliness of this research. By strengthening relevant knowledge and the analysis of integral technological and ethical hindrances as well as fields of future research, this literature review strengthens a base for the subsequent course of action of the dissertation. Furthermore, it assists the motive of the study to be an informational hub for professionals and researchers associated with this field, and it also aids the acquisition of collective advancement in pursuit of clinical transition of bioprinted kidneys (Liu et al., 2023; Liyanage et al., 2015).

3 Research Methodology

This chapter describes the methodology employed to determine the feasibility, readiness and challenges in terms of bioprinting kidneys of diabetic patients who suffer from renal failure. The research methodology is developed to achieve the aims and objectives of the study using mixed methods of research approach by combining theoretical and empirical research. The following chapter considers the justification for the choice of the methodology used, the research design, testing and amendments, methods of data collection, analytical methods, ethical aspects, limitations, and materials.

3.1 Research Philosophy

Pragmatism

The philosophical support for this research is pragmatism, which advocates more practical solutions to sermons rather than rigid positivism and interpretivism. The study is especially suited for the practice of pragmatism, because it is a study aimed at acquiring practical insights about how bioprinting might be useful for combating diabetic kidney failure. Pragmatism unlike positivism (absolute truth) and interpretivism (pure subject meaning), permits an integration of approaches. It promotes a combination of quantitative data: survey results, and qualitative details from a case study and literature review. This pluralistic approach provides a broader range of understanding of the topic (Foster, 2044).

Additionally, the rational formula reverberates to the experimental and troubleshooting viability essence of the research which makes way for a balance of definite scientific practices and its practical involvement. It enables the researcher to be elastic in the workings of the methodology and to make necessary amendments as per the rising trends in the bioprinting technology as well as the learnings from distinctive stakeholders or revelations in the process of the research. This flexibility is important considering the rate at which medical bioprinting is evolving.

3.2 Research Approach

Abductive Reasoning

An abductive approach has been employed in this research, further enabling a dynamic equation of theory and empirical data. Specifically, abduction is proper for exploratory research pertaining to sensitive areas like bioprinting, where existing theories may miss out on depicting new phenomena (Hulst and Visser, 2025). It is a link between deductive and inductive reasoning; it lets the researcher start with observations such as those of experts and patients and cycle back and forth between data and theory, he or she develops a full understanding of the issue.

The abductive approach also contributes to the incorporation of emerging data while conducting research. For example, incorporating new results on the models of bioprinted kidneys into a theoretical framework has always been possible if the results are published. This enables the methodology to be thorough, adaptable, and relevant to both academic discussions of current affairs and practical problems of the field.

3.3 Research Strategy

Mixed Methods

To realize the research purposes, a mixed methods approach was implemented (both qualitative and quantitative areas of data collection and analysis). The quantitative dimension incorporated structured

surveys with diabetic patients, their family members, and healthcare professionals, that recorded insights of acceptance, knowledge, and readiness regarding kidney bioprinting. The qualitative part involved a deep literature review and analysis of lying behind the project of bioprinting, case studies, and analysis of technological assessments.

The reason why mixed methods are applied is its capacity to articulate breadth and depth. The aspect of quantitative data allows statistical generalizability while qualitative data is full of in-depth context and explanatory information. Triangulated datasets give an overall idea of the landscape of kidney bioprinting as well as what it means to diabetic patients.

The search on bio printed kidneys for diabetic people that suffer renal failure requires a research strategy that considers both the technical and social aspects. This is the doable topic for pragmatism. Consolidating quantitative data, that identifies the current situation and economic potential of them, along with qualitative data that puts together the latter's understanding as well as of medical professionals', a comprehensive method is put in order. While positivism strives to identify one definitive truth, the pragmatist approach is all about solutions. This is precisely what the research objectives are based on, which is to pinpoint a viable solution for a specific patient population. Further, the pragmatism's flexibility can be adjusted to research plans as the bioprinting industry grows. Finally, pragmatism appreciates a few perspectives, and the result is integrating the information from diabetes patients and the medical professionals to get the full picture of the potential and impediments of the bio printed kidneys in this environment.

3.4 Time-Horizon

The study utilizes a cross-sectional time horizon, and this involves collecting data at a given point in time. This is appropriate because of the time constraints of the dissertation as well as the need to give an overview of how things stand with kidney bioprinting. Although a longitudinal study may present more information on time changes, a cross-sectional study can provide reliable and output-usable data within the available period.

3.5 Techniques and Procedures

Surveys

The quantitative aspect comprised the use of structured surveys on three groups: medics, diabetic patients and the families of diabetic patients. The surveys were developed using google form to measure attitudes

and perceptions about feasibility, acceptance, and ethical issues concerning kidney bioprinting. The questions were divided into the following sections:

- Demographics (age, gender, professional background, medical history)
- Impact of Diabetes on patient's lifestyle
- Awareness and knowledge of 3D bioprinting
- Attitudes toward new medical technologies
- Readiness to accept bioprinted organs
- Ethical and safety concerns

Surveys were conducted via emails, social media sites and even via medical networks. The answers were taken within a month and stored securely for analysis.

Case Studies and Document Analysis

The qualitative aspect of this research assumed the form of heavy use of case studies and document analysis to understand the contemporary state, the practice (i.e., real-world applications), and the wider problematics of the 3D bioprinting to develop kidneys. This approach enabled detailed analysis of current bioprinting projects and its employability in the clinical aspect, specifically diabetic kidney failure.

The case studies that have been used were based on diverse valid sources, from white papers, industry reports, and peer reviewed academic journals. In addition, publicly accessed articles in verified scientific and medical websites were reviewed as well. They covered specialist publications in the areas of regenerative medicine, tissue engineering, biomedical innovation and nephrology. To ensure that information is reliable, only articles from recognized and credible platforms were chosen. The focus of attention was the verification of the credentials of authors, the affiliations to institutions and peer review status of each publication.

There was an effort to weigh up the most recent studies and developments to reflect what is the current stage of technology and research. Where applicable, only sources published within the past five years were given preference as to capture the rate of development in the field of bioprinting. Additionally, widely and highly cited journals were used to ensure that the research was thorough, academically strong, and useful to the research community.

3.6 Pilot Testing

The survey was pre-tested with a sample group of five respondents from each target segment, recording 15 people in total, prior to advancing onto full scale data collection. The process encouraged and recorded feedback pertaining to the question clarity, survey structure, and overall perceived relevance. As per the feedback responses, some minor changes were then put in order, like rewording questions to eliminate ambiguity, and also shuffling the question serial to maintain a better flow of understanding and thus response collection. The pilot established that the instrument was reliable and valid.

3.7 Final Implementation

After the pilot testing was completed, the last survey was released using both digital and paper methods. Qs were organized logically to ensure respondent interest and decrease the survey fatigue. Open-ended questions were also used to obtain qualitative responses, hence enhancing the analysis. Ethics approval was self-declared. The participants were informed about voluntary participation, as well as their ability to withdraw, and the overall confidentiality.

Literature review and case studies proceeded side by side, the attention should be brought to the sources that provide believable sources obtained in the form of peer reviewed data on the bioprinting of kidneys. These were critically examined based on the quality of methods, outcome, and relevance of findings to diabetic kidney failure.

3.8 Data Collection

The basis for data collection was enabled through the access to relevant participants and background knowledge of both the cultural dynamics and the medical system. The Google Forms were used for conducting the surveys and they were given digitally.

Doctors

They were recruited in three different ways. First, I reached doctors, who I knew through networks of acquaintances and professions. Secondly, it was these contacts that provided me with special contacts in the field of nephrology and transplant medicine, whose contributions were important to this study. Third, I have had jobs as an interpreter for medical appointments in Dublin, Ireland. I contacted several doctors with whom I had dealt with in this capacity, and they agreed to participate and facilitated access to other healthcare professionals willing to fill in the survey.

Patients and family members

They were contacted via my personal ties and cultural background. Having come from South Asia where Diabetes is rampant, I contacted family members who had diabetes and invited their caregivers or relatives. These were critical in understanding levels of public readiness and what the public had to say regarding bioprinted kidney transplants from the perspective of the patient. Their knowledge of diabetes' complications, and realities of sparse choice in transplanting, gave them appropriately rich answers.

The collected data was kept relevant and assorted to the people overburdened by the topic using personalized recruitment strategy.

3.9 Explanation

The chosen techniques of the methodology unite the benefits of quantitative as well as the qualitative methods, it allows to analyze the issue of research thoroughly. Application of quantitative methods, such as statistical analysis and quantitative evaluation, can be productive in the evaluation of kidney bioprinting, detection of the missing link and cost efficiency search. Our understanding of the research phenomenon through qualitative methods is enhanced enabling the possibility of the launching of the bioprinting of kidneys due to the expectations, experience and perspectives of the stakeholders who are taking part in this process, characterized by – the patients with diabetes, healthcare professionals and researchers.

3.10 Ethical Implications

The ethical aspects were distinctive in this research. Critical information regarding the aim of the study, rights, and use of the data was given to all participants. Informed consent was obtained digitally. Names or identifiable figures were not collected without consent and voluntary assistance, and anonymity was also intact. There was no coercion or incentive either. Moreover, precautions were taken to ensure the neutrality of survey language to create unbiased responses. All secondary sources in the literature-based data were properly referenced to avoid plagiarism as well as to keep the authenticity of the research.

To maintain integrity and credibility of this research, this study followed the set ethical guidelines. The participants were told about the purpose of the study, their rights, and how their data would be used. The participants were given their informed consent first. No personal sensitive data was collected, and all data was anonymized during the analysis. Citations were made strictly to prevent any claims of plagiarism and

show exchanges in ideas. The study also considered social responsibility considering the wider societal and medical consequences of kidney bioprinting

3.11 Research Limitations and Challenges

It was, however, discovered that several challenges arose in the collection and analysis of data. Bioprinting remains a specialty, making it possible to only find a small number of professionals capable of offering in-depth analyses. The technical sophistication of replicating a functional chunk of kidney tissue implies that current results may not be indicative of future abilities. The challenge was also the diversity in knowledge of the participants; medical professionals were often very well informed while patients at times did not understand the concepts underlying bioprinting well enough to require explanatory framing within the survey.

Even though the study had colossal planning and excellent research strategy, the study also experienced some challenges during the data collection and data analysis process. A big drawback was the challenge to get expert respondents that had to be closely experienced in the process of bioprinting technology. Given that bioprinting is still a rather niche and emerging field, the pool of medical professionals who specialize in this discipline is small. This problem was compounded as one tried to locate and reach doctors involved directly in the care of patients with diabetes and are aware about advanced treatment avenues like organ bioprinting. However, the process of approaching diabetic patients directly wasn't particularly complicated—mainly as diabetes is quite common in the South Asian community and elsewhere in my extended circle of family and friends—approaching and engaging relevant members of the healthcare and medical profession was considerably more difficult to do. The requirement of having doctors present, who are familiar with both diabetic kidney complications and bioprinting, to select participants limited the availability of eligible candidates.

In addition, the communication challenges involved in explaining the complex scientific and technical aspects of bioprinting to patients with a paucity of medical/ scientific background was another challenge. Even if the efforts were made to make terminology more transparent and to explain the context, still some survey respondents could have been misled with this concept of bioprinted organs, and thus their answers could have been affected (in terms of the accuracy and depth) by such misunderstanding. This cross-sectional nature of the research design while apt for the study's duration, by its nature constrained the ability to observe changing perceptions or trace progress in the development of bioprinting technology over time. Longitudinal approach could have recorded more dynamic changes (in attitudes, knowledge

levels and technological readiness). What is more, the lack of clinical trials or complete functionalities of bioprinted kidneys robbed the findings of their empirical anchoring. There is a lot that is speculative and theoretical in this discussion because current practical approaches are not yet in actual situations or clinical applications. These restrictions provide pointers for future studies and emphasize the relative dynamism of the area.

3.12 Justification of Methodological Choices

A solution to adopt a mixed methods strategy based on pragmatism and guided by abductive reasoning was designed to cover the whole scope of the research question. Quantitative methods supported the measurement of readiness and acceptance at the stakeholder level while qualitative methods formulated the depth of explanation and context. The strategy enabled data sources' triangulation and hence heightened the reliability and detailed depth of the findings. This approach was particularly well suited to a multidisciplinary field such as bioprinting, which overlaps with medicine, engineering, ethics and patients care.

3.13 Thematic Analysis

The qualitative dimension of this research used document analysis and case studies to distill themes that represent the technological, clinical, and ethical environment of diabetic kidney failure in the context of bioprinting. A systematic thematic analysis was carried out to determine key areas of relevance that followed the research purposes. Credible sources such as peer-reviewed academic journals, government white papers, industry reports, and high quality open-access publications were engaged and based on their findings, literature was carefully selected. Heated by subjecting each document to credibility measurement using peer-review status, author expertise, citation frequency and date of publication so that quality and relevance was promised. Thematic coding was done manually during review and grouping of content around recurrent patterns and critical ideas, and there were five major themes that cropped up.

Bioprinting Technology

Bioprinting technology is the topic itself of this study. The literature reviewed for this theme highlighted the different example of how 3D bioprinters can be used such as extrusion-based, inkjet, laser-assisted, and stereolithography (Wyss Institute, 2016). Each technology has its own strengths and weaknesses, under complex organ systems such as kidneys. For example, extrusion is one of the bioprinting

technologies that have been extensively studied because of its capacity to deposit high viscosity bioinks containing living cells, which are essential in reproducing multi-layer tissue structures (Murphy & Atala, 2014). However, challenges of print resolution, cell viability, and post-printing tissue maturation still exist yet to be resolved.

Moreover, a critical technological difficulty is that of vascularization. Successful kidney bioprinting requires the right structure as well as integration of functional blood vessels to ensure that nutrients reach the organ and waste is removed from it (Seol et al 2014). Sacrificial materials, growth factors, or co-culturing with endothelial cells have been used in current studies to try and solve this to some extent but complete integration to a scale needed for human transplantation has not been achieved (Turunen et al. 2018). Review of case studies revealed that although technological novelties are developing at an accelerated rate, their use with intricate, fully functioning organ systems is largely experimental.

Diabetes and Kidney Disease

The second recurring theme in literature and case studies is the cross-over between diabetes and kidney disease and this is a central theme to the rationale of study. Diabetic nephropathy is a common and serious diabetes long-term complication, and it is the leading cause of end-stage renal disease (ESRD) worldwide (Liyanage et al., 2015). As outlined in several documents, the present therapeutic modalities, i.e. dialysis or donor-based kidney transplant, are propelled by limited supply as well as long-term patient effects.

The theme underlines the clinical need and attention on the necessity which derives the browsing of substituting treatment modalities like bioprinting. Literature underscored how diabetic patients are especially vulnerable because of weakened immune system as well as cardiovascular predisposition that makes them poor candidates for standard transplantation (Koye et al., 2018). Bioprinting with their promise of patient-associated, immunologically compatible organs may be the perfect answer to this problem if technical and clinical barriers can be surmounted (Christou et al., 2023).

In addition, diabetes-caused injuries do not only impair renal filtration, but also damage the neighboring microvascular networks (Anders et al., 2018). As such, any efforts to strive to bioprinted kidneys to such a population must consider the altered metabolic environment of patients suffering from diabetes besides the nephron structures; thus, the engineering task becomes incredibly complex.

Bioprinting of Organs

The third theme is concerned with the wider field of organ bioprinting outside the kidney. Literature reviewed in this category was useful as a comparative framework. Organs such as liver, the heart, and skin have been studies of interest for bioprinting because of relative simplicity (in the case of skin) or value in drug screening (in the case of liver organoids) (Zhang et al., 2017). Such organs are such platforms of Early adoption of bioprinting techniques that may be later upscaled for other intricate systems like kidneys (Vijayavenkataraman et al. 2018).

These comparative cases yielded significant insight that delineated what was practical, and what was still theoretical. For instance, bioprinted liver tissues have been promising in pharmacological testing, but its application is strictly to single layer or small constructs. This theme also brought to light that fact that successful clinical trials of bioprinted tissues (skin patches or cartilage implants) often require years to get the ethical and regulatory clearance (Pati et al., 2016). Consequently, even with the enthusiasm that surrounds organ bioprinting, the route to clinical translation, particularly for life-saving organs such as the kidney, is long and arduous.

Biomaterials and Bioinks

The fourth major theme is the role played by biomaterials and bioinks in making or restricting bioprinting capabilities. The reviewed literature and case studies repeatedly stressed that the success of any bioprinting exercise deeply depends on the choice and conduct of bioinks. Traditional materials, such as alginate, gelatin, fibrin, collagen and decellularized extracellular matrix have been used more often because of their biocompatibility and resemblance with the natural tissue environment (Benwood et al., 2021).

These materials, however, do not have sufficient mechanical strength for larger or structurally complex organs. High mechanical stability alternatives synthetically based commonly remain cytocompatibility (Chimene et al., 2016). Case studies showed that multi-component bioinks—the combinations of synthetic and natural materials—have proved to be most promising in forming biologically responsive tissue constructs while being stable. In addition, bioinks' thermal, rheological and crosslinking characteristics are vital to functionality of bioinks during post printing processes.

For kidney specific applications, the need for more fine-tuned biomaterial is even more important. The anatomy of the kidney with nephrons, glomeruli, and tubules incorporated into its internal structure requires not only structural accuracy but different material properties within its anatomy (Benwood et al.,

2021). This theme, however, continues to be a critical benchmark in determining the viability of bioprinted kidneys.

Bioprinting the Kidney

The final and most directly relevant theme revolves around the specific application of bioprinting for the kidney. The literature shows that while significant research is underway, the kidney is one of the most complex organs to replicate due to its diverse cellular composition and intricate filtration function (Yan et al., 2018). Unlike simpler tissues, the kidney's function cannot be achieved by simply layering cells; it requires a highly organized 3D architecture capable of fluid exchange, selective filtration, and hormonal regulation (Humphreys, 2021).

Documents reviewed under this theme discussed early attempts to create kidney organoids using induced pluripotent stem cells (iPSCs), as well as prototype devices that mimic part of the kidney's function in laboratory settings (Xu et al., 2024). These innovations, though promising, are far from clinical readiness. The recurring issues include lack of long-term functionality, absence of proper vascular integration, and regulatory uncertainty regarding how such organs would be tested and approved for human use (Turunen et al., 2018).

Furthermore, case studies revealed that many of the current efforts remain at the proof-of-concept or preclinical stage. Even though some constructions have shown partial success in animal models, scalability and reproducibility remain significant barriers. This theme underscores both the potential and the limitations of kidney bioprinting as it currently stands.

3.14 Conclusion

Consequently, in this way this framework enabled an informed, thorough, and versatile examination of the possible advantages of 3D bioprinting in the case of diabetic kidney failure. This approach utilizes a myriad of perspectives and data has not only increased academic discourse but also resulted in substantial practical recommendations for enhancing clinical care and technology improvement.

Complementary, the identified themes provide an all-round insight into bioprinting in the given context of diabetic kidney failure. These themes expose both the technical and biological barriers as well as the broader clinical and material science aspects that must be addressed. With such systematic thematic approach taken on, the research achieves its objectives effectively and promotes comparison of both qualitative and quantitative data.

This approach exploits the benefit of qualitative and quantitative research by providing an overall understanding of the bioprinting of kidneys for the diabetic population. The acceptance of a practical philosophy and abduction enables adaptability and creativity that are essential in investigating cutting-edge technologies like bioprinting. This study is comprehensive because it combines case studies, survey responses, and the analytical process of thematic analysis to shed equitable and contextually informed light on the current status and prospects for bioprinting in the treatment of diabetic kidney disease.

4 Findings and Analysis

The chapter describes and assesses the major research findings drawn from a structured survey used on various stakeholder groups such as diabetic patients, those who had diabetic relations and medical personnel. The purpose of the survey was to evaluate existing understanding, readiness for adoption, and barriers to the use of bioprinting as a therapeutic option for kidney transplants in diabetic kidney disease patients.

A total of 70 respondents provided completed responses to the survey. The age, gender, and diabetes know-how of the participants group varied. The patients affected, caregivers, and healthcare professionals in this case completed a survey representing the diverse population in society concerning how this new technology is perceived. The study's findings were made more relevant and credible by the inclusion of individuals who knew something about diabetes, either by experience or expertise.

4.1 Analysis

Hospitalization History by Respondents of Diabetic Patients

Accessing information on diabetes-related health care is a key element to appraising the possible use of advanced treatments as bioprinted kidneys among diabetics. Since hospitalization rates had to be understood, respondents were asked about their or referred patient's experience with hospital stays. Many respondents (71.4%, n=50) indicated they had experienced hospitalization, while only 24.3%, representing n=17, responded in the contrary sense. An ambivalent few participants (4.3%, n=3) indicated "Maybe".

There are two important aspects to this result. First, it brings attention to the high rate of urgent need for medical care among patients with diabetes; as a matter of fact, one of the central reasons that push the patients to hospitalization is kidney complication. Second, it indicates that the large proportion of

respondents who have been hospitalized or know someone that has been hospitalized represents their actual engagement in current health care response to diabetic complications. The general attitude of patients with comorbidities was more open to new approaches that could lessen the need for long-term dialysis, or face problems in organ transplant.

Caregivers and healthcare professionals were specifically asked about the follow-up question: “How many of your diabetic patients had to be hospitalized?” Almost 53% reported “Not Applicable” because they neither cared as caretakers nor treated as medical personnel but those that responded affirmed the earlier finding:

- 18.6% stated “Most of them” had been hospitalized.
- 12.9% indicated “Only a few of them.”
- 8.6% reported “None of them.”
- 7.1% said “All of them.”

8. Have you or the diabetic patient ever been hospitalised?

70 responses

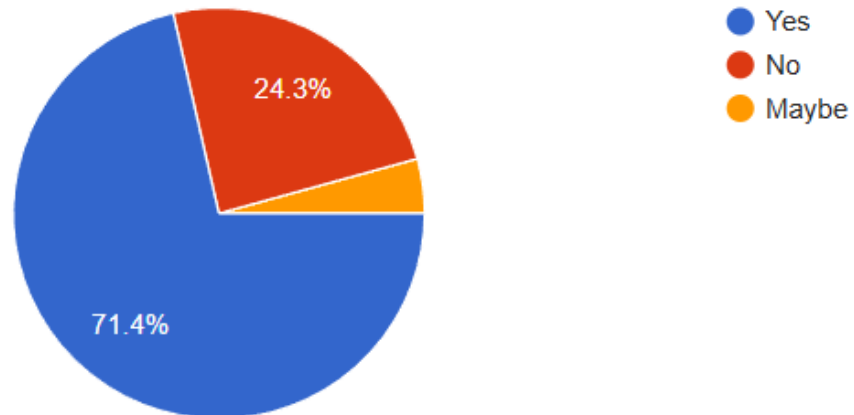


Figure 1: Survey Analysis 1 (Compiled by Author)

9. If you are a caregiver or a healthcare professional, how many of your diabetic patients have been hospitalised?

70 responses

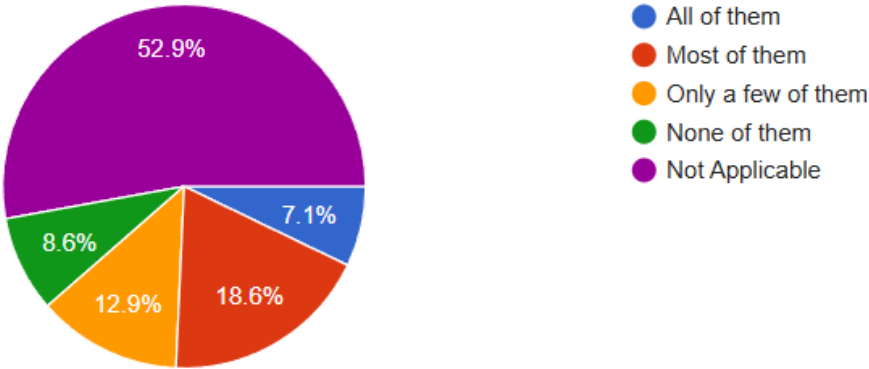


Figure 2: Survey Analysis 2 (compiled by author)

Care givers concurred that hospitalization is a common phenomenon in the management of diabetes, particularly when renal complications are brought forth, in agreement with patient reports. The results align with Liyanage et al. (2015) who document that diabetes has high rates of hospitalization worldwide, mostly due to the progression of nephropathy.

Incidence of Kidney-Related Issues Among Respondents

Measurement of the rates of kidney complications in survey respondents is important for the interpretation of the answers concerning acceptance of bioprinting. The survey asked how often respondents or the diabetic patient that they referred to had ever been faced with nephropathy—a widespread and serious complication of diabetes. 50% of the respondents had obviously experienced kidney-related problems while another 11.4% responded “Maybe” which might describe the uncertainties or unwarranted symptoms. The first response rate of “No” was 45.8%, but 38.6% was not willing to answer to “No”, which meant that most of the respondents either had personal experience with kidney issues or reported that their referred diabetic patients affected, therefore, the prevalence of kidney complications among survey

10. Have you or the diabetic patient faced kidney-related issues (Nephropathy)?

70 responses

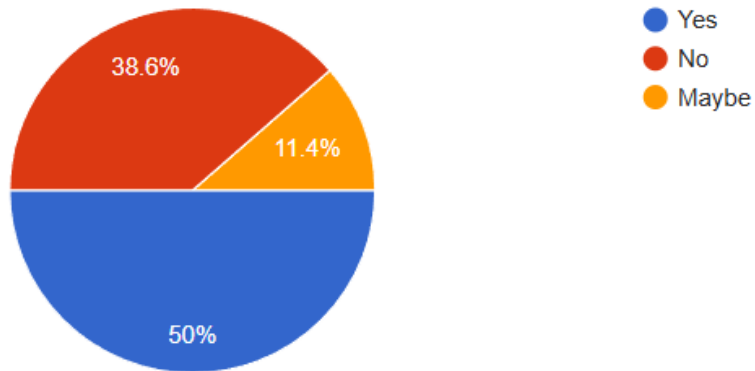


Figure 3: Survey Analysis 3 (compiled by Author)

11. If you are a caregiver or a healthcare professional, how many of your diabetic patients have faced kidney-related issues (Neuropathy)?

70 responses

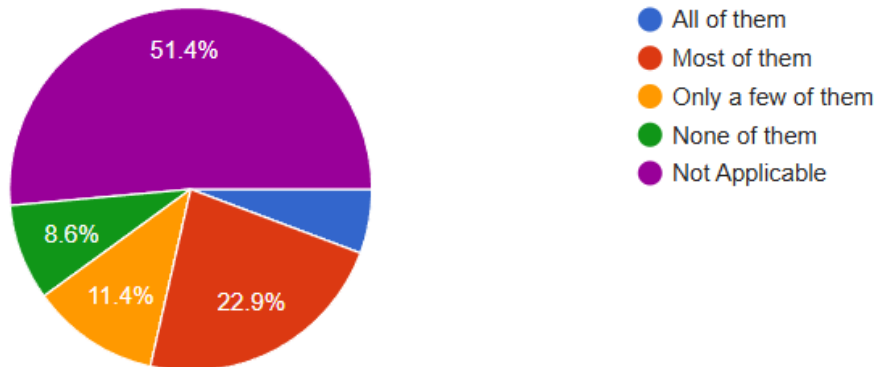


Figure 4: Survey Analysis 4 (compiled by Author)

Such results illustrate the high global load of diabetic nephropathy and are in congruence with the studies of Liyanage et al. (2015) who reported a strong link between diabetes and end-stage renal disease. Understanding obtained from findings shows that respondents who experienced or observed nephropathy were especially responsive to such developments as bioprinted kidneys, thereby reinforcing the observation that exposure to disease tends to increase willingness to embrace state-of-the-art therapies.

Respondents who were healthcare providers and caregivers were required to give an account of the number of their diabetic patients who presented with kidney-complaints. However, 51.4% ticked “Not Applicable” with the remaining showing the 22.9 This data underlines the significance of nephropathy in treating diabetes and critically demonstrates the need for new treatment options.

The findings clearly show that bioprinting technology has both medical and substantial emotional value for the patients who suffer from kidney problems caused by diabetes. It highlights the need for additional exploration of bioprinting as a viable and patient-oriented solution to deal with diabetic kidney failure at a larger scale.

Familiarity with Bioprinting

The respondents were queried concerning their comprehension of 3D bioprinting as a tool for organ transplantations solutions; a clear tendency emerged from the results. Almost half (49%, n=34) of those surveyed said that they had “no familiarity” (n=34) with the technology. In contrast, 30 % (n=21) reported only “somewhat familiar”, while just 21% (n=15) were “very familiar”.

12. Have you heard about the 3D bioprinting organ before this survey?

70 responses

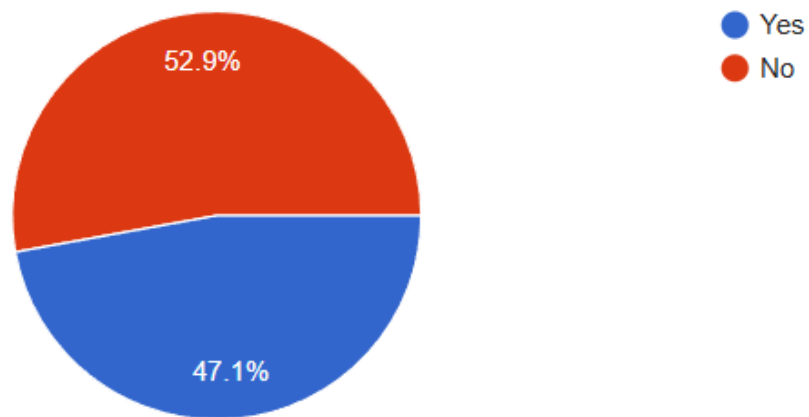


Figure 5: Survey Analysis 5 (compiled by author)

13. How familiar are you with the idea of 3D bioprinting as a solution to organ transplantation?

70 responses

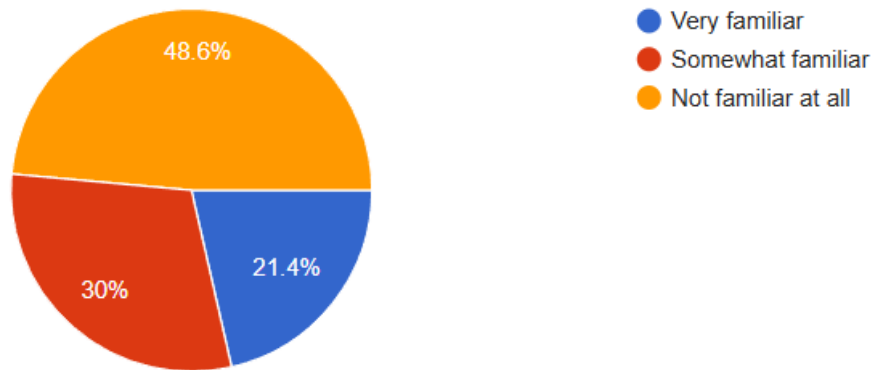


Figure 6: Survey Analysis 6 (compiled by Author)

The fact that these results demonstrate a significant deficiency in understanding bioprinting among respondents of a general and healthcare experience nature suggests that there was little knowledge in this area. The rate of application of bioprinting in experimental and preclinical settings has been on the rise, yet awareness remains behind. The current findings reflect former reports that have shown the general population rarely knows about healthcare technology, especially in new areas like regenerative medicine. The general population's knowledge of healthcare technology is often lagging scientific advancements (Murphy and Atala, 2014). This evidence demonstrates that the assurance of understanding of the public and the free exchange of scientific breakthroughs is a prerequisite.

Support for Bioprinted Kidneys

Despite a lack of any thorough understanding, the results illustrate significant potential for positive attitudes towards bioprinted organs if they are found to be not harmful and functional. If people were guaranteed that bioprinted organs are not only safe but also effective, the majority would agree and enthusiastically support using them in liver transplants.

- 63% (n=44) answered "Very likely",
- 27% (n=19) responded "Likely",

- Only 10% (n=7) were “Neutral or Not sure”.

17. If bioprinted organs are proven to be safe and effective, how likely would you be to support their use in kidney transplantation?

70 responses

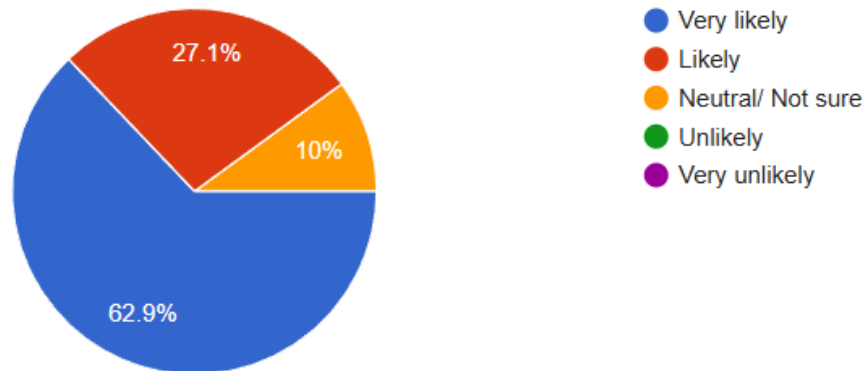


Figure 7: Survey Analysis 7 (compiled by Author)

The level of support emerged from people who weren’t familiar with bioprinting suggests that the public is enthusiastic about adopting frontier medical advancements, especially considering organ shortages and the promises of revolutionary treatment. This finding agrees with previous trends that show the medical promise has the potential of overwhelming fear for new technologies in healthcare innovations adoption (Vijayavenkataraman et al, 2018).

Willingness to Consider a Bioprinted Kidney

The participants responded and most of them indicated willingness, which is the technology’s potential for social acceptance. The collection of such information is paramount in the pathway of identifying the readiness of patients and healthcare professionals regarding adopting bioprinting as a real-life problem-solving procedure. The willingness of stakeholders to adopt bioprinting as a potential solution to individual or family health problems is a valuable metric of the future potential of this technology. Participants were asked: “Whether you will be in need of a kidney transplant yourself, or for your patient, or for a loved one, would you seriously consider the use of a 3D bioprinted kidney?”

The responses were highly indicative of cautious optimism:

- 64% (n=45) selected “Maybe, but I need more information.”
- 34% (n=24) responded “Yes, definitely.”

- Only 1 respondent answered “No, I would not consider it.”

15. If you, your patient, or a loved one needed a kidney transplant, would you consider a 3D bioprinted kidney as a solution?

70 responses

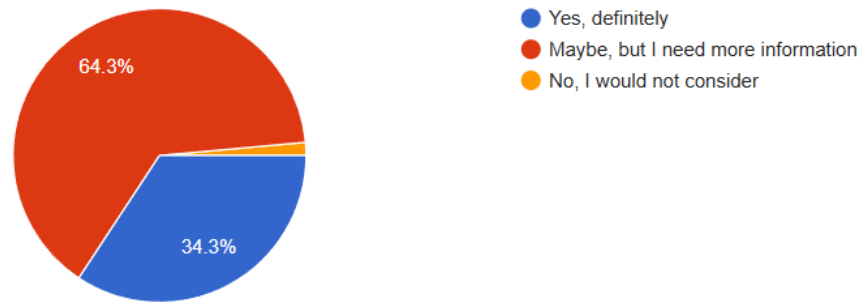


Figure 8: Survey Analysis 8 (compiled by Author)

The findings reveal complicated reality: Respondents have a high interest in bioprinting but are still cautious about some aspects of the technology’s scientific basis. This itself is proof of the fact that scientific breakthroughs are mostly closely related to public awareness as well as public acceptance. Murphy and Atala (2014) posit that the new medical technologies need to be mainstreamed widely which will be necessitated by both educational exercises for the affected patients as well as programs geared towards building trust in these innovations.

The data indicates a great opportunity for improvement. If outreach and patient-centered educational initiatives were undertaken, the chances are that a lot of people would find it easy to support the use of bioprinted kidneys, at least in the light of current donor shortages and waitlists.

Perception of Medical Sector Readiness

The expression of willingness of the medical community to consider bioprinted kidneys as a potential choice for the transplantation was met with somewhat more restrained responses. Most reported ambivalence, reflecting the fact that though individual support exists, it appears that an overall view is still that institutional frameworks, technical, or regulatory conditions are still not yet adequate for this technology.

This approach is confirmed by regulatory research such as Mladenovska et al. (2023), which states that ambiguous legal guidelines and inadequate standard protocols for the bioprinted organs are substantial barriers to adoption. Such worries on readiness might quell public euphoria the moment clinical application starts portraying the difficulties of successfully transitioning experimental technology into the routine healthcare practice.

Respondents to the survey on the medical sector's preparedness for the bioprinted kidneys for transplantation were resiliently mixed.

- 46% (n=32) answered "Yes",
- 40% (n=28) selected "Not sure",
- 14% (n=10) responded "No."

19. Do you think the medical sector is ready to accept bioprinted kidneys as a solution to organ transplantation?

70 responses

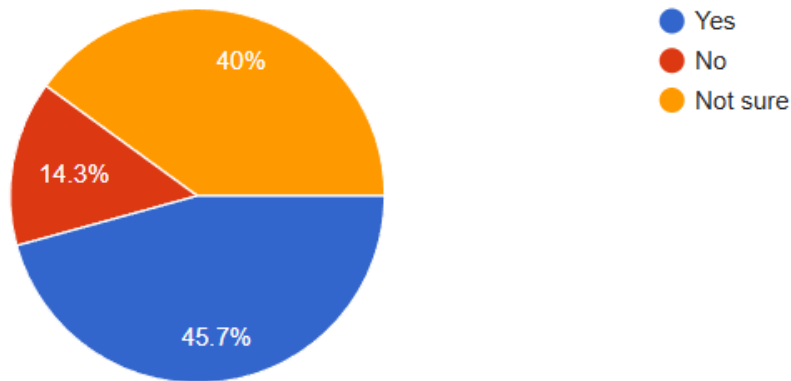


Figure 9: Survey Analysis 9 (compiled by Author)

This result shows that, however favorable attitudes toward bioprinting may be, the people also tend to doubt that the existing systems are ready for such innovations. The difference in sentiment may be due to the novelty of technology and the absence of clinical testing, or formal guidelines.

Our results, like those reported by Mladenovska et al. (2023), show that even groundbreaking biotechnologies can fail to advance if a clear regulatory framework and a set of clinical protocols are not

in place. Uncertainties from respondents might be related to their being aware of systemic blockades such as lack of funding, lack of development of skills, and the regulatory barriers needed.

Perceived Concerns

To understand the attitude of the public toward the 3D bioprinting technology, respondents were requested to provide their major concerns concerning the development and application of the bioprinted organs. Participants could identify more than one answer, reflecting the diversity of concerns that come out. The data shows that respondents were most concerned about Safety and Effectiveness (70%) and Cost and Accessibility (67.1%). Such concerns clearly overwhelm others, which indicates that technical effectiveness and fair access rather shape public concerns about the technology.

16. What is your main concern regarding the technology of 3D bioprinted organs?
(Select all that apply)

70 responses

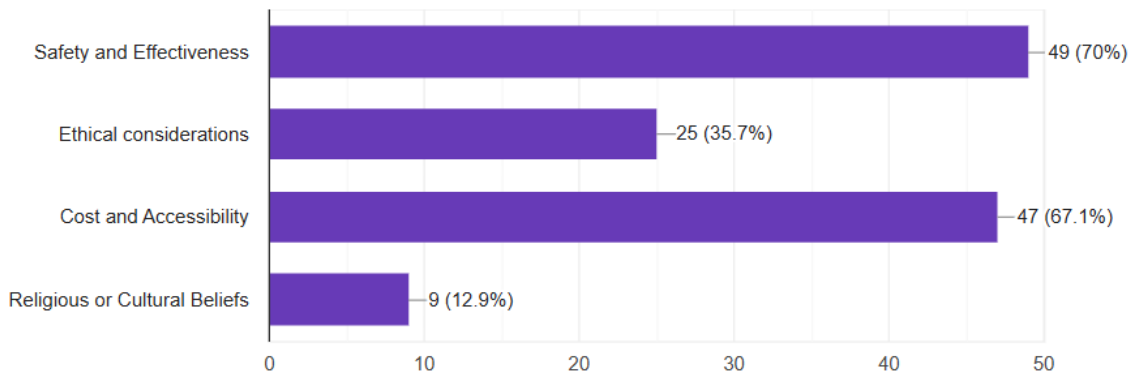


Figure 10: Survey Analysis 10 (compiled by Author)

The rest of the public concern about safety and effectiveness reflects scholarly findings that emphasize the experimental and unproved character of bioprinting. Several studies by Turunen et al. (2018) and Christou et al. (2023) have identified that this generation of bioprinted organs does not have full functional parity with normal organs and requires extensive clinical trials. This reluctance of respondents is the result of prudent hesitation: Public confidence on the projected success of bioprinted organs will only be capitalized on if bioprinted organs have been proven in terms of successful integration, prevention of organ rejection and long-term function.

Cost and Accessibility were next with postulated concerns from 47 out of 70 participants. Although the possibilities of bioprinting in general are widely recognized, an overwhelming sense of uncertainty is still

hanging in the air, when it comes to the potential for technology to become available more widely or in terms of affordability. Supporting findings include studies such as those by Chun et al. (2024) highlight the need for low-cost and large-scale bioprinting systems for adoption increases.

Ethics is one of the critical concerns for about 35.7% of sampled participants. Some common topics covering the concept are regarding the man-made organs, modification of human cells, and the general questionability of autonomy and boundaries. On the contrary, religious or cultural concerns were voiced by as little as 12.9% of the participants, suggesting a preoccupation with practical matters and scientific issues on the part of this community, rather than religious or moral protests.

From these results, it is necessary to prioritize the resolution of practical and procedural issues to enhance bioprinted kidney technologies use.

Perceived Barriers to Adoption

These results underscore the need to come together to combine the needs of researchers, policymakers, and the public to develop the use of bioprinted kidneys. As Christou et al. (2023) note, the incorporation of bioprinted organs into actual clinical usage necessitates an infrastructure that enables both technologies and public trust and system readiness.

Participants were encouraged to detail “the greatest barrier to using bioprinted kidneys”. Four main barriers were identified:

- Lack of awareness – 41% (n=29)
- High costs – 39% (n=27)
- Limited medical acceptance – 19% (n=13)
- Ethical or religious concern – 1 respondent

18. In your opinion, what do you think is the biggest barrier to the use of bioprinted kidneys?

70 responses

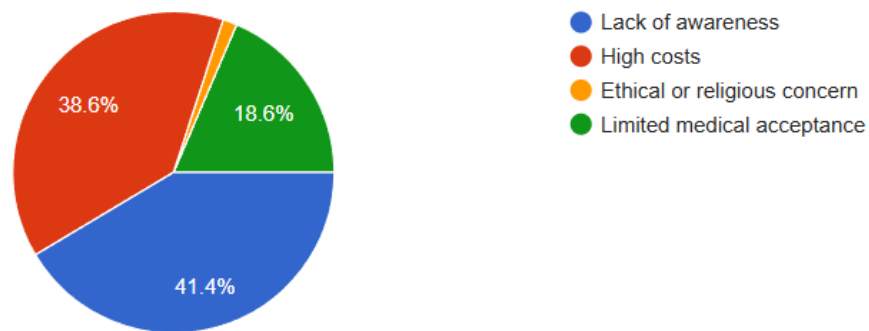


Figure 11: Survey Analysis 11 (compiled by Author)

The common assertion of an “lack of awareness” to be an obstacle is supported by prior studies that point to the importance of awareness and information demand. Such conclusions highlight the need for transparent information, greater public awareness, and collaborative stakeholder involvement for the enterprise of technological integration. For this endeavor to move forward, the world needs research organizations and public health institutes to take an active role in airing debates on these technologies.

In addition, the considerable number of cost-related issues identified by almost 40% indicate systemic impediments at work. While the lab research promises advances, for the widespread use of bioprinted kidneys, a great amount of work must be performed to distribute resources, draft legislation, and structure reimbursement. This viewpoint applies to the results obtained by Chun et al. (2024), who emphasize the need to make bioprinting technology less expensive and more accessible to increase its appeal in regenerative medicine.

4.2 Summary

The effect of this study was to evaluate the feasibility, adoption, and challenges of adopting 3D bioprinting technology as the treatment of kidney failure among diabetes patients. From answering questionnaires from 70 individuals, which included diabetic patients and family caregivers, and healthcare providers, prominent patterns and views were found.

To start with, though only 21% of the respondents found bioprinting technology reasonably well-known to them, the high support for bioprinted kidney technology was remarkable. Based on the responses to the survey, it was possible to note that more than 90% of those surveyed would probably agree to use bioprinted kidneys for transplantation into the kidneys if their safety and efficiency were proven. The high level of support means that, armed with the right information, and confirmation, the public and the professionals view bioprinting favorably.

Second, the study showed high receptiveness on the side patients as well as caregivers to explore alternatives to standard kidney failure treatments. This was most evident in respondents who had had kidney complications or hospitalization, where 71.4% had been hospitalized and 50% were evidence of nephropathy. The fact that the respondents with medical issues were responsive to the bioprinting points to the impact of medical experience on personal levels regarding the responsiveness to new technologies.

However, the findings mentioned several severe obstacles and reservations. Safety and effectiveness were always the top priorities in the list, followed by cost and awareness. Significant deficiency in ethical and religious considerations indicates that cultural barriers on bioprinting technology are unlikely to be significant within this population. Further, only 46 % of the participants believed that the medical sector was ready to take bioprinted organs into use, which demonstrated the lack of link between public excitement and institutional ability.

These outcomes continue to prove the importance of exploring the current research challenge: << the dire lack of vital organ and the need to apply fresh ways of handling it. Bioprinting demonstrates the possibility of being an innovative medical solution, and significant steps are needed to promote trust and stimulate research activity as well as create effective clinical facilities.

4.3 Recommendations

For Research and Academics

1. Expand Longitudinal Studies: An analysis of cross-sectional data does not show how public opinion develops. Further studies should track attitudes commensurate with development in bioprinting, especially in preclinical and clinical stages.
2. Targeted Educational Campaigns: Strong attempts are needed to inform the population of 3D bioprinting technologies. It is essential for universities and hospitals and government bodies to

come together to create information that is user friendly which explains the technology, how dangerous it is, and the long term uses.

3. Focus on Real-World Case Studies: Scholarly work in the future should explore contemporary bioprinting clinical trials around the designated areas and keep track of patient implications, therefore broadening empirical knowledge and providing various examples to the doubtful.

For Healthcare Practice

4. Engage Medical Professionals Early: It is vital that the education of bioprinting be incorporated into the available training programs while consideration of ethics and technical aspects makes the systematic integration possible.
5. Include Patient Voices in Development: Patient-involvement at the design and experimentation phase of bioprinting can lead to solutions that address clinical and user need.

For Policy and Regulation

6. Develop Clear Regulatory Guidelines: Government agencies, biotech organizations and bodies in charge of health should work in partnership to develop sophisticated and comprehensible regulations regulating the establishment, assessment and introduction of bioprinted organs.
7. Subsidize and Incentivize Innovation: A major challenge found was the high financial barriers that accompany bioprinting. Government incentives for research and clinical expenses reduction will be of critical help towards facilitating access to disadvantaged demographics.
8. Establish Ethical Frameworks: While the number of ethical issues in this examination is limited, it is essential that strong ethical regulations are maintained to solve future problems and provide future patients with confidence, while the bioprinting is implemented into medical care.

4.4 Key Findings from Literature Review

The rapid development of 3D bioprinting has attracted significant interest in the function of 3D bioprinting in solving worldwide kidney shortage, particularly in diabetic patients with end-stage renal disease (ESRD). Based on contemporary academic materials, this section reviews the bioprinting technologies, describes its important barriers for adoption, estimates its economic advantages, and refers to specific connections to diabetic patients. Each section is meant to support the central goal of research. To serve as a repository for knowledge on kidney bioprinting as a reference point for researchers and clinicians engaged in kidney bioprinting.

Bioprinting as a Technological Response to Diabetic Kidney Failure

Qualifying as one of the worst outcomes of living with diabetes for a long period of time, diabetic nephropathy is a major contributor to the global incidence of ESRD (Liyanage et al., 2015). As its currently the best therapy, the ever dwindling supply of organs for transplantation pushes investigators to look for another solution. Under these conditions, bioprinting constitutes a compelling theoretical option. Works by such scholars as Christou et al. (2023) as well as Turunen et al. (2018) prove the ability of 3D bioprinting to manufacture individually tailored and immune-compatible kidney structures consisting of living cells and hydrogels.

Turunen et al. (2018) posits that bioprinting is both an attractive yet apprehensive undertaking gesturing at the possibilities and questionable possibilities with realistic complications. From their investigation, they find that simple tissues such as cartilage have already had success in the bioprinting field while replicating kidney with its intricate vascular anatomy and nephrons and glomeruli is still one of the most challenging aspects of bioprinting. The significance of precise vascularization and tissue organization are at the center of the existing kidney bioprinting challenges though stem cell-derived organoids bring much hope for additional progress (Chun et al., 2024).

Challenges and Barriers in Bioprinting Kidneys

A critical hindrance to accomplishing functional kidney tissue through bioprinting is getting this balance of vascularization right. The survival of kidneys depends on its complex capillary and vessel network responsible for filtering blood and maintaining electrolyte balance. Budharaju et al. (2024) investigate the use of embedded 3D bioprinting for building large sized, vascularized tissue tissues. Their study has significant milestones in maintaining cell viability and scale up of printing processes, but it also outlines obstacles towards attaching printed tissues into host vasculature, a crucial condition for functional network transplantations.

Another major barrier is immunogenicity. One of the key limitations (according to Elalouf, 2021), is the immune response of the system to the biomaterials that are used in bioprinting technologies. While bioprinted tissues are synthesized using materials designed to reduce immune reactions, foreign body response by the body continues to be a challenge and this may lead to inflammation and fibrosis of the tissues, which reduces the organ's ability to perform its functions. Diabetics having poorly functioning immunity, such complications could mean a higher risk for them. It is considered that immunomodulatory

techniques used in combination with the patient are an option to improve immune tolerance but lots of research work must be carried out.

Material alternatives remain an important topic of research discussion. Benwood et al. (2021) also gave a full review of natural biomaterials that are used as bioinks in the context of kidney bioprinting. While the natural polymers, such as alginate, collagen, and hyaluronic acid provide a scaffold that models the components of extracellular matrix, they are affected by the problems like batch deficiencies and lack of adequate mechanical strength. Having the balance between strength and biocompatibility, multi-component bioinks have been suggested as the promising resolution. Even with attempts, it is still challenging to attain bioinks that provide standardized properties, reproducible performance, and scale-up.

The existence of regulatory uncertainty introduces another layer of complexity to the area. According to Mladenovska, et al (2023), current medical regulations fail to properly deal with the complexities of bioprinted organs. The existence of living tissues in bioprinted kidneys makes it more difficult to classify and approve them, as with traditional medical devices or drugs. Regulatory guidelines' lack of certainty prevents the development of clinical trials and investment in, and innovation of the given area. This is in direct accordance with the objective of the research to identify major systemic challenges existing to implementation.

Cost-Effectiveness of Bioprinting Technologies

The research wanted to determine whether bioprinting can be economically justified in the formation of kidneys. Although launching a venture with the help of bioprinting technology, materials and experts would cost a lot, there seems to be some evidence of possible savings over the long term that might make up for the initial outlay.

As Christou et al. note (2023), the bioprinting technologies could help lessen the dependence on lasting dialysis or transplantation, i.e., using specific patient cells to reduce immunosuppression therapy. In the long term, the resultant decline in need for lifelong dialysis and repeat transplantation would put significant fiscal relief on both health-care systems and patients. Moreover, the possibility of eradicating organ waitlists may reduce costs related to emergency dialysis as well as demand for the hospital.

Chun et al. (2024) have taken this concept further by producing an appropriate cheap open-source bioprinting technology capable of printing out iPSC-derived kidney organoids. The sub cost and free platform they develop helps more institutions and hospitals to be a part of the cutting edge in term of

research hence their playing field is being leveled regarding regenerative therapeutics. The formation of nephron-like structures by the platform offers potential to improve drug evaluation, disease modeling, and ultimately will lead to clinical therapies.

Furthermore, the current venture of NASA on space bioprinting (NASA, 2023) shows that such new discoveries on microgravity can result in economy in the terrestrial applications. Although it is still not applied, this research suggests that technological advancements in space bioprinting can lead to more inexpensive treatments for terrestrial applications.

However, Mladenovska et al. (2023) states that attaining cost effectiveness will depend upon accelerated regulatory landscapes and higher manufacturing capacity. Assembling each organ separately in tight conditions would probably make the procedure unaffordable. The attainment of major economic gains of course demands the concurrent enhancement of technical capabilities, regulatory processes and infrastructure.

Adequacy of Bioprinting for Diabetic Patients

The bioprinting strategy's applicability to the peculiar challenges of diabetic patients is one of the highlights of this dissertation. Complications, including vascular damage and immune defects as well as saturation of associated comorbidities make diabetic patients less appropriate candidates for standard transplantation. Faced with the need to provide their diabetic patients with their own, tailored tissues, bioprinting might help reduce some of the risks related to their conditions.

The proposition for this theory receives considerable support from research studies analyzed in this project. As stipulated by Liu et al. (2023), 3D tissue analogs are customizable to specific contexts, and regarding diabetes, they are customized as designed kidney tissues that consider long-term damage by high blood sugar. The research implies that although complete bioprinted kidneys are not practical in clinics yet, specialized tissue models designed for diabetes-related studies, and drug assays offer meaningful benefits.

Fransen et al. (2021) add value by pointing the importance of bioinks in achieving their results. It would be highly effective to use bioinks targeted at the diabetic kidney's milieu. The authors argue for increased research into biomaterial properties customized for target disorders, particularly disorders that perturb the cellular microenvironment such as diabetes.

The research bioprinted pancreatic islets by Klak et al. (2023) provides valuable indirect evidence of the application of bioprinting. Although their research mostly focuses on Type 1 diabetes, the successful outcome of implantation of the insulin-secreting bioprinted tissue in the mouse model indicates the wider regenerative potential for bioprinting in the case of organ failure in diabetes.

Xu et al, (2024) advocate for the need to work with accessibility before developing bioprinting platforms with focus on under resourced communities. This is especially important for diabetic patients who are encountering obstacles to receiving healthcare in places where diabetes occur very commonly. The nature of their approach has scrolling open-source development and scalability as an early step to more inclusive biomedical innovation.

Synthesis: Bridging Hope and Practicality

Literature always clearly indicates that there is great promise in Bioprinting, and major barriers are what currently block its clinical application. Bioprinting lies, as Turunen et al. (2018) remark, between elevated expectations and promising prospective options. Although advances in bioprinting are taking place at a fast pace, the kidney's complex structure, immunological hurdles, and eventual adoption by medical praxis make it especially difficult to reproduce.

Predicate upon reviewed literature, almost everywhere, the critical role that interdisciplinary research needs to play in the future is highlighted. Developments in this field are coming on through material advances (Benwood et al., 2021), changes in regulations (Mladenovska et al., 2023), and in technical scalability (Chun et al., 2024).

Besides, the excessive correlation of this technology's objectives with crucial medical demands, especially for diabetic patients, significantly enhances the ethical and societal urgency of research that is at an ongoing stage. According to Sundaram et al. (2025), bioprinting goes beyond technical pinnacles and indicates a patient break-through regarding kidney failure. It signifies an essential opportunity for people with no other practical treatments and who are headed for permanent dialysis or dying without a donor kidney.

4.5 Conclusion

The literature reviewed indicates that while 3D bioprinted kidneys are still under development, the science basis, material technology and the medical imperative are aligned with the planned outcome in treating diabetes related kidney failure. The reviewed studies not only confirm the practicality of the process on

the applied side but also demonstrate major scientific, clinical, financial, and regulatory barriers that require overcoming for broad implementations.

With this research, we achieve a relevant and patient-clustered knowledge of what lies ahead for 3D bioprinting in renal treatments. It shows that impacted people – primarily diabetic individuals and ESRD patients – are both aware of limitations of the system and eager to look for new approaches. If despite existing hurdles, the convergence of patient demand, technical capabilities, and a willing population is a strong foundation for bioprinting to become the game changer that it can be in the realm of organ transplant.

The conduct and analysis of this vast literature buildup allows this research to meet its purpose, which is the creation of a unified knowledge repository for the stakeholders in academia, healthcare, and industry. Investment and cooperation made by various stakeholders continue to be essential for bringing the bioprinting closer to real-world solutions.

5 Conclusion

This dissertation aimed to find out whether 3d bioprinting technology can be used as a solution regarding diabetic kidney failure with special attention paid to its technical feasibility, social acceptance, and cost. By combining research findings from both academic and original survey findings, this research has explored the feasibility of bioprinted kidneys as an alternative to classical transplantation and dialysis. By combining not only scholarly research insights but also insights from the real-world stakeholders, this chapter presents the study findings robustly, discusses their implications, suggests guidelines for future clinical practice and additional study, recognizes constraints and personal growth encountered in research, respectively.

Research highlighted that even though the development of bioprinted kidneys is yet in its infancy, it promises good opportunities for developing clinical approaches to renal failure, especially for the patients with diabetes. Consistent academic findings pointed out that advances in stem cell technology, use of biomaterials and micro vessel structuring were all converging to drive the aim of generating clinically viable, personalized organs to the realization. Results of a structured survey revealed that low familiarity with technology has not been a barrier to positive attitudes from both laypeople and healthcare providers towards embracing bioprinted organs, if they are both safe and effective. Respondents were positive and ready to accept innovation regardless of their level of understanding of the technical aspects.

The results of this research are very important. The reason why the participants supported bioprinted kidneys comprised more of direct personal experience of diabetes and hospitalization than understanding of the technology. Those (patients) who were struggling with the conditions of dialysis or who suffered from the waiting period for the organ transplant were correspondingly optimistic about the opportunities bioprinting might present. The consequences of the chronic disease are personally experienced by those who show high motivation to adapt to new medical innovations. While the literature around bioprinting is typically very conservative and focuses on constraints and regulatory hurdles, it turned out in this study that patient perspectives are characteristically optimistic and forward-looking. These findings shed light on an important misplacement between how the topic is structured by researchers, and the way patients perceive the options.

Findings of the research show that, from an academic perspective, the primary technical and biological barriers for the bioprinting of kidney, including proper blood vessel development, immune response matching, and exact structure, are poorly described in the literature. Yet, ingenious developments continue to pop out from all corners of the world, from public institutions engaging with private organizations. The work of Chun et al. (2024) got world headlines, describing a new approach to developing economic, high-volume bioprinting platforms that can reliably produce kidney organoids. On similar notes, the preliminary data highlighted the concerns on cost by participants though these surveys also identified interest in forward movements that would create level playing fields as regards treatments. The financial implications of the survey responses ran along with the findings in published literature that, at most recommendations, focus on the high associated charges of the equipment used in bioprinting and clinical trials as limitations. However, both sets of findings indicate that in future, bioprinting can help reduce the costs of immunosuppressants, repeated hospitalizations, as well as dialysis making it economically viable when applied with expansion.

Other parties also demonstrated significant concern with respect to the safety and performance of the bioprinting technology. Even though the survey respondents generally approved of bioprinting technology, many highlighted the importance of knowing more before choosing. The same viewpoint coincides with the ideas represented in the scholarly literature on the ethical and regulatory frameworks for bioprinting. To the Mladenovska et al. (2023), regulators face enormous challenges in assigning a suitable category to bioprinted products, which are in the periphery of medical devices, tissue

transplantation, and pharmacological therapies. Improvements, regardless of success, may be in danger due to delays in approval and deployment if such a framework is lacking. The experimental skepticism in the participants of the study was reflective of a doubt as to whether the healthcare system was ready to accept this sophisticated and complicated treatment option.

Results from the study show a strong correlation between the issues participants mentioned regarding bioinks and materials and what has been published in academic studies. The participants tended not to talk much about material related issues, however, the academic evidence highlighted that the choice of biomaterials is crucial for determining cell function, structural support and compatibility with tissues. According to the data by Benwood et al. (2021), the design of bioink is a decisive factor for successful bioprinting. Respondents were not always clear on the technical issues, but their concerns about safety, performance, and immune compatibility show a certain insight into the problem.

The core academic and applied success of the dissertation uncovered the discrepancy between the enthusiasm of the stakeholders and the ability of the healthcare systems to deliver bioprinted organs. Although in general the idea is supported by the public, the systems for infrastructure, preparation of workforce and oversight in regulation to scale up the production of bioprinted kidneys yet are unavailable. Building on these insights, the dissertation suggests a family of first steps ahead. First, some public awareness campaigns should be initiated to raise awareness concerning patients; patients, families, and healthcare professionals; about the scientific and safety aspect of bioprinting. Second, we need to strengthen interconnection between engineers, immunologists, nephrologists, and ethicists to face multifaceted challenges of this technology. Third, it is time for policymakers and health agencies to begin drafting guidelines that address ethical, legal and financial integration of bioprinted organs into existing transplantation platforms. Fourth, the researchers should pay attention to studying the long-term effects in vulnerable populations, namely diabetics with immunodeficiencies.

There are a few limiting aspects in the current research. At first, the investigation relied on individuals willing to inform them about their experience and the small portion of people extrapolating the answers was not possible. Second, while the research could easily get well to diabetic patients and their families, finding medical professionals who can be well versed in bioprinting or taking care of kidneys proved more challenging. Being cross-sectional study, the focus is made on some moment, rather than on changes in perspectives as technology evolves over time. Moreover, in reviewing existing literature, a comprehensive

view was obtained but was limited to English language material hence not involving research from other language or other areas that could bring a diverse perspective.

With these limitations, however, the work provides value for scholarly knowledge and for discussions related to implementation. The study highlights the experiences of people living with diabetic kidney disease and portrays that in addition to medical need, there is enhanced social and emotional need for more innovative and integrated approaches to their treatment. The conceptual framework of this research, which related bioprinting technology, patient need, stakeholder acceptance, cost, and regulation has application in other disciplines of tissue engineering and regenerative medicine. It gives a structure that allows future researchers and policymakers to assess the viability of bioprinting technology in the treatment of diseases other than diabetic kidney disease.

Researchers would be able to adopt various perspectives in current investigations. Long-term studies of patients' attitudes from the beginning of clinical trials to standardization of regulatory pathways may turn out to be of high value. Investigating bioprinted kidney organoids' application in drug trials or part of the organ substitution could lead to whole kidney transplantation. Ideal economic practices can be identified through juxtaposed analysis of how various healthcare systems run bioprinting. The qualitative study made on patients' experience and attitude towards lab grown organs should complement our current biomedical perspectives.

In retrospect, over the course of writing this dissertation, I have had this rare opportunity to cross these disciplines: engineering, medicine, ethics, public health and get an insight on their interactions in meaningful progress in healthcare. Doing this has increased my reverence for interdisciplinary efforts. answering they should have the support of society, regulatory atmospheres that exist, good ethical practices, and smooth integration into medical care. The research, originally academic in nature, evolved into a focused attempt to promote transparent and open models for health innovation.

Generally, this study shows that bioprinting emerges as an exciting strategy to transform kidney care, particularly for diabetic patients who are currently frustrated by the limitations of available treatments. Although there are still obstacles, the concurrence of public support, scientific findings, and institutional change may soon allow for a practical application of bioprinted kidneys. The research presented in this dissertation has laid a strong platform for other studies and helps stakeholders who want to innovate in the sector.

References

- 3D Bioprinting - NASA, 2023. URL <https://www.nasa.gov/missions/station/iss-research/3d-bioprinting/> (accessed 5.4.24).
- 3D Bioprinting of Living Tissues [WWW Document], 2016. Wyss Institute. URL <https://wyss.harvard.edu/technology/3d-bioprinting/> (accessed 5.4.24).
- Agaram Sundaram, V., Sowndharya Balamurugan, B., Viruthachalam, V., Chopra, H., Emran, T.B., 2025. Advancing organ and tissue repair through 3D bioprinting: a breakthrough solution to the global organ shortage crisis. *International Journal of Surgery Open* 63, 55. <https://doi.org/10.1097/IO9.0000000000000238>
- Aljohani, W., Ullah, M.W., Zhang, X., Yang, G., 2018. Bioprinting and its applications in tissue engineering and regenerative medicine. *International Journal of Biological Macromolecules* 107, 261–275. <https://doi.org/10.1016/j.ijbiomac.2017.08.171>
- Anders, H.-J., Huber, T.B., Isermann, B., Schiffer, M., 2018. CKD in diabetes: diabetic kidney disease versus nondiabetic kidney disease. *Nat Rev Nephrol* 14, 361–377. <https://doi.org/10.1038/s41581-018-0001-y>
- ARPA-H launches program to bioprint organs on demand | ARPA-H [WWW Document], 2024. URL <https://arpa-h.gov/news-and-events/arpa-h-launches-program-bioprint-organs-demand> (accessed 5.4.24).
- Benwood, C., Chrenek, J., Kirsch, R.L., Masri, N.Z., Richards, H., Teetzen, K., Willerth, S.M., 2021. Natural Biomaterials and Their Use as Bioinks for Printing Tissues. *Bioengineering* 8, 27. <https://doi.org/10.3390/bioengineering8020027>
- Budharaju, H., Sundaramurthi, D., Sethuraman, S., 2024. Embedded 3D bioprinting – An emerging strategy to fabricate biomimetic & large vascularized tissue constructs. *Bioactive Materials* 32, 356–384. <https://doi.org/10.1016/j.bioactmat.2023.10.012>
- Chimene, D., Lennox, K.K., Kaunas, R.R., Gaharwar, A.K., 2016. Advanced Bioinks for 3D Printing: A Materials Science Perspective. *Ann Biomed Eng* 44, 2090–2102. <https://doi.org/10.1007/s10439-016-1638-y>
- Christou, C.D., Vasileiadou, S., Sotiroudis, G., Tsoulfas, G., 2023. Three-Dimensional Printing and Bioprinting in Renal Transplantation and Regenerative Medicine: Current Perspectives. *Journal of Clinical Medicine* 12, 6520. <https://doi.org/10.3390/jcm12206520>
- Elalouf, A., 2021. Immune response against the biomaterials used in 3D bioprinting of organs. *Transplant Immunology* 69, 101446. <https://doi.org/10.1016/j.trim.2021.101446>
- Foster, C., 2024. Methodological pragmatism in educational research: from qualitative-quantitative to exploratory-confirmatory distinctions. *International Journal of Research & Method in Education* 47, 4–19. <https://doi.org/10.1080/1743727X.2023.2210063>

Fransen, M.F.J., Addario, G., Bouten, C.V.C., Halary, F., Moroni, L., Mota, C., 2021. Bioprinting of kidney in vitro models: cells, biomaterials, and manufacturing techniques. *Essays Biochem* 65, 587–602.

<https://doi.org/10.1042/EBC20200158>

Huang, G., Zhao, Y., Chen, D., Wei, L., Hu, Z., Li, J., Zhou, X., Yang, B., Chen, Z., 2024. Applications, advancements, and challenges of 3D bioprinting in organ transplantation. *Biomaterials Science* 12, 1425–1448. <https://doi.org/10.1039/D3BM01934A>

Humphreys, B.D., 2021. Bioprinting better kidney organoids. *Nat. Mater.* 20, 128–130.

<https://doi.org/10.1038/s41563-020-00881-5>

Kidney Engineering Technology for New Tissue Replacement Therapies [WWW Document], 2021. . Wyss Institute. URL

<https://wyss.harvard.edu/technology/kidney-engineering-technology-for-new-tissue-replacement-therapies/>

Klak, M., Wszola, M., Berman, A., Filip, A., Kosowska, A., Olkowska-Truchanowicz, J., Rachalewski, M., Tymicki, G., Bryniarski, T., Kołodziejka, M., Dobrzański, T., Ujazdowska, D., Wejman, J., Uhrynowska-Tyszkiewicz, I., Kamiński, A., 2023. Bioprinted 3D Bionic Scaffolds with Pancreatic Islets as a New Therapy for Type 1 Diabetes—Analysis of the Results of Preclinical Studies on a Mouse Model. *Journal of Functional Biomaterials* 14, 371.

<https://doi.org/10.3390/jfb14070371>

Koye, D.N., Magliano, D.J., Nelson, R.G., Pavkov, M.E., 2018. The Global Epidemiology of Diabetes and Kidney Disease. *Advances in Chronic Kidney Disease, Diabetic Kidney Disease (c. 2018)* 25, 121–132.

<https://doi.org/10.1053/j.ackd.2017.10.011>

Li, C., n.d. Applications of Three-Dimensional Printing in Surgery - Chi Li, Tsz Fung Cheung, Vei Chen Fan, Kin Man Sin, Christy Wai Yan Wong, Gilberto Ka Kit Leung, 2017 [WWW Document]. URL

<https://journals.sagepub.com/doi/abs/10.1177/1553350616681889> (accessed 2.8.25).

Liu, S., Cheng, L., Liu, Y., Zhang, H., Song, Y., Park, J.-H., Dashnyam, K., Lee, J.-H., Khalak, F.A.-H., Riester, O., Shi, Z., Ostrovidov, S., Kaji, H., Deigner, H.-P., Pedraz, J.L., Knowles, J.C., Hu, Q., Kim, H.-W., Ramalingam, M., 2023. 3D Bioprinting tissue analogs: Current development and translational implications. *J Tissue Eng* 14, 20417314231187113.

<https://doi.org/10.1177/20417314231187113>

Liyanaage, T., Ninomiya, T., Jha, V., Neal, B., Patrice, H.M., Okpechi, I., Zhao, M., Lv, J., Garg, A.X., Knight, J., Rodgers, A., Gallagher, M., Kotwal, S., Cass, A., Perkovic, V., 2015a. Worldwide access to treatment for end-stage kidney disease: a systematic review. *The Lancet* 385, 1975–1982.

[https://doi.org/10.1016/S0140-6736\(14\)61601-9](https://doi.org/10.1016/S0140-6736(14)61601-9)

Liyanaage, T., Ninomiya, T., Jha, V., Neal, B., Patrice, H.M., Okpechi, I., Zhao, M., Lv, J., Garg, A.X., Knight, J., Rodgers, A., Gallagher, M., Kotwal, S., Cass, A., Perkovic, V., 2015b. Worldwide access to treatment for end-stage kidney disease: a systematic review. *The Lancet* 385, 1975–1982.

[https://doi.org/10.1016/S0140-6736\(14\)61601-9](https://doi.org/10.1016/S0140-6736(14)61601-9)

Mirshafiei, M., Rashedi, H., Yazdian, F., Rahdar, A., Baines, F., 2024. Advancements in tissue and organ 3D bioprinting: Current techniques, applications, and future perspectives. *Materials & Design* 240, 112853.

<https://doi.org/10.1016/j.matdes.2024.112853>

- Mladenovska, T., Choong, Peter F., Wallace, Gordon G., and O'Connell, C.D., 2023. The Regulatory Challenge of 3D Bioprinting. *Regenerative Medicine* 18, 659–674.
<https://doi.org/10.2217/rme-2022-0194>
- Murphy, S.V., Atala, A., 2014. 3D bioprinting of tissues and organs. *Nat Biotechnol* 32, 773–785.
<https://doi.org/10.1038/nbt.2958>
- Nagarajan, N., Dupret-Bories, A., Karabulut, E., Zorlutuna, P., Vrana, N.E., 2018. Enabling personalized implant and controllable biosystem development through 3D printing. *Biotechnology Advances* 36, 521–533. <https://doi.org/10.1016/j.biotechadv.2018.02.004>
- Pati, F., Gantelius, J., Svahn, H.A., 2016. 3D Bioprinting of Tissue/Organ Models. *Angewandte Chemie International Edition* 55, 4650–4665.
<https://doi.org/10.1002/anie.201505062>
- Salybekov, A.A., Kinzhebay, A., Kobayashi, S., 2024. Cell therapy in kidney diseases: advancing treatments for renal regeneration. *Front. Cell Dev. Biol.* 12.
<https://doi.org/10.3389/fcell.2024.1505601>
- Seol, Y.-J., Kang, H.-W., Lee, S.J., Atala, A., Yoo, J.J., 2014. Bioprinting technology and its applications. *European Journal of Cardio-Thoracic Surgery* 46, 342–348.
<https://doi.org/10.1093/ejcts/ezu148>
- Shin, J., Chung, H., Kumar, H., Meadows, K., Park, S., Chun, J., Kim, K., 2024. 3D bioprinting of human iPSC-Derived kidney organoids using a low-cost, high-throughput customizable 3D bioprinting system. *Bioprinting* 38, e00337.
<https://doi.org/10.1016/j.bprint.2024.e00337>
- Singh, N.K., Han, W., Nam, S.A., Kim, J.W., Kim, J.Y., Kim, Y.K., Cho, D.-W., 2020. Three-dimensional cell-printing of advanced renal tubular tissue analogue. *Biomaterials* 232, 119734.
<https://doi.org/10.1016/j.biomaterials.2019.119734>
- Turunen, S., Kaisto, S., Skovorodkin, I., Mironov, V., Kalpio, T., Vainio, S., Rak-Raszewska, A., 2018a. 3D bioprinting of the kidney—hype or hope? *AIMS Cell and Tissue Engineering* 2, 119–162.
<https://doi.org/10.3934/celltissue.2018.3.119>
- Turunen, S., Kaisto, S., Skovorodkin, I., Mironov, V., Kalpio, T., Vainio, S., Rak-Raszewska, A., Turunen, S., Kaisto, S., Skovorodkin, I., Mironov, V., Kalpio, T., Vainio, S., Rak-Raszewska, A., 2018b. 3D bioprinting of the kidney—hype or hope? *CTE* 2, 119–162.
<https://doi.org/10.3934/celltissue.2018.3.119>
- van Hulst, M., Visser, E.L., 2025. Abductive analysis in qualitative research. *Public Administration Review* 85, 567–580.
<https://doi.org/10.1111/puar.13856>
- Vijayavenkataraman, S., Yan, W.-C., Lu, W.F., Wang, C.-H., Fuh, J.Y.H., 2018. 3D bioprinting of tissues and organs for regenerative medicine. *Advanced Drug Delivery Reviews, 3D-Bioprinting and Micro-/Nano-Technology: Emerging Technologies in Biomedical Sciences* 132, 296–332.
<https://doi.org/10.1016/j.addr.2018.07.004>
- Wragg, N.M., Burke, L., Wilson, S.L., 2019. A critical review of current progress in 3D kidney biomanufacturing: advances, challenges, and recommendations. *Ren Replace Ther* 5, 18.
<https://doi.org/10.1186/s41100-019-0218-7>

Xu, K., Han, Y., Huang, Y., Wei, P., Yin, J., Jiang, J., 2022. The application of 3D bioprinting in urological diseases. *Materials Today Bio* 16, 100388.
<https://doi.org/10.1016/j.mtbio.2022.100388>

Yan, Q., Dong, H., Su, J., Han, J., Song, B., Wei, Q., Shi, Y., 2018. A Review of 3D Printing Technology for Medical Applications. *Engineering* 4, 729–742.
<https://doi.org/10.1016/j.eng.2018.07.021>

Zhang, Y.S., Yue, K., Aleman, J., Mollazadeh-Moghaddam, K., Bakht, S.M., Yang, J., Jia, W., Dell’Erba, V., Assawes, P., Shin, S.R., Dokmeci, M.R., Oklu, R., Khademhosseini, A., 2017a. 3D Bioprinting for Tissue and Organ Fabrication. *Ann Biomed Eng* 45, 148–163.
<https://doi.org/10.1007/s10439-016-1612-8>

Zhang, Y.S., Yue, K., Aleman, J., Mollazadeh-Moghaddam, K., Bakht, S.M., Yang, J., Jia, W., Dell’Erba, V., Assawes, P., Shin, S.R., Dokmeci, M.R., Oklu, R., Khademhosseini, A., 2017b. 3D Bioprinting for Tissue and Organ Fabrication. *Ann Biomed Eng* 45, 148–163.
<https://doi.org/10.1007/s10439-016-1612-8>

Appendices



Ethics Application & Declaration Form

DISSERTATION TITLE: Bioprinting Solutions for Diabetic Kidney Failure: The Future of Tissue-Engineered Organs

RESEARCHER'S NAME: Reema Amin

PROGRAMME OF STUDY: MSc. in Digital Transformation in Life Science

SUPERVISOR'S NAME: Dr. Ankit Chaturvedi

DECLARATION:

The information in this application form is accurate to the best of my knowledge. I undertake to abide by the principles outlined by Innopharma/Griffith College ethics policy in my research dissertation. I confirm that I have completed a full ethics assessment for my research dissertation as per the college guidelines. I will not begin my primary research until such approval from my supervisor and/or ethics Committee has been obtained.

I pledge to carry out my research according to the Innopharma/Griffith College academic integrity standards. Any results presented in my dissertation will be from my own, original research, I will reference and/or acknowledge any material or sources used in its preparation and I will not plagiarise the work of anyone else.

For Student:

STUDENT SIGNATURE: Reema Amin

DATE: 28/03/2025

The research contained within this research dissertation proposal has been approved.

For Supervisor:

Ethics Committee Approval Required: Yes No ✓

SUPERVISOR SIGNATURE: *Ankit Chaturvedi*

DATE: 28 March 2025

For Ethics Committee (if required):

Ethics Committee Approval Given:

Yes

No



ETHICS COMMITTEE MEMBER SIGNATURE:

DATE:

NOTE: Supervisors are responsible for ensuring their students fill in this form correctly and that all ethical areas have been considered.

SECTION 1: DESCRIPTION OF RESEARCH STUDY

1. Purpose and objectives of research

Studies on Bioprinting with a goal of creating workable kidneys for mitigating diabetic cases with kidney failure is a great step in healthcare. Diabetic nephropathy is among the most serious diseases that leads to severe complications that are associated with prolonged (or poorly treated) diabetes. High blood glucose level injures the small vessels in the kidneys that filter waste and excess fluid, and slowly, they impair the functioning of kidneys, to result in end-stage kidney failure that requires dialysis or trans-plantation. With its promising stand, bioprinting technology opens up the possibility of creating patient-specific kidneys to fit each patient's needs. Such an approach might increase the chances for a successful kidney transplant and improve the life quality of patients significantly while coping with the extreme lack of donor organs. In theory, bioprinted kidneys may alleviate the strain on healthcare systems by shortening the transplant waiting list.

One of the major strengths of this technology is that it enables the use of one's own cells for the development of the organ with reduced risk of rejection and decreased need of drugs suppressors of immune system, whose negative effects are known. Moreover, the cultivation of kidney tissues based in labs will not only have better results from kidney transplants but will also provide a good model for the study of diabetic kidney disease. Such models can help gain deeper insights on the course of the disease and provide an impetus for the testing new therapeutic interventions.

The objective of this research is to determine at which stage the kidney bioprinting is currently in, what its challenges and barriers in its implementation are, to estimate its cost effectiveness, and to identify whether it is suitable for diabetic patients. The study will therefore examine the preparedness of medical professionals and patients to embrace this innovative technology thus bringing an all-inclusive representation of how it could be clinically applied.

2. Research methodology:

Philosophy: Pragmatism

Researching the possibility of bio printed kidneys for diabetic patients experiencing renal failure necessitates a research strategy that considers both the technological and human factors. This topic is best suited for pragmatism. By combining quantitative data—such as surveys and cost analyses—to evaluate the technology's present state and economic viability with qualitative data—such as interviews—to comprehend the viewpoints of patients and medical professionals, it enables a thorough approach. In contrast to positivism, which aims to find a single, unchanging truth, pragmatism is solution focused. This is exactly in line with the research objectives, which center on identifying a workable solution for a particular patient population. Furthermore, pragmatism's adaptability allows modification to research strategies as the bioprinting industry develops. Ultimately, pragmatism recognizes the value of several perspectives, enabling to integrate information from diabetes patients and medical professionals to obtain a comprehensive understanding of the promise and difficulties associated with bio printed kidneys in this setting.

Approach: Abductive

It will allow me to investigate all facets of this novel notion, which will make it ideal for our research into the use of bioprinting to generate kidneys for diabetic patients suffering from kidney failure. With the help of this approach, theoretical and empirical data can be combined to provide a comprehensive and nuanced picture of the potential applications and difficulties associated with kidney bioprinting. It also maintains standards of research which will enable to be at the forefront of research incorporating any newly discovered findings in the field. Furthermore, with abductive analysis, we won't just be doing research, we're employing a journey of discovery which expands the boundaries in treatment of diabetic patients on kidney treatment.

Strategy: Qualitative and Quantitative

Choices: Mixed method

For the research on bioprinting kidneys for diabetic patients experiencing renal failure, a mixed methods research plan provides a thorough way to meet the various goals of the research. Through a mixed type of research, such as a quantitative and a qualitative

approach, I would be able to understand several topics, including the current state of bioprinting technology, the hurdles and obstacles, the cost-effectiveness, and the suitability for diabetic individuals. Conduction of both qualitative and quantitative methods will allow me to deeply discuss the beliefs, attitudes, and experiences of stakeholders, including patients and healthcare givers who could assume some roles. In this way, valuable information that might have been left by quantitative data alone would be revealed. By harmonizing the findings of the various techniques, I am that much surer of the accuracy and dependability of the results obtained and my understanding of the subject is likewise made more complete. This mediation way of the presentation will be helpful in dealing with different perspectives and the complexity faced while using the bioprinting in clinical practice. Therefore, the knowledge that will be gathered will be deep and unbiased.

Time Horizon: Cross-Sectional as there is a deadline that needs to be met.

Techniques and Procedures: Survey and Case study

Surveys: By gathering quantitative data from a sizable sample of participants, surveys will assess broad viewpoints on issues like the state of kidney bioprinting at the moment, the degree to which medical professionals are willing to adopt this technology, and the degree to which patients are prepared for this innovation. Surveys offer statistically significant insights on attitudes, beliefs, and patterns that are useful for examining the overall bioprinting technological landscape concerning kidney development.

Case Study: By allowing for a close examination of actual cases, case studies shed light on situations, procedures, and results pertaining to kidney development bioprinting. It will help to investigate the difficulties in putting bioprinting technology into practice as well as the elements that contribute to its success or failure by looking at case studies of bioprinting projects or initiatives. Contextualized data from case studies can shed light on the challenges and realities of bioprinting kidney development in actual environments.

SECTION 2: POSSIBLE ETHICAL ISSUES

Answer 'yes' or 'no' to the following questions.

SUBJECT MATTER

Does the research proposal involve:

Research into specific company activities that would be deemed sensitive or confidential	No	
Research into politically and/or racially/ethnically and/or commercially sensitive areas	No	
Sensitive, personal, professional or corporate issues		No

RESEARCH PROCEDURES

Does the research proposal involve:

Research that might damage the reputation of companies or participants		No
Research that may negatively affect the reputation of Griffith College/Innopharma		No
Use of personal records without consent	No	
Use of company data without consent		No
The offer of any inducements to participate		No
Audio or visual recording without consent		No
Using a language other than English		No

PARTICIPANTS

Does the research proposal involve:

People who are not competent and/or fluent in English		No
Does your research group include any of the following vulnerable groups		No

SECTION 3: STEPS TAKEN TO AVOID ETHICAL ISSUES

Not Applicable

SECTION 4: ABOUT YOUR PARTICIPANTS

4.1. Characteristics of the participants condition and reasons being selected for this study.

This research will include diabetic patients and other related people such as family members or care givers who are to be part of the survey. These participants have been selected explicitly because they have actual first-hand experience about diabetes and its complications such as diabetic nephropathy and it can cause the failure of kidneys. Their insights are critical to knowing the effect of this condition and assessing the viability of this process as a possible treatment using bioprinting for kidney transplantation.

Diabetic individuals with prospects or currently suffering from kidney failure will give useful insight about their healthcare challenges, treatment experience, and readiness to embrace new solutions such as bioprinted kidneys. Family members and carers will provide advice regarding the daily struggle of living with diabetes and kidney disease, their views regarding the new medical breakthroughs.

By involving such participants the study intends to find out significant information about the acceptance of concerns and possible benefits of the use of bioprinting technology among diabetic kidney failure.

4.2 What do you intend to use to reach/ contact/ approach your participant(s).

In order to access the participants, I will combine a mix of the online and offline methods. I intend to target diabetic patients and their caregivers through diabetic support groups, advocacy organizations for patients and healthcare facilities like hospitals and dialysis centres.

For recruitment through online, I will use social media platforms, online health forums, and diabetes-specific communities to distribute the survey link. Besides, I will approach other concerned organizations and seek their help in conducting the survey among their members.

The participants will be given an explicit description of the study's purpose, thus ensuring that they understand that participation is voluntary. Responders will be asked for informed consent prior to collecting of any response. There will also be an available contact option for the participants to ask questions or seek clarifications. This strategy keeps the pool of participants diverse and adhered to ethical tenets of research.

SECTION 5: INFORMATION, CONSENT AND CONFIDENTIALITY

5.1 Participant Information Letter (PIL) for participants

Please confirm below that your information letter covers:

Description of the research topic and method	Yes
Details of what participation will involve	Yes
Rights to anonymity	Yes
Confidentiality	Yes
Rights to withdraw from the research	Yes
The contact details of the researcher and supervisor (if necessary)	Yes

5.2 Informed Consent Form (ICF) for participants

Please indicate below if your research requires a signed consent form by selecting the relevant option only:

My research study involves an online survey only and/or does not require signed consent

SECTION 6: STORAGE OF DATA

6.1. How will you keep the data of research and for how long? What is the management of data protection issues?

With all survey participation information, we follow a strict confidentiality policy. All participants and any persons mentioned shall be held in strict confidence at all times. Until completion of my degree, meaning until December 2011, I will store the original forms of Participant Information leaflet (PIL) and questionnaire data files on my computer securely. Once done, the data will be deleted permanently. Participants are entitled to have access to the information that they provided, according to the regulations of information freedom. Regarding the storage of data, I will classify research files into specific folders, based on research elements, and regularly backup data to cloud storages (Google drive) for the data preservation. All the files will be protected with password while sensitive data to be encrypted to ensure security. Access will be restricted to those who are authorized only.

SECTION 7: NON-DISCLOSURE AGREEMENT & STUDENT CONSENT

7.1 Non-Disclosure Agreement (NDA)

Will the final dissertation contain any information pertaining to any source what would warrant the use of a Non-Disclosure Agreement (NDA) e.g. industry-based research?

No

7.2 Student consent

If a Non-Disclosure Agreement (NDA) is not required, does the Student consent to allow their completed dissertation to be held/published by Innopharma/Griffith College?

Yes

SECTION 8: RECORDING AND RETENTION OF DISSERTATION VIVA

8.1 Viva Recording

The Dissertation viva will be recorded. This recording may be used to facilitate assessment by Innopharma staff, a third reader if necessary and/or if requested by the external examiner for the Programme. The recording will be held in line with current GDPR guidelines and will not be made publicly available.

SECTION 9: DOCUMENT CHECKLIST

NOTE: Applicants must attach the following documents in electronic format to the appendix.

Which documents are added to the appendix? Please tick N/A if not applicable:

- | | |
|--|-----|
| 9.1 Participant Information Letter (PIL) for participant | Yes |
| 9.2 Informed Consent Form (ICF) for participant | N/A |
| 9.3 Questions/survey for interviewees/focus groups etc | Yes |
| 9.4 Any other documents e.g. Non-Disclosure Agreement | N/A |

I confirm that this application is complete and all required documents are included in the appendix.

For Student:

STUDENT SIGNATURE: Reema Amin

DATE: 28/03/2025

SECTION 10: APPENDIX

Questionnaire for Survey

This research explores the potential of 3D bioprinting as a solution for diabetic kidney failure, focusing on its feasibility, challenges, and acceptance among patients. Diabetic nephropathy is a serious complication of diabetes that can lead to kidney failure, often requiring transplantation. However, the shortage of donor kidneys remains a significant barrier, leaving many patients on long waiting lists. Bioprinting technology offers a promising alternative by creating lab-engineered kidneys tailored to individual patients, potentially reducing transplant rejection and improving treatment outcomes.

Your participation in this survey is valuable in understanding public awareness, acceptance, and concerns regarding bioprinted kidneys. By sharing your views, whether as a diabetic patient, caregiver, or family member, you will contribute to research that could help shape future advancements in organ transplantation. Participation is entirely voluntary, and your responses will be kept strictly confidential. Your insights are crucial in assessing the readiness of patients and the medical community for this innovative medical solution.

Please read the following statements carefully before proceeding with the survey.

- **I confirm that I have read and understood the purpose of this research and what my participation involves.**
- **I voluntarily agree to participate in this survey, knowing that I can withdraw at any time without consequence.**

By ticking both boxes, you confirm your understanding and consent to participate in this research. If you do not wish to proceed, you may exit the survey at any time.

1. What is your age?

- Under 18
- 18 to 30
- 31 to 50
- 51 to 60
- Above 60

2. What is your gender?

- Male
 - Female
 - Others

3. How are you related to Diabetes? (Select all that apply)

- I am a Diabetic Patient
- I am a Health care Professional working with Diabetic Patient
- I am a caregiver for Diabetic Patient
- I have a family member with Diabetes
- Others:

4. If you are a caregiver or a health care professional, how many Diabetic patients have you assisted or cared for?

- Not Applicable
-

5. How long have you or the diabetic patient been diagnosed?

- Below 1 year
- 1 to 5 years
- 6 to 10 years
- More than 10 years

6. How supportive is your or your patient's family in managing the disease?
- Extremely supportive - they provide constant emotional and practical assistance.
 - Somewhat supportive - they help occasionally but not consistently.
 - Neutral - they neither help nor hinder disease management.
 - Not very supportive - they provide minimal assistance or understanding.
 - Not supportive at all - they are uninvolved or unsupportive.
7. How much does Diabetes affect your or your patient's lifestyle?
- Significantly – It affects almost every aspect of daily activities and requires constant management.
 - Moderately – It impacts some areas of life but is generally manageable.
 - Slightly – It causes occasional challenges but does not majorly disrupt daily activities.
 - Not at all – It has little to no impact on daily life.
8. Have you or the Diabetic patient have ever been hospitalized?
- Yes
 - No
9. If you are a caregiver or a health care professional, how many of your Diabetic patients have been hospitalized?
- All of them
 - Most of them
 - Only a few of them
 - None of them
 - Not Applicable
10. Have you or the Diabetic patient faced Kidney related issues (Neuropathy)?
- Yes
 - No
11. If you are a caregiver or a health care professional, how many of your Diabetic patient have faced kidney related issues (Neuropathy)?
- None of them
 - Only a few of them
 - Most of them
 - All of them
 - Not Applicable
12. Have you heard about the 3D Bio printing organ before this survey?
- Yes
 - No

13. How familiar are you with the idea of 3D bio printing as a solution to organ transplantation?
- Very familiar
 - Somewhat familiar
 - Not familiar at all
14. Do you think there is a need for 3D bio printing technology as a substitute for organ transplantation?
- Strongly Agree
 - Agree
 - Neutral
 - Disagree
 - Strongly Disagree
15. If you, your patient, or a loved one needed a kidney transplant, would you consider 3D bio printed kidney as a solution?
- Yes, definitely
 - Maybe, but I need more information
 - No, I would not consider
16. What is your main concern regarding the technology of 3D bio printed organs? (Select all that apply)
- Safety and Effectiveness
 - Ethical considerations
 - Cost and Accessibility
 - Religious or Cultural Beliefs
 - Others:
17. If Bio printed organs are proven to be safe and effective, would you support its use in kidney transplantation?
- Strongly Agree
 - Agree
 - Neutral
 - Disagree
 - Strongly Disagree
18. In your opinion, what do you think is the biggest barrier in the use of bio printed kidneys?
- Lack of awareness
 - High costs
 - Ethical or religious concern
 - Limited medical acceptance
 - Others:
19. Do you think the medical sector is ready to accept Bio printed kidneys as a solution to organ transplantation?
- Yes
 - No
 - Not sure

20. Would you be interested in receiving more information about bioprinting advancements in kidney transplants?
 Yes
 No
21. Do you have any additional comments or concerns regarding bioprinting and kidney transplants?

Participant Information Letter

Alternative Bioprinting solutions for Diabetic Kidney failure: The Future of Tissue-Engineered Organs

I would like to offer you an opportunity to be involved in a research study. Before you make up your mind, you are expected to know why the research is being conducted and what it would require of you. Kindly take time to read the following information seriously. In case you do not understand something, or you need more information, ask questions. Allow time in deciding the need to participate.

WHO I AM AND A DESCRIPTION OF THE FOLLOWING STUDY

I am a student of Griffith college following my master's in Digital Transformation in life sciences. I wish to conduct this study in order to determine the promise of 3D bioprinting for development of kidneys for patients who suffer from failure of kidneys due to diabetes. The purpose of the present study is to determine the current level of bioprinting technology capability, challenges associated with it, our ability to draw its cost effectiveness and suitability for diabetic patients who need transplant of kidney. This research seeks to provide meaningful answers as to whether the bioprinting has a potential to solve the problem of donor organs shortage in the world and provide a personalized long-term solution to the treatment of kidney failure. This study is directly associated with some of my courses. In Analysis of Data, we will use various statistical methods of investigation to demonstrate the effectiveness and cost-effectiveness of bioprinting. Research Method is critical for designing our study as well as for us to get accurate and reliable data. The two areas, Business Strategy and Change Management are appropriate as we examine the viability and adoption of bioprinting technology in the healthcare sector; Quality Management will navigate us in identifying the quality criteria that will be needed for successful bio printed organs. This research unites these disciplines and works toward the more general goal of advancing healthcare procedures.

WHAT WOULD TAKING PART INVOLVE?

You are invited your contribution in an survey concerning my current research, called Bioprinting Solutions for Diabetic Kidney Failure: The Future of Tissue-Engineered Organs. Questions in this survey are aimed at collecting the opinions and insights of your on various aspects of bioprinting solutions for diabetic kidney failure, future potential of tissue engineered organs etc.

WHY WAS IT THAT YOU HAVE BEEN REFERRED TO JOIN IN?

Diabetic patients are vital for this research because they are directly implicated in diabetic kidney failure which is a chief cause of kidney transplants. Their opinions and experiences will be useful in providing ideas of how the acceptance and utility of bioprinted kidneys may be, which will assist in determining both the viability and effect of this innovative treatment.

DO YOU HAVE TO BE INVOLVED?

All participation in this survey is voluntary. You are entitled to refuse to participate in any way, refuse to answer any particular question, or cease participation as a part of the survey at any moment without any repercussions. Whatever decision you make will not in any way influence you in terms of the relationship between the researcher and other institutions involved. You can contact +353899630609 in the case you wish to withdraw from the survey.

WHAT ARE THE POTENTIAL RISKS AND ADVANTAGES THAT CAN BE DERIVED?

By improving the knowledge on the bioprinting for diabetic kidney failure; this research has potential impacts which can make its possible for improvement in treatment. There are no significant risks to my study, since all the data would be kept confidential and applied for the research only. There is no expectation of significant risks, rather, the well-being of participants will be prioritized.

WILL TAKING PART BE CONFIDENTIAL?

We have a strict confidentiality policy with every survey participation information. Stricter anonymity for all participants and references will be observed.

WILL THE INFORMATION PROVIDED BY YOU BE STORED AND SECURED?

Up to the time I finish my degree, I am to retain the original Participant Information Leaflet (PIL) forms and questionnaire data in my computer. The data will then be destroyed on permanent basis. Information submitted can be obtained by participants in an act of compliance with regulations in terms of the freedom to access information. By data storage, I will arrange research files into specific folders and divide them by research elements; additionally, I will make regular one copy backups to cloud

storage (Google Drive), to prevent data loss. All files will have a password protection and sensitive data will be encrypted to assure protection. Access will only be available for authorized personnel.

THE CONSIDERATION WILL BE GIVEN TO THE OUTCOMES OF THE STUDY?

The outcome of this study will mainly be written to support my dissertation. Once completed, the dissertation will go into the college library and it may or may not be uploaded in online e-journals or 'repositories'. Currently, there are no established program for publication in academic journals or presentation in different conferences. However, in case there are future opportunities, the findings might be exposed through academic discussions, research seminars, or through publications. The research could also contribute to teaching materials that relate to the subject. Any reporting of results will ensure that the participants are protected while their personal identifiable information will remain in-tact.

WHO SHOULD YOU CONTACT FOR FURTHER INFORMATION?

Name- Reema Amin

Contact- +353899630609

Email- reema.amin.binti@gmail.com

Affiliation- Griffith College Dublin and Innopharma Education

THANK YOU