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Development, Implementation and Evaluation of the Fellowship Course Regenerative Medicine in Dentistry

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ABSTRACT

Introduction: Scientists have developed solutions, for oral health by leveraging advancements in medicine. These solutions, known as " reconstructive dentistry " aim to address the limitations and short lifespan of restorative methods. Unlike restorative treatments, reconstructive dentistry focuses on not only restoring the structure of tissues but also their physiological functions. To achieve this, it requires an effort among dentists, biologists, stem cell researchers, material scientists, tissue engineers and other experts. Consequently, this study was carried out to create and evaluate a fellowship program called "Reconstructive Medicine in Dentistry." The program aims to foster an approach towards reconstruction, in dentistry.

Materials and Methods: This research involved three stages. Utilized a mixed method approach. In the first stage, we developed a design based on the Kern model, which involved conducting a review of relevant studies to extract and determine the goals and topics related to medical reconstruction, in dentistry. Expert panel meetings were held to finalize these goals and topics. For each target group, we identified the learners, learning environment and educational strategies. We also made arrangements for implementing the program. Established evaluation methods for both students and the program itself. Subsequently, we implemented the designed curriculum for two groups of students. Finally, we evaluated the program's effectiveness through questionnaires and semi structured interviews, with students, professors and organizers. The collected data was analyzed using statistics.

Results: In 2020 and 2021, two groups of students were meticulously selected from disciplines such as maxillofacial surgeons, oral medicine specialists, periodontists, endodontists, and more, after passing the entrance exam. The primary objective of this program is to educate graduates with the skills to restore missing tissues in the mouth, jaw and facial regions using cutting edge regenerative medicine techniques. The curriculum was developed in collaboration with experts from areas like tissue engineering, dental specialization (including maxillofacial surgeons) biomaterials and developmental biology. Both students and professors expressed satisfaction, with the program.

Conclusion: A group of professors, from specialties came together to implement a fellowship program in reconstructive dentistry. The main goal of this program was to train specialists in tissue reconstruction for patients who have suffered jaw and facial injuries; by using advanced methods in medicine. Additionally, this initiative can also be a step towards strengthening the university's movement towards third and fourth-generation universities. The findings from this study can provide insights, for those involved in planning and implementing interdisciplinary fellowship programs.

Keywords: Dentistry; Regenerative medicine; Curriculum design; Interdisciplinary.

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Introduction

Throughout history, dentistry has evolved significantly providing a range of techniques to address dental issues such, as extraction, repair and replacement of tissue. However traditional reconstructive approaches have their limitations in terms of effectiveness and durability. To overcome these shortcomings researchers have embraced the advancements in science to develop improved solutions, for health known as "reconstructive dentistry" [1]. Given that the objective of medicine is to regain the functionality of impaired organs and tissues. it's clear that dentists and supporters of tooth restoration have been aligned with this goal from the very beginning. Dental medicine is one of the few medical fields that emphasizes restoring organ and tissue function. In fact, dental medicine presently incorporates a range of biomaterials, biomedical engineering, tissue engineering and regenerative medicine concepts to provide treatment to patients [2]. Traditional dental treatments are unable to restore the structure and natural function of tissues. However, by extracting stem cells from sources, in the mouth and utilizing materials for delivering cells and growth factors we can potentially develop alternative treatments that are biologically based. To achieve functional construction rather than replacement treatment, a multidisciplinary approach is necessary, incorporating dentists, biologists, stem cell researchers, materials scientists, and other specialists [3]. Due to the advances in regenerative medicine in dentistry, a paradigm shifts in root canal treatment from traditional to complete replacement of damaged pulp tissues is being performed. Two valuable scientific approaches, cell transplantation and cell mobilization, including revitalization and revascularization are being researched. While the cell mobilization approach is simpler to operate, it may not be suitable for tissues with large defects, especially in conditions of regeneration of new pulp along the entire length of the root. In addition, the origin and quantity of cells entrapped in the fibrin clots during the process of revascularization/revascularization are uncertain, making it difficult to characterize the phenotype of the regenerated substitutes for root canal fillings. As a result, the therapies effectiveness varies. Conversely there is evidence indicating that combining tissue engineering components, like stem cells, scaffolds and signaling molecules for cell transplantation has shown outcomes. This approach using cells has the potential to repair tissue defects. However, despite these accomplishments, there are still obstacles that must be addressed to make cell transplantation a practical clinical treatment method. It is crucial to continue research in these areas in order to develop an approach to dentin/pulp regeneration that can be applied in a clinical setting. The future of reconstruction depends on the efforts of dentists, biomaterial scientists and engineers working together with their different expertise to advance dentin/pulp regenerative therapy [4]. Interdisciplinary education, where knowledge and approaches are integrated, often leads to change or emergence of new disciplines. Klein and Newell defined interdisciplinary education as "the process of answering a question, solving a problem, or addressing an issue that is too broad or too complex to be adequately addressed by a single discipline or profession" [5]. Interdisciplinary approaches have long existed in regenerative medicine, addressing common conditions such as spinal cord injury, stroke, joint replacement, etc [6]. Promoting sustainability, in care involves an effort in reconstructive dentistry to restore and preserve the health of oral, jaw and facial tissues. Recognizing the significance of dentistry as a piece of the puzzle it is crucial to develop an innovative curriculum for effective training of future dentists [7]. In line with this objective our study focuses on designing, implementing and evaluating the interdisciplinary fellowship course "Reconstructive Medicine, in Dentistry."

Materials and Methods

This study was a mixed method study and was conducted in three stages.

Stage one: Curriculum planning

A systematic search of studies with keywords (curriculum OR interdisciplinary OR learning OR instruction) AND (regeneration medicine) AND (Dental) was done in Eric, PubMed databases. The input languages of the studies were English and Farsi. The search was done without time limit. Furthermore, we gathered information by exploring courses offered in different countries. This data was then utilized to develop the curriculum for "Regenerative Medicine, in Dentistry." The researchers used Kerns curriculum elements to analyze the content of articles. Additionally, they organized a focus group meeting, with 12 specialists from fields such, as endodontics, oral and maxillofacial surgery, periodontics, oral medicine, oral pathology, dental materials, orthodontics, tissue engineering, post-doctorate in tissue engineering and regenerative medicine, doctorate in biomaterials, doctorate in developmental biology, tissue engineering and regenerative medicine. During this meeting they engaged in brainstorming sessions to gather their insights and perspectives. Then, in a meeting of a panel of experts

consisting of 10 people from different fields of dentistry, tissue engineering, biomaterials and medical educationist, the elements of the interdisciplinary curriculum were reviewed and finalized. In addition, at this stage, the target learners and the target learning environment were determined. Then, the general and specific goals of the curriculum regarding the expected learning outcomes were determined. Based on the achieved goals we determined strategies that align with our anticipated objectives. In this phase we. Allocated the resources (such, as personnel, time, facilities and finances) based on the established goals and strategies. We also designed implementation mechanisms to support the curriculum while anticipating and planning for any obstacles. Finally, a decision was made to implement the curriculum as a pilot program. The decision was made to assess the students based on the goals they achieved. To evaluate the program, we conducted surveys and semi-structured interviews with the students. Additionally, we also interviewed the teachers using structured interviews at the ending of the course.

Stage two: Curriculum implementation

At this stage, the necessary notifications for the students' registration were made. The entrance exam for the fellowship course was conducted among the registration candidates in the form of an exam with interdisciplinary questions. Reconstructive dentistry curriculum was held using an interdisciplinary approach in the form of joint interdisciplinary teaching sessions, presentation of interdisciplinary projects and joint journal clubs. We made all the necessary preparations to ensure that the program runs smoothly. We received support, from the faculty and university to facilitate the implementation. The course was conducted as a fellowship lasting between 15 and 18 months with one semester held in the Faculty of New Technologies. The remaining time was dedicated to working on the project either in the laboratory or, in clinics.

Stage three: We made all the necessary preparations to ensure that the program ran smoothly. We received support, from the faculty and university to facilitate the implementation. The course was conducted as a fellowship lasting between 15 and 18 months with one semester held in the Faculty of New Technologies. The remaining time was dedicated to working on the project either in the laboratory or, in clinics.

Stage three: Curriculum evaluation

The evaluation of the program was carried out according to the sixth step of Kern's curriculum model. To develop the questionnaire items, we carefully reviewed existing literature. Ensured content validity, by consulting with a panel of 5 experts in dentistry, tissue engineering and medical education. During this phase, the experts were requested to share their insights, on the necessity, relevance and clarity of the questionnaire items. The questionnaire's reliability was assessed by calculating the consistency of its items, known as Cronbach alpha (ICC α=0.87). Students were asked to provide feedback on aspects of the course and instructors as well as the overall process and outcomes. This feedback was collected through questionnaires and semi structured interviews conducted at the conclusion of the course. The questionnaires were distributed to students, in person allowing them time to complete them before being collected during the same meeting. Additionally at the end of the course students, professors and organizers participated in structured interviews to gather further insights. The participants were engaged in structured interviews that lasted for approximately 30 minutes. During this time the researcher and interviewee interacted to gather information. The interviews were recorded after obtaining consent, from the participants and transcribed immediately. To analyze the interview content, a conventional content analysis approach was used, including classification of codes and determination of code frequency using Summative content analysis [8].

Results

Based on the searches and similar courses in other countries, the "regenerative Medicine in Dentistry" fellowship course was developed. Specialists in dentistry, tissue engineering and applied cell sciences, developmental biology and biomaterials were identified as involved fields. The learners of the target group include specialists in oral-maxillofacial surgery, oral maxillofacial diseases, oral medicine, periodontics, endodontics and, depending on the case, in cases where the applicants related to these branches were identified. The educational needs of the students were determined based on reviewing the literature and experts' opinions (Table 1). The training program determined the exit outcomes, for graduates who possess the skills to restore and repair damaged tissues in the mouth, jaw and face using the newest reconstructive methods in medicine. We identified objectives and effective educational strategies to achieve these goals. (see Table 2). We explored approaches, such, as interactive lectures, small group discussions, film screenings, project-based learning and learning through laboratory and simulated environments. To select students for the program we designed

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an entrance exam that consists of 50% questions related to courses in the field and 50% questions covering the fundamental principles of tissue engineering. Once we obtained the permits we collaborated with oral surgery and tissue engineering professors to create the exam course for fellowship participants. The entrance exam took place in May 2020 followed by the training course with a student in October of the year 2020. The second course was held during the year 2021. We evaluated the course according to our design plan. Student feedback was collected through questionnaires and semi structured interviews while professors and course officials also participated in structured interviews, for further analysis.

From the perspective of professors and course officials, the course had its merits in terms of familiarizing experts, with topics in basic science. It emphasized the application of knowledge from sciences in settings aiding patients through the use of advancements in reconstructive medicine for diagnosing and treating diseases. However, one drawback was the lack of a budget allocation. This is particularly important considering that this fellowship requires laboratory testing before application, which demands substantial funding. Another downside was the weak cooperation between clinical and non-clinical professors. Students' opinions were collected through a questionnaire (Table 3) and a semi-structured interview. Based on the analysis of the results, the initial theoretical content of the course is appropriate, but due to the rapid worldwide progress of science in this field, it is better to update it in each course. Regarding the practical part, the need to provide more facilities and more cooperation with other research institutes or international centers active in this field was raised. Regarding the students' familiarity with the duties and objectives of the course, it was suggested to design a study guide or to hold a face-to-face meeting with the lecturers and course officials upon arrival to get to know the students better and create a more intimate atmosphere. Regarding the research part, there is a need to become more familiar with internal techniques, facilities and capabilities to carry out projects and especially the funding stages. Considering the design of the course as a fellowship, it seems like in other countries, the presence of pre-defined projects by the professors and the student's involvement with a specific project from the beginning of the student's admission can help in better use of the course and more effective learning. Furthermore, students and professors expressed concerns, about the university's emphasis on the significance of the program, need for this particular course as well as the lack of favorable conditions to facilitate its completion. However, considering the advancements in dentistry students generally believe that this course is crucial for dentists and recommend it to others. Overall, both students and professors expressed satisfaction, with the course.

Table 1. The codes acquired from the headings found during the literature review phase.

No.	*Items*
1.	*Using the principles of regenerative medicine in the treatment of tissue defects*
2.	*How to use all kinds of natural and artificial scaffolds in tissue regeneration*
3.	*Regeneration of bone and soft tissue in patients with cleft palate and congenital lesions using regenerative medicine*
4.	*Selection of appropriate growth factors in tissue regeneration*
5.	*Regeneration of periodontium using regenerative medicine*
6.	*Regenerative medicine in temporomandibular joint*
7.	*Regenerative medicine in the oral mucosa and nerves of the mouth, jaw and face*
8.	*Stimulating the remaining salivary glands of patients who have undergone head and neck radiotherapy*
9.	*The application of regenerative medicine in increasing the success of dental implants*
10.	*Regenerative medicine and dental pulp regeneration treatments*
11.	*Isolation of stem cells from cancer tissues*
12.	*Early diagnosis of diseases*
13.	*Regenerative medicine in dental hard tissue*
14.	*Regenerative medicine in accelerating tooth movement and tooth movement in damaged tissues and damaged tissues following tooth movement*

Table 2. Specific objectives of the reconstructive fellowship course in dentistry.

No.	Goals
1.	Familiarity with biomaterials and synthesis methods of nano-scaffolds in dentistry (theory-practical)
2.	Getting to know the principles of tissue engineering and regenerative medicine in dentistry (theory)
3.	Familiarity with the methods of making scaffolds used in bone, cartilage, nerve, tooth, skin and mucous membrane and tissue of periodontium (theory-practical)
4.	Characterization methods of scaffolds used in bone, cartilage, nerve and teeth, skin and mucous membrane and periodontium tissue (theoretical-practical)
5.	Biology of stem cells and their extraction and differentiation methods into osteo-blast, chondroblast, ameloblast and odonto-blast, epithelial and sensory and motor neurons and their application in dentistry (theoretical-practical)
6.	Two-dimensional culture and three-dimensional cell culture (theory-practical)
7.	Application of PRP and signaling molecules such as rh BMP, rh-PDGF in dentistry (theoretical-practical)
8.	The role of scaffold surface characteristics and its topography on cellular respons-es in dentistry (theory-practice)
9.	Examining the tests used to evaluate cell life (theoretical-practical) synthesis methods
10.	Studies on biocompatibility and differentiation power of stem cells on scaffolds used in bone, cartilage, nerve and tooth, skin and mucosa and periodontium tis-sue (theoretical-practical)
11.	Cell therapy in dentistry (theory-practical)
12.	Principles of gene therapy in dentistry (theoretical-practical)
13.	In vivo dental studies (theoretical-practical)
14.	Bioprinters (theory-practical)
15	Ethical considerations (theory)

Table 3. Students' opinions about the fellowship course "Regenerative Medicine in Dentistry" based on a questionnaire.

No.	Goals	Mark 1-5
1.	Was the course well-structured and organized?	2
2.	Did the organizers/lectures commit enough for the source of the success of the course?	2
3.	Were the objectives and methods clearly defined?	2
4.	Did the course present and discuss appropriately important topics?	2
5.	Was the time and materials provided adequate for the preparation of the course?	1
6.	Was the duration and schedule of the course adequate?	4
7.	Did the course provide sufficient opportunities for informal interaction with organizers/lectures?	3
8.	Did the organizers/lectures stimulate critical thinking and participation of the students?	2
9.	Did you find the course useful for the fellowship Program?	4
10.	Do you recommend including this course in the next edition of the fellow-ship program?	Yes

Discussion

In the forty years there has been progress, in the field of tissue engineering and regenerative medicine. Researchers, engineers and medical professionals have been working towards developing alternatives that can replicate tissues. These substitutes serve purposes such, as diagnostics, research and the regeneration or replacement of damaged tissues [9]. Tissue engineering is a field that focuses on developing materials and strategies to replace damaged or lost tissues. It integrates principles, methods and knowledge, from chemistry, physics, engineering and biology [10]. Accomplishments achieved by tissue engineering in the past few years have led to new treatments such as skin production for the treatment of burns [11], bone grafting to replace large bone defects [12], small-caliber arteries for the treatment of atherosclerotic vascular disease [13] and cartilage for plastic-surgeries [14]. Reconstructive medicine, in dentistry has also made

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progress in the reconstruction of tissues such as the temporomandibular joint [15], periodontal ligament [16,17], dentin [18], enamel [19,20], pulp [18,21] and integrated tissues of teeth [22,23] and jaw bone [24]. Dental education worldwide mainly emphasizes the aspects of clinical practice and skill acquisition. However, given the paced advancements, in dentistry, it is crucial for upcoming dentists to have a solid understanding of basic science and biological processes that influence regenerative and reconstructive treatments. This will better equip them to handle developments, in the field. However, while assessing the knowledge of students about reconstructive dentistry the usual focus is on their understanding of stem cells, the resources of knowledge, their sources of knowledge, their interest in further education and pursuing advanced studies in regenerative dentistry as well as the practical applications of stem cells in clinical settings. Although these assessments may not specifically measure the biological mechanisms that form the foundation of reconstructive dentistry, they still indicate an integration of new advancements in the biomedical field within dental curriculum. As a result, teaching biological and biomedical sciences (BMS) in the dental curriculum as a part of core curriculum was emphasized by Special Interest Working Group in the Association for Dental Education in Europe (ADEE) [7,25].

In the field of medical sciences, in the form of different educational and research courses, various universities have taken measures regarding the training of experts and researchers in the field of tissue engineering and regenerative medicine [26-28]. Despite the remarkable achievements in the field of medical reconstruction in dentistry, there is still a need for more studies in order to apply it clinically in this field [4,14,15]. Moreover, stem cells taken from tissues of mouth, jaw and face are extensively employed for reconstructing other tissues, like the nervous system, optical system, cardiac muscle system, etc. These cells possess unique characteristics that make them highly effective, in reconstruction procedures [24,29-33].

Modern reconstructive dentistry, which aims to use stem cells and tissue regeneration to replace tissues or actually whole teeth, is a complex and multidisciplinary science that requires knowledge of biology, molecular, genetics, tissue engineering, and nanotechnology. Measures have been taken regarding the presentation of this science even in the course of general dentistry. For example, a dedicated lecture series can be designed and presented in the pre-clinical and clinical years either through an independent topic, i.e., "reconstructive dentistry" or as a sub-topic of existing course materials, for example, biology dental materials, etc [34]. SIG fully supports the trend, towards education, where biomedical sciences (BMS) are seamlessly incorporated alongside clinical disciplines. However, it acknowledges that integrating BMS education into curricula is a crucial matter that should be addressed separately. In addition, it may be possible to transfer some elements of the bachelor's curriculum to the master's environment, which requires more integration between the bachelor's and master's [25]. Introducing subjects, like these into undergraduate dentistry curricula may add challenges like lack of funding, faculty and trained personnel, among other factors which are expected to be time-consuming, allowing institutions to adjust accordingly [35,36].

Since regenerative treatment of different parts of the mouth, jaw, and face is expanding, and dentists who perform reconstructive treatment must have sufficient knowledge about anatomy, physiology, histology, pathology and more; a supplementary course called the Fellowship has been specifically designed for expert dentists from various disciplines. Similar courses have also been established in countries at a level. For instance, the Faculty of Dentistry at Cardiff University in England offers an MSc course called Tissue Engineering and Regenerative Medicine. This course is developed through collaboration, between dentists and professors specializing in tissue engineering.

This course is a one-year, full-time program that begins in September of each year with the first phase of a 6-month educational component that includes four mandatory modules. In this course, all participants must accomplish following modules: Cellular and Molecular Biology, Tissue engineering from concept to practice, Research Methods, Stem Cells, Regenerative Medicine and Scientific Methods. Upon completion of Phase 1, students undertake a 5-month laboratory-based research project between April and September (Phase 2). Phase 2 ends with the presentation of a master's thesis based on the findings of the master's project [26]. The Herman Ostrow USC School of Dentistry offers a Master's program called Biomedical Implants and Tissue Engineering. This program is designed to enhance the knowledge and critical thinking skills of students who're interested, in the biological and clinical aspects of bone integration as well, as the clinical applications of tissue engineering. However, it should be noted that only periodontology specialists are eligible to participate in this course [37]. It appears that various dental specialties should be provided with this oppor-

tunity to become acquainted with this field of study; as it was made possible through our study. Some other departments have offered this opportunity for experts, from fields to collaborate in research. The Division of Biomaterials and Tissue Engineering, at the University of Maryland School of Dentistry, in the United States focuses on conducting research in the area of biomaterials and tissue engineering. Their work involves developing types of scaffolds that're bioactive and can be absorbed by the body as well as exploring biomimetic and injectable carriers [38]. Additionally, they study how stem cells and growth factors can be utilized for tissue engineering, maxillofacial bone and tooth regeneration and repair. The second important research area of this department is the development of new dental materials and smart nanocomposites to facilitate controlled release of caries inhibition substances, for tooth restoration purposes. The research team utilizes cutting edge stem cell cultures. Examines techniques, for material engineering and synthesis. These efforts are backed by funding, from the NIH/NIDCR, the Maryland Stem Cell Fund and the University of Maryland School of Dentistry [38]. Although conducting research projects often involves collaboration, between disciplines it is highly beneficial to train individuals who possess expertise in both dentistry and tissue reconstruction. This dual knowledge allows for an understanding of issues and diseases thereby facilitating the development of practical solutions and more impactful studies for patients. To fulfill this, aim an interdisciplinary course has been designed that integrates training and collaborative projects involving experts from the fields of dentistry and tissue engineering. This program, referred to as a fellowship spanned 15-18 months was delivered in partnership of specialists in the fields of dentistry and tissue engineering, from backgrounds much like other academic institutions. The primary objective of this program aimed to educate experts, in the field of tissue reconstruction for individuals who have experienced injuries to their jaw and face. By implementing these techniques, we sought to enhance patient care and recovery. Additionally, this initiative can also be a step towards strengthening the university's movement towards third and fourth-generation universities. The findings from this study can provide insights, for those involved in planning and implementing interdisciplinary fellowship programs.

Conflict of Interest

There is no conflict of interest to declare.

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