Journal of Engineering and Sustainable Development
Vol. 29, No. 05, *August* 2025
https://jeasd.uomustansiriyah.edu.iq/index.php/jeasd
ISSN 2520-0917
Research Article
https://doi.org/10.31272/jeasd.2899

Using Data Mining to Investigate Iraqi Digital Dentistry Software: Pilot Study

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Article Info

Received 01/08/2024
Revised 11/05/2025
Accepted 11/06/2025

Abstract

Digital dentistry means using digital technology in dentistry. This pilot study investigates the state of digital dentistry in Iraq and how to increase the usage of digital dentistry by using a text mining method within thematic analysis. The study consists of three steps: dataset collection (a questionnaire was sent to dentists, academic dentists, dental students, and practitioners working in Baghdad). Data processing using thermal analysis for feedback. The period of the study was four months. 120 responses have been collected. K-means cluster (k=3) as a data mining algorithm used within the concept of thematic analysis to automate the process of feedback analysis. The study demonstrated that about 60% of Iraqi dentists did not use any digital dentistry devices (nearly 25% of them used a CBCT device, while 12% used an intraoral scanner, and 5% used a 3D printer). Approximately 20% of Iraqi dentists use dentistry software. The findings revealed that digital dentistry is underutilized in Iraq, with limited applications at the governmental level and minimal use in the private sector. The high costs, the complexity of digital technologies, and the lack of training were identified as significant barriers to adoption.

Keywords: CAD/CAM, Digital dentistry, Digital dentistry software, K-means cluster, Open-source software, Thematic analysis.

1. Introduction

With the development of smart devices and IOT technology, everything runs brighter and smoother than before. The healthcare sector witnessed significant growth with the help of technology, providing quick access to information and professionals. Although dentistry had been a decade late in employing digital technology, the steady development offered more patient care opportunities compared to other fields of science [1]. Using computer technology in dentistry is referred to as digital dentistry, including branches such as digital occlusion, digital impression, aesthetic dentistry, virtual articulators, and many more in the foreseeable future. Digital dentistry made the work easy, reliable, less time-consuming, accurate, and clean. From a patient's point of view, digital dentistry provided an uncomplicated and painless treatment process [2], [3]. Digital dentistry was also an immense aid in pediatric dentistry [4]. It provides support to dentists, prosthodontists, oral surgeons, and orthodontists in their professional practice. Before digital dentistry, the analog methods used included physical diagnosis tools and indicator wax or paper, which were costly, inefficient, inaccurate, and time-consuming. Additionally, they were uncomfortable, and not self-sufficient, requiring constant monitoring [5], [6]. With minimal training, digital solutions completely flip the narrative. They provide simplistic tools and accurate solutions with clean and fast results [2], [7],[8]. In digital dentistry, patients can see the final result of the dentist's work using computer graphics before the procedure begins.

Digital dentistry delivers a customized treatment plan for each patient. In cases where the patient requires more than a simple tooth filling, the procedure starts by scanning the mouth. The software, which is an important part, uses the input from the scanners to build a 3D model and make different calculations, predictions, and suggestions to the dentist. In this step, the connection to computer science is highlighted, as many data mining, predictions, and artificial intelligence algorithms are used to achieve optimal results and deliver the right results [1], [9]-[11]. The digital devices used in dentistry (the hardware) include CAD/CAM 3D Printers, visualization monitors, smart goggles, and robots [12].

There are many digital devices [1]-[12]; thus, in Table 1, the most notable and popular devices related to digital dentistry

were considered. Table 1 shows the widely used digital dentistry hardware and its applications in dentistry. The questionnaires associated with this study used devices in that table to measure how familiar Iraqi dentists are with those technologies. The research aims to identify whether digital dentistry is applied in Iraq, and explore the factors that could increase the digitalization of dentistry in Iraq. The objective of this study is to use data mining techniques within thematic analysis, focusing on a semantic approach to automate feedback analysis.

Table 1. Common Digital dentistry tools and devices.

Digital device	Dentistry field
CBCT	Digital impression, visualize abnormality in teeth, cleft palates, jaw, or face
Intraoral Scan	Digital Impression, bright smile, restorative dentistry
3D Printers	Ceramic (and other material) inlay, onlay, crown, and virtual articulators.
Software	Tele dentistry, Patient records, Learning, treatment planning, Visualization, and decision support.

This study is structured as follows: section 2 displays the literature in the field of digital dentistry, which was grouped according to the software the computer algorithms made use of. The state of the art of digital dentistry in Iraq is addressed in section three, including the method used and the results. Section four presents the conclusion of our study. The discussion is demonstrated in section five.

2. Literature review

The history of dentistry dates back to 3700 BC in ancient Egypt, where they diagnosed diseases related to dental health and prescribed treatments. Still, there were no restorative or conservative dental processes exhibited then. (Odontology was the terminology used and not dentistry.) [13]. The first tools used in dentistry were the scraper and the extractor, mechanical dentistry tools were developed gradually in 1871. The development of the treadle drill was a game-changer in dentistry [14]. Later, the development of electricity revolutionized dental surgery. The discovery of the X-ray introduced dental radiography in 1896, and in 1960, lasers were used in dental procedures. Finally, the 1970s brought digital dentistry along with it [15]. Nano dentistry is the current future trend in dentistry [16].

Digital dentistry uses AI, data mining, Augmented and virtual reality. The term digital dentistry refers to the use of digital hardware and software to aid in the practice of dentistry [17]. Using such technologies provides a customized and accurate treatment plan, leading to reduced time and effort of the dentist and laboratory, in turn, enhancing the customer service experience. For the patient, that means a faster treatment journey, in addition to cost and waste reduction [12], [15], [18]. The most prevalent disease is dental cavities; it affects the majority of the worldwide population. Traditional examination methods used by dental practitioners are subjective and quantitative. Thus, non-invasive cavity detection tools provided a massive leap in dentistry, especially for pediatric dentists. The cavity detection tool could be classified as a digital hardware that provides a friendly environment via the colored 3D images and minimizes/maximizes capabilities; it is used by dental practitioners to detect cavities at their early stages [4]. Digital dentistry can be classified into two main categories: Hardware and software [15], [19]-[21].

Digital dentistry hardware, such as 3D printer/Manufactory, CBC, intraoral scanner, and digital radiography, completely reformed dentistry [3], [12], [22]-[24]. The development of such devices requires training. Thus, traditional dental education curricula need to be updated to incorporate the use of digital tools, which often come with built-in software. This study focuses on showcasing the application of computer science technology in digital dentistry. Different dentistry software was classified to study the computer techniques used in each. Dentistry software was classified by Peter T. et al. [25] depending on task and purpose. In this paper, dentistry software is classified from a computer science perspective into three categories: Simulation software, dentist support systems, and clinic management. This classification of software depends on algorithms that were used in each category. Fig. 1 depicts our classes.

Simulation software is used in image processing and vision technologies; it could be 3D, 4D, or in any dimension (nD). Medical image processing plays a central role in diagnosis and treatment planning [26]. Image processing tools are usually associated with T-Scan, CBCT, and other imaging devices. These tools enable dentists to examine the posterior teeth using image processing techniques. Therefore, hidden cavities are discovered and treated at early stages. Video conferencing, which is a type of software that involves image processing (used in tele dentistry), spread rapidly during COVID-19, not just for patient treatment but also for online learning too [27]. Virtual reality and augmented reality for education and training proved to be an affordable and safe alternative to train graduates and refine dentists' craft [6], [28].

Dental support systems offered many innovative solutions for orthodontics, aesthetics, digital occlusion, artificial articulators, and complex oral surgery thanks to artificial intelligence and data mining algorithms [29], [30].

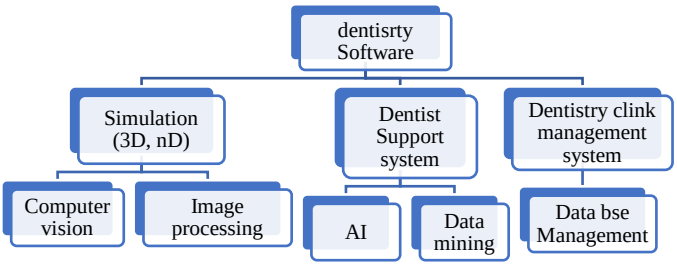

Figure1. Dentistry software classification from a computer science point of view.

Artificial intelligence provides support for dentists, especially in complex cases. Digital occlusion uses T-scans that apply AI algorithms to enhance the occlusion arch, outperforming the traditional occlusion methods [31]. Much literature has explored AI solutions in digital dentistry, [32]- [38]. Data mining uses patient healthcare records to predict complications related to treatment or prescribed drugs and predict the likelihood of future complications for patients after implant or jaw surgery. Generally, data mining and AI considerably aid the workload of dentists, increase patient satisfaction, and open advanced solutions for patients with special needs and seniors [10], [33]- [40].

Clinician management systems play an important role in enhancing the productivity of digital dentistry. The entire patient's information and dentists' treatment plans are safely stored in the special healthcare database; this data could be used to follow up each case or predict treatment options for future cases. It is highly beneficial for dental practitioners to view their patients' medical history. There are a lot of such systems, some of which are even provided freely by open-source software [9]. Every clinic should have an up-to-date database about all its patients [3], [9]. Patients' main concern with such a system is the use of their data without consent and data breaches [41]-[43]. The solution to this concern is using cybersecurity and computer encryption algorithms to make data hard to access or read.

3. Digital Dentistry in Iraq: The state of the art

This study aims to answer the following research questions:

Is digital dentistry applied in Iraq? How to increase the application of digital dentistry in Iraq? How to implement data mining principles in feedback analysis?

Generally speaking, healthcare in Iraq still needs more attention to be able to handle the vast, growing population [44], [45]. The Iraqi population, according to [46], has good preventive dental knowledge. Considering the various situations Iraq has faced, there are a decent number of Primary health centers (PHC) [47]. Each PHC had an oral health unit, but with traditional dentists' devices. To answer the research questions, a questionnaire was sent to dental practitioners, academics, and dentistry professionals. The questions relate to how familiar the practitioners, dentists, and students are with different types of well-known digital tools (please refer to Table 1). There were 120 participants, and the results were processed using two techniques: statistical analysis for the first three questions. For feedback questions, the last group of questions was of a long-answer text type (feedback). Thus, the principle of thematic analysis has been applied. The coding part of the thematic analysis was done using the text mining k-means method [48], [49]. The resulting clusters represent topics that participants suggest developing.

3.1. The Method

To determine if Iraqi dentists are using digital dentistry, a pilot study has been conducted, and a questionnaire has been used to collect the data. The questions were about digital dentistry hardware/software and how they are used. The answers were collected over a period of four months. The targeted group in this questionnaire was academic dentists, dentistry students, and dentists working at private clinics, all living in Baghdad. A simple statistical method was used to analyze the first group of questionnaire questions, while K-means clusters were used to process the second group of feedback questions. Thematic analysis was used in the context of k-means clustering to find the topics in each text in the feedback questions. Fig. 2 represents the proposed method.

Before applying the k-means algorithm, data preprocessing is a must. The following steps represent the required preprocessing for the data resulting from the last group of questions:

- Tokenization: All the 120 responses (long text answered-message) were tokenized
- Stop word removal, because the text was written in the Arabic language. Not only were commas, semi-commas, and white space removed, but also some other conjunction letters and words. This step represents data cleaning.
- Stemming the tokens, the Arabic word stemming tools (https://www.arabitools.com/Stemmer.html) were used to find the stem of the words.

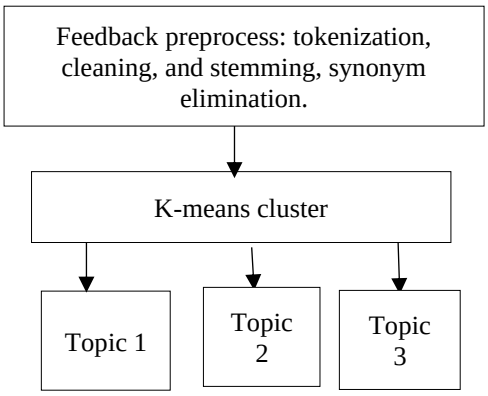

Figure 2. The proposed data mining aims to identify feedback clusters.

Then, a synonym removal is used to clean the dataset further. After that, the text was transformed into numerical values by calculating the frequency for each feedback using (1).

$$tf(t,i) = \log(1 + frq(t,i)) \quad (1)$$

Where t represents the frequency of token occurrences in the I-feedback, and d represents the length of the feedback. The

numerical values are used to perform the K-means clustering to find the set of clusters that defines the topics from the feedback. A post-process is needed. In the post-processing, a simple synonym analysis is performed. If two topics are synonyms, the topics are merged.

3.2. The Results

The first question in the conducted questionnaire was about digital dentistry devices shown in Table 1, (CBCT, intraoral scanner, and 3D printer) the aim was to identify the percentage of dentists who used such devices, Fig. 3 shows the result of using each device. From the figure, more than 60 % of Iraqi dentists did not use any digital dentistry devices. About 25% used CBCT, while 12% had the opportunity to use an intraoral scanner, and less than 5% used a 3D printer. Although there was an option in the questionnaire that allowed the participants to enter any other dental device that they may use, unfortunately, none specified any.

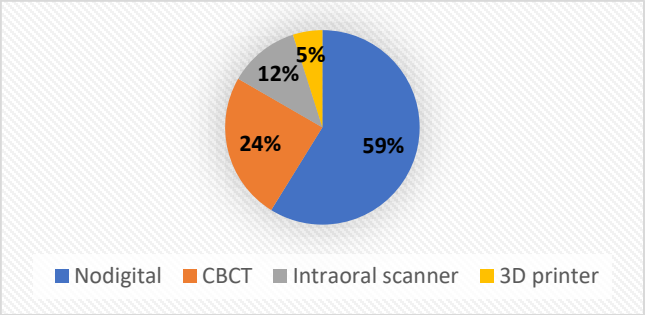

Figure 3. Responses to the questionnaire regarding the usage of digital dentistry hardware.

After determining the digital devices Iraqi dentists are familiar with, the following questions are used to determine if such devices were provided in the private sector or in governmental facilities. The results show that half of the digital dentistry hardware used by the participants was located in the private sector, and only a limited number of governmental facilities (hospitals or universities) had such devices. Fig.4 depicts the results. Regarding digital dentistry software, the results weren't better. Specifically, 80% of participants did not use any dentistry software, 20% stated that they use patient reservation applications (a type of clinic management system), and the software is mainly used by dentists working at private clinics.

The last set of questions was feedback questions related to the dentist's opinion/suggestion/experience of digital dentistry in Iraq. The Arabic language contains a lot of English words, special symbols, spaces, commas, dots, and whitespace, which should be eliminated.

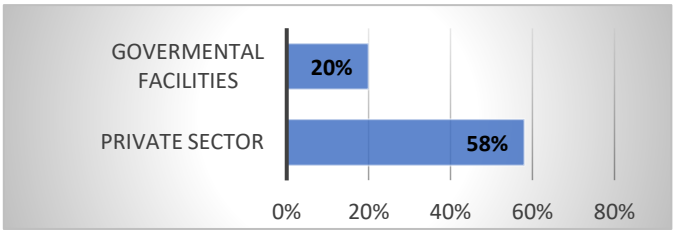

Figure 4. The places where digital dentistry devices exist in Iraq.

A built-in MATLAB function was used for K-means clustering. Firstly, to determine the correct value of K, the algorithm was executed multiple times. The resulting cluster was scattered due to the presence of synonyms. Thus, a further cleaning of the dataset was done by removing synonyms. The best value of K was 3; the Elbow test was used to determine the best K Value. For each value of K, Euclidean distance was calculated, and the clustering algorithm was executed twelve times to reach the linear behavior (steady state) at k=3. Fig.5 depicts these values. From the 120 feedback responses, three main topics were obtained which are:

- Cost.
- Training.
- Complexity

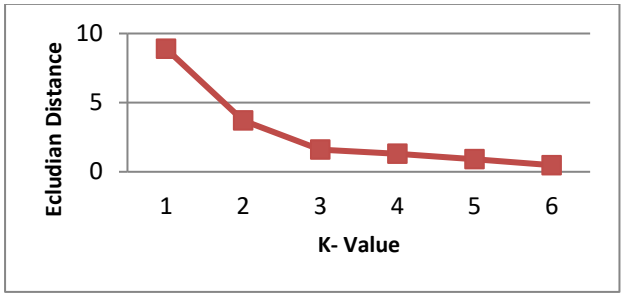

Figure 5. K-value corresponding to Euclidean distance.

To test the validation of the resulting cluster, the heat map graph was applied to the resulting text cluster. Fig.6 shows the heat map and dendrogram for the three classes.

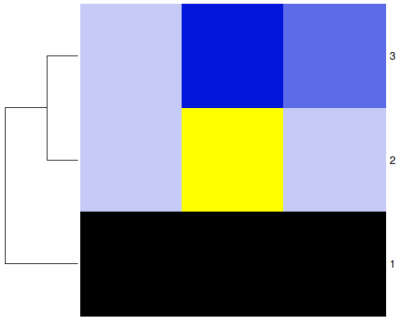

Figure 6. Heat map analysis for the clusters.

4. Discussion

The pilot study aimed to answer the following research questions:

Is digital dentistry applied in Iraq? How to increase the application of digital dentistry in Iraq? How to implement data mining principles in feedback analysis?

The questionnaire showed that about 40% of Iraqi dentist used digital dentistry devices, while, the lack of training and cost made dentistry software less used.

The implementation of data mining within thematic analysis effectively automated the feedback analysis process. It resulted

in three clusters that represent the main factors that could play a central role in Iraqi digital dentistry. The validation of the cluster algorithm was done using a heat map (Fig.6).

To increase the usage of digital dentistry in Iraq, researchers and government support are needed. In Iraq, digital density devices exist in the private sector (private dentistry colleges, private dental centers, and clinics), and very few governmental dentistry colleges have CBCT devices (and fewer have an old version of a 3D printer). Despite the existence of such devices in governmental facilities, they are still not available for all to use due to high maintenance costs and restricted use. Undergraduate dentistry students were unable to use digital dentistry devices. Dental practitioners who work in private clinics get more opportunities to deal with digital dentistry devices.

Most Iraqi dentists are not familiar with dentistry software, according to the study. Computer visualization and graphics are essential parts of dentistry software, as they provide a deeper understanding of the case and facilitate the decision-making process for treatment plans [1], [3], [6], [49]. In Iraq, there is a lot of research in digital image processing and 3D visualization; unfortunately, there is little related to digital dentistry due to a lack of collaboration between these two areas of study.

Thematic analysis for the feedback was done using K-mean cluster to find the themes. Data mining has been used successfully to cluster the input. Preprocessing and post-processing were applied to the text before and after the clusters. The three themes (topics) resulting from the text clustering algorithm were: Cost, Training, and Complexity. Those reflect the areas that affect digital dentistry in Iraq.

The first cluster (with words that have similar or related meanings to cost and money) sees the cost of digital dentistry as the main reason for not applying digital technology in private clinics. This was the opinion obtained from dentists who own or work in private clinics or centers; they claimed that the added cost of such devices will not make any profit, as the patient will refuse to pay more, and look for other options with less cost at other clinics.

Most academic dentists claimed that training is the main shortcoming of applying digital dentistry; even if the CBC device or other devices exist, training on such new technology is needed. Thus, training courses delivered by professional and well-known companies will advance digital dentistry in Iraq.

Other dentists and dental students claimed that the complexity of dental software is the main **obstacle**; they believe that digital software associated with digital devices is complex. Accordingly, it is a challenge for senior dentists and complex for young ones.

There is a lot of simulation and dental support software available online. Some may offer a reasonable price per year. Mostly, such software offers cloud-based storage, which eliminates the need for locally stored data and provides affordable solutions from a cost point of view. The study highlights some dot points regarding our findings:

- According to Nh Albujeer [48], most dentists in Iraq graduate from Iraqi colleges. The results of the study show that dentistry graduates and academic faculty members at Iraqi dentistry colleges lack training in digital dentistry. Our finding is supported by Khoshnevisan M. et al. in [49]. Dentistry colleges in Iraq have not yet applied the concept of digital dentistry in undergraduate or postgraduate curriculums because of the lack of digital devices and training. CBC device is the only one that could be found in limited governmental and private dentistry colleges in Baghdad, even with the existence of such device it is not available to be used by all students because of the maintenance cost.
- Private dentistry clinics and centers offer digital dentistry. The patient will be more comfortable with the treatment plan. CBCT, Intraoral scanner, and simulation software are used in such clinics, which adds to the cost, thus it is only for high-income patients.
- The lack of a healthcare database to keep digital patient records in governmental hospitals is notable. In contrast, private hospitals have a local database that is only used within their own facilities.
- Although there are Iraqi medical journals with impact factors, there are limited research efforts in the field of digital dentistry. This is mainly because of the absence of multidisciplinary teams. Digital dentistry is not just about studying dentistry; it is about the use of software, digital devices, and nanotechnology.

Generally, Virtual and Augmented reality [50]-[52] used effectively for education. It provides an effective tool to train doctors to do surgery; the simulation seems too real [53]. Dentistry students will gain confidence and be stress-free if they use such technology, according to Alfallaj et al. [54]. The main reasons that Fifth-year Iraqi dentistry students feel stressed are clinical requirements and patients not showing up or being late. VR/augmented reality training will ease that stress. Students can train on virtual patients, with a supervised AI bot available to guide them through the steps needed for help.

Comparing our findings regarding the application of digital dentistry to other countries nearby (please refer to Table 2) showed that digital dentistry in these countries, according to [55]-[59], needs more support and attention.

Approximately 40% of Iraqi dentists are aware of dental hardware, such as CBC, intraoral scanners, or other devices listed in Table 1. In comparison, awareness among Egyptian dentists ranges from 48% to 73%, followed by Turkey. On the other hand, the UAE and Saudi Arabia emphasize not only the use of digital dentistry devices but also the incorporation of digital dentistry into the undergraduate curriculum at dental schools.

Digital dentistry is a revolution soon or late every dentist will be used. It offers so much for both the patient and the dentist. The benefits of deploying digital dentistry overcome the cost incorporated. Although digital dentistry hadn't developed early like other medical fields, it overcomes the traditional ones [5], [59], because of its benefits [1], [17], [19] for doctors, patients,

and clinicians, and when thinking of green solutions, digital dentistry is the one.

Table 2. Digital dentistry in some nearby countries.

Country	Ref.No	Outcome
Saudi Arabia	[55[, [56]	Digital dentistry needs to be integrated into dental schools by about 60%
Turkey	[59]	A few dentists in Turkey can incorporate digital devices in their practice
UAE	[58]	For undergraduate students at dentistry school, the study showed a satisfactory awareness
Egypt	[55]	level of awareness about digital dentistry was 48%-73%
Iraq	The pilot study	40% of Iraqi dentists were aware of digital dentistry.

5. Conclusions

In this study, a questionnaire was used to collect data on digital dentistry in Iraq. It was submitted to dentistry specialists, academics, and dental students. Text mining algorithm has been applied to thematically analyze the feedback to conclude the factors that affect digital dentistry in Iraq. The result of the 3-mean cluster algorithm showed that three main factors play a central role in the implementation of digital dentistry.

The cost and complexity of digital technology impact the application of Iraqi digital dentistry. Thus, the digital dentistry at the governmental level is not applied, while there is some degree of digitalization in the private sector. Training is an essential factor; an Iraqi dentist claims that there is a lack of training on such technology (digital dentistry), especially during academic studies. Dentists need training to be more confident when using digital dentistry equipment and software.

According to Table 2, the state of the art of digital dentistry in these countries needs more attention toward the application of digital dentistry.

6. Recommendation

The analysis of the questionnaire concludes the following recommendations that could enhance digital dentistry in Iraq:

- Training. There are many new devices and software tools available. Training on how to use them effectively and implement best practices is essential to make full use of the latest technology from the pilot study. The lack of training was an important point that practitioners and academic dentists mentioned.
- Investing in new technology. Digital technology is expensive; thus, governmental support is highly recommended, especially in governmental facilities.
- Updating the curriculum of dentistry schools, from undergraduate students to include digital dentistry, as many Iraqi dentists graduate from Iraqi institutions.
- Multidisciplinary academic collaboration is to advance digital dentistry in Iraq. Unfortunately, in Iraq, there is minimal research effort in this area. Therefore, dentists, computer scientists and engineers have to collaborate to enrich the literatures in digital dentistry.

Acknowledgments

We want to express our appreciation to the College of Science at Mustansiriyah University for its academic advice. Also, we express our gratitude to the Information Technology Center at Mustansiriyah University for distributing the questionnaire link.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contribution Statement

Wurood Albayati and Mohammad A. Alshomali proposed the research problem. Mohammad A. Alshomali: developed the theory, investigated, and supervised the findings of the pilot study.

Wurood Albayati: performed the computations and programmed the cluster algorithm.

Jason Holdsworth: guide the brainstorming process, review the research aim, questions, and enhance the structure of the study.

All researchers participate in organizing the study.

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