

Awareness of Malaysian Towards 3D Printed Healthcare Products

Chin Lu Tong¹, Lee Te Chuan^{1*}

¹ Department of Production and Operations Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, 86400, MALAYSIA

*Corresponding Author: tcllee@uthm.edu.my

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Abstract

3D printing is an emerging additive manufacturing technology in Malaysia's healthcare industry. However, there are some problems, such as the critical global organ shortage crisis, challenges in 3D-printed applications in healthcare, and the lack of studies on Malaysians' awareness of 3D printing in the medical field. The objectives of this study were (1) to measure the level of Malaysian awareness of 3D-printed applications in healthcare and (2) to investigate the relationship between perceived benefits, knowledge of 3D printing, and attitudes towards Malaysian awareness of 3D-printed applications in healthcare. This study was conducted using quantitative methods, where questionnaires were used to collect the data. Random sampling was applied. The targeted number of respondents in this study was 120, and the data was gathered using a questionnaire and quantitatively evaluated using SPSS software. The findings of this research show that there is a high level of awareness among Malaysians regarding 3D-printed applications in healthcare, with an average mean score of 3.588. All the variables showed a positive impact on Malaysians' awareness of 3D-printed applications in healthcare, with attitude having the highest impact (Spearman's correlation coefficient value of 0.839, $p = 0.000$), followed by knowledge of 3D printing (Spearman's correlation coefficient value of 0.782, $p = 0.000$) and perceived benefits (Spearman's correlation coefficient value of 0.774, $p = 0.000$). Consequently, there were several expected advantages from this study on the awareness of 3D-printed applications in healthcare: patients would have a higher quality of life, doctors would be able to work more efficiently, and researchers would be able to make technological breakthroughs.

1. Introduction

In today's technology-driven world, industries rely on evolving technologies to improve production costs, effectiveness, and efficiency (Marak *et al.*, 2019). Among the emerging trends for 2024, 3D printing stands out, especially in Malaysia, where it remains a relatively new concept despite its long-standing use in other fields. This technology is poised to significantly impact sectors such as engineering, industry, the arts, education, and healthcare (Shahrubudin *et al.*, 2020).

3D printing has already made significant progress in medical technology. It utilizes digital models created from medical imaging techniques such as MRIs, CT scans, and X-rays to fabricate complex shapes (Yeong *et al.*, 2006). This technology has enabled advancements in medical equipment, implant materials, and cell printing. Notable medical applications include the successful use of 3D printing to restore an occipital bone in a newborn

and to replace a prosthetic for a woman with a rare tumor in her wrist joint (Kaminski, 2022). These cases highlight how 3D printing is advancing medical treatments and improving outcomes.

One of the most promising applications of 3D printing is in prosthetics. The ability to print prosthetics based on individual patient data, such as CT scans, allows for precise, customized fits that improve comfort and functionality. This technology is revolutionizing prosthetic design by enabling the rapid creation of personalized, anatomical structures. According to Precedence Research, the global market size for 3D printing in healthcare was estimated at USD 1.2 billion in 2022 and is expected to reach approximately USD 6.25 billion by 2032, growing at a compound annual growth rate (CAGR) of 18% during the forecast period from 2023 to 2032.

3D bioprinting has significant potential for Malaysia's healthcare industry, with initiatives like the e-Nable Organization providing affordable 3D-printed prosthetics to those in need. This effort aligns with national policies such as Industry4WRD, which promotes Industry 4.0 applications, including 3D bioprinting. By 2020, Malaysia had invested RM 6.1 billion in 51 healthcare-related 3D printing projects, creating over 11,000 jobs (Malaysian Investment Development Authority, 2021). Notable achievements include Malaysia's first 3D-printed calcaneal bone replacement, highlighting the technology's ability to revolutionize patient-specific therapies and surgical procedures.

According to Vanar (2024), Malaysia's first 3D-printed molded calcaneal bone (heel bone) replacement was successfully completed. This result shows the rapid adoption and success of 3D printing technology in Malaysia's medical industry, as well as its potential to transform patient-specific therapies and surgical procedures. The successful execution of such a sophisticated and innovative surgery demonstrates Malaysian healthcare professionals' and institutions' confidence in adopting cutting-edge technologies to improve patient outcomes. 3D printing technology can also be used to print skin, develop drugs and pharmaceuticals, fabricate bone and cartilage, create replacement tissues and organs, support cancer research, and produce models for visualization, education, and communication (Shahrubudin *et al.*, 2019).

Organs in the human body can be classified according to their functions and locations in systems: internal organs, digestive organs, reproductive organs, excretory organs, respiratory organs, circulatory organs, and sense organs (Çetin *et al.*, 2013). Internal organs encompass a range of structures, including the trachea, esophagus, lungs, heart, stomach, liver, gallbladder, duodenum, pancreas, intestines, large intestine, rectum, spleen, kidneys, and appendix. These internal organs must be well cared for, as proper care can help prevent the need for organ transplants and reduce waiting lists for organs.

Theoretical models like TAM and UTAUT have been widely used to study 3D printing adoption in healthcare (Chang *et al.*, 2016; Holzmann *et al.*, 2020; Kim *et al.*, 2019). TAM focuses on perceived usefulness and ease of use to predict behavioral intentions (Chang *et al.*, 2016), while UTAUT incorporates factors such as performance expectancy, effort expectancy, and social influence (Holzmann *et al.*, 2020; Slegers *et al.*, 2022). Studies across Taiwan, the Netherlands, Korea, and other countries have applied these models to explore technology adoption in diverse healthcare contexts (Chang *et al.*, 2016; Slegers *et al.*, 2022; Kim *et al.*, 2019). By integrating TAM and UTAUT, researchers can gain a comprehensive understanding of the factors influencing technology acceptance and adoption, including usability, social influences, and environmental conditions (Holzmann *et al.*, 2020; Kim *et al.*, 2019).

Previous research has explored the challenges of implementing 3D printing technology in Malaysian manufacturing firms. These challenges primarily stem from issues related to social factors, technological constraints, economic considerations, environmental impacts, political dynamics, and values, as outlined in Wahab *et al.* (2020). Additionally, Shahrubudin *et al.* (2020) identified key challenges such as staff re-education, product pricing strategies, limited regulatory guidelines, cybersecurity concerns, marketing hurdles, and issues related to patents and copyrights. Moreover, a survey conducted by Ng *et al.* (2022) revealed that Malaysians exhibit a low awareness level, lack sufficient knowledge about advanced technologies, and have limited experience with 3D printing technology. These findings underscore the multifaceted challenges that need to be addressed for the successful integration and adoption of 3D printing in the Malaysian manufacturing sector.

Hence, this study adopts the Theory of Planned Behavior (TPB) as it effectively analyzes factors influencing awareness of 3D-printed applications in healthcare. TPB provides a structured framework to assess perceived benefits, knowledge, and attitudes, contributing to the overall understanding of technology acceptance in Malaysian healthcare contexts. This study aims to measure the level of Malaysian awareness of 3D-printed applications in healthcare and investigate the relationship between perceived benefits, knowledge of 3D printing, and attitudes towards Malaysian awareness of 3D-printed applications in healthcare.

2. Literature Review

2.1 3D Printed of Healthcare

The integration of 3D printing into healthcare has significantly transformed medical practices, enabling the creation of patient-specific implants, prosthetics, and even bioprinted tissues and organs (Pathak *et al.*, 2023). The history of 3D printing in healthcare began in 1984 when Charles W. Hull invented stereolithography, a technique to create three-dimensional objects layer by layer, which later became foundational for medical applications (Whitaker, 2014). According to Whitaker (2014), researchers achieved a milestone in 1999 by creating replacement urinary bladders through manually constructed scaffolds seeded with patients' cells, marking a significant advancement in regenerative medicine. The early 2000s witnessed further progress in bioprinting, including the development of cell-depositing inkjet technologies patented by Dr. Thomas Boland in 2003, which enabled the precise placement of viable cells for tissue engineering (Keane, n.d.). More recently, in 2019, Israeli researchers 3D-printed a rabbit-sized heart complete with blood vessels, demonstrating significant potential for organ replacement in humans (NBC News, 2019). Today, 3D printing is pivotal in creating customized prosthetics, implants, surgical planning models, bioprinted tissues, and even personalized pharmaceuticals, revolutionizing patient care by offering precise, efficient, and patient-specific solutions (Ventola, 2014). The continuous evolution of this technology holds immense promise for addressing organ shortages and advancing regenerative medicine, potentially transforming the future of healthcare.

2.2 Advantages of 3D Printed Application

3D printing, also known as additive manufacturing, offers significant advantages that are transforming industries worldwide. One of its primary benefits is rapid prototyping, which allows for the swift creation of prototypes and accelerates the product development process. This capability enables businesses to iterate designs quickly, reducing time to market and improving innovation. Furthermore, 3D printing provides cost efficiency, particularly for small production runs, as it minimizes material waste by depositing material only where necessary. This approach is especially beneficial in sectors like aerospace and healthcare, where precision and minimal waste are crucial (Jayakrishna *et al.*, 2023). Another advantage is the design flexibility that 3D printing offers. Traditional manufacturing methods are often limited by tooling constraints, but 3D printing can produce intricate and customized designs that would otherwise be impossible. This flexibility is pivotal in industries such as fashion, automotive, and architecture, where unique geometries are often required. Additionally, 3D printing promotes sustainability by reducing material usage and supporting localized production, thereby cutting down transportation emissions and fostering environmentally friendly practices (Nadagouda *et al.*, 2020). In the healthcare sector, 3D printing has been a game changer. It enables the creation of customized medical devices, such as prosthetics, implants, and surgical guides, tailored to individual patients. This personalization improves patient outcomes and reduces the risks associated with generic solutions (Ventola, 2014). Furthermore, advancements in bioprinting are opening new possibilities, such as the creation of tissues and organs for transplantation, addressing critical shortages in donor organs (Jayakrishna *et al.*, 2023). These advantages underscore the growing significance of 3D printing in creating efficient, sustainable, and patient-specific innovations.

2.3 Challenges and Limitations of 3D Printed Application in Healthcare

While 3D printing holds significant promise in healthcare, several challenges and limitations hinder its widespread adoption. One major concern is the lack of standardized quality assurance and control. Unlike traditional manufacturing, 3D printing can produce varying results due to differences in materials, printers, and parameters, potentially compromising the precision and reliability required for medical devices (Wang *et al.*, 2020). Regulatory hurdles also pose significant obstacles. The current regulatory framework often focuses on the final 3D-printed products rather than the printing processes or materials used, leading to uncertainties and delays in approvals. This lack of clear guidelines can impede the timely introduction of innovative medical solutions. Additionally, the limited range of biocompatible materials suitable for 3D printing restricts the types of medical devices and implants that can be produced. This limitation affects the ability to create complex composite devices or those requiring special materials, thereby constraining the technology's applicability in certain medical scenarios. Addressing these challenges is crucial for the successful integration of 3D printing technologies in healthcare, ensuring that they meet the stringent standards necessary for patient safety and efficacy.

2.4 Awareness level

Awareness of 3D-printed applications in healthcare is steadily increasing, particularly in advanced fields like orthopedics, dentistry, and regenerative medicine, though general practitioners and smaller medical facilities

often lack exposure to the technology. Public awareness, driven by media coverage of breakthroughs like bioprinted organs and customized prosthetics, is growing, but misconceptions about its practicality persist, especially in developing regions where limited infrastructure and training hinder adoption. Studies on the acceptance of 3D printing in healthcare are limited, with much research focusing on technical aspects or other industries. Using frameworks such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), researchers have identified factors influencing acceptance, including perceived usefulness, ease of use, performance expectancy, social influence, and familiarity. For instance, Chang and Chen (2016) found perceived usefulness and confidence significant for medical acceptance, while Millet *et al.* (2021) and Slegers *et al.* (2022) emphasized ease of use and social factors in occupational therapy. In other contexts, Kim and Hong (2019) highlighted performance expectancy in the 3D printing industry, Holzmann *et al.* (2020) explored adoption among teachers, and Chang *et al.* (2024) and Ng *et al.* (2022) identified sensory appeal, environmental friendliness, and familiarity as key factors in 3D-printed food acceptance. Overall, the studies demonstrate the varied objectives, methodologies, and theoretical frameworks used globally, underscoring the need for targeted educational initiatives, affordable technologies, and infrastructure development to bridge the gap in awareness and adoption.

2.5 Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT)

The Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) are widely used frameworks for understanding technology adoption. TAM, developed by Lin & Yu (2023) and popularized by Lederer *et al.* (2000), identifies two key predictors perceived usefulness (PU) and perceived ease of use (PEOU) which influence users' attitudes (AT) and behavioral intention (BI) to use a system, closely linked to actual behavior. The model has been extensively validated across various fields and contexts, with external factors aiding its evolution (Aziz *et al.*, 2020). Similarly, UTAUT, proposed by Venkatesh *et al.* (2003), integrates constructs from eight theoretical models, including TAM, TPB, and Innovation Diffusion Theory. UTAUT identifies four core determinants performance expectancy, effort expectancy, social influence, and facilitating conditions that predict behavioral intention and usage, moderated by gender, age, experience, and voluntariness. These frameworks offer robust tools for predicting and analyzing technology adoption across diverse contexts and user groups.

2.6 Perceived Benefits

Perceived benefits refer to an individual's belief in the positive outcomes or advantages resulting from engaging in a particular behavior or adopting a specific technology. This concept is central to various behavioral theories, including the Health Belief Model, which posits that individuals are more likely to engage in health-promoting behaviors when they perceive significant benefits. Perceived benefits and perceived usefulness are related concepts, and perceived usefulness can be considered a subset of perceived benefits, but perceived benefits encompass a wider range of positive factors beyond just usefulness (Ajzen, 2012).

2.7 Knowledge on 3D Printed

Knowledge of 3D printing refers to an individual's understanding and familiarity with the processes, technologies, materials, and applications involved in 3D printing. This encompasses awareness of how 3D printing operates, the various types of 3D printers (such as Fused Deposition Modeling (FDM) and Stereolithography (SLA)), the materials used (including plastics, metals, and resins), and the diverse industries where 3D printing can be applied (such as manufacturing, healthcare, architecture, and education). Having knowledge about 3D printing means being aware of its capabilities, limitations, and potential for innovation, which influences how individuals or organizations perceive, adopt, and use 3D printing technology (Vaishya *et al.*, 2018).

2.8 Attitude

Global and relentless predispositions, whether or not favourable or negative, regarding a stimulus as well as class of stimuli are referred to as "attitudes" (Wittenbrink & Schwarz, 2007). An individual's attitude is defined as their viewpoint, evaluation of an individual or thing, and ability to react either positively or negatively to a particular idea, object, person, or circumstance. It usually falls into three categories: cognitive (perceptions and beliefs), personality (actions along with mentioned intent towards something based on both "cognitive" alongside its "affective" responses). Another dimension is feelings, which include both likes and dislikes as well as feelings and evoked emotions (Vargas *et al.*, 2016).

2.9 Hypothesis Development

2.9.1 Perceived benefits towards awareness of Malaysian of 3D printed application in healthcare

Users' opinion of perceived usefulness is the degree to which they feel that utilizing particular technology could improve their work Davis *et al.* (1989). Chang & Chen (2016) conducted research on a theoretical model state that perceived benefits has a positive effect 0.466 towards acceptance and awareness 3D bio-printing in the medical treatment. Wendo *et al.*, (2022) conducted a study provides valuable insights into the perceived benefits of 3D printed upper limb prosthetics. The results of the study, which encompassed 58 devices, highlighted the general specifications, mechanical and kinematic specifications, and details about the 3D printing technology employed for these prostheses. The overview showcased prostheses catering to different upper limb amputation levels with various control types and a maximum material cost of \$500. The study emphasized that while a wide range of 3D printed prostheses have been developed, with a majority used by children, there is a lack of evidence regarding user acceptance, functionality, and durability of these prostheses. According to Kim & Hong (2015) research states the strong positive relationship between perceived benefits and the awareness to use 3D printing technology. The study found that the perceived benefits of 3D printing technology significantly increase the intention to adopt it. The path coefficient for perceived benefits was $\beta = 0.63$, indicating a strong influence on adoption intentions. Therefore, the following hypothesis is proposed:

H1: There is a positive relationship between perceived benefits toward Malaysian's awareness of 3D printed application in healthcare.

2.9.2 Knowledge on 3D printed towards awareness of Malaysian of 3D printed application in healthcare

According to Ng *et al.*, (2022) stated the status of knowledge about 3D food printing among respondents was reported as low. Most participants were not familiar with the concept or its applications, leading to neutral attitudes toward the technology initially. The study found that providing additional information significantly improved participants' understanding and positively influenced their attitudes, highlighting the critical role of education and awareness in promoting acceptance of 3D food printing. According to Lau & Sun (2022) stated the knowledge was assessed by comparing the understanding of congenital heart disease (CHD) in students using 3D printed heart models (3DPHM) versus traditional materials. The results indicated no significant difference in the immediate or long-term knowledge retention between the two groups. Thus, the hypothesis is that:

H2: There is a positive relationship between knowledge on 3d printed toward Malaysian's awareness of 3D printed application in healthcare.

2.9.3 Attitude towards awareness of Malaysian of 3D printed application in healthcare

Attitude is a psychological construct referring to a person's mental and emotional evaluation of a concept, object, person, or situation. Bain, (1928) describe attitudes can be positive, negative, or neutral and are influenced by experiences, social norms, and individual personality traits. Previous studies have highlighted the role of the role of attitudes in shaping consumer behavior, particularly how initial perceptions of novelty, trust, and risk influence acceptance of new food technologies. According to Brunner *et al.*, (2017) identified reveals that consumers' attitudes can evolve over time through exposure to information and hands-on experiences, suggesting that education and direct interaction with 3D-printed food can positively influence their perceptions and acceptance of this innovative food technology. According to Parikh *et al.*, (2019) identify most participants had a positive attitude toward the technology. While 89% were aware of 3D printing in orthodontics, 83% acknowledged its benefits over other digital imaging methods. Despite the strong awareness and favorable attitudes, 47.5% of orthodontists had not integrated 3D printing into their daily practice, indicating a gap between positive perceptions and actual implementation. Therefore, the following hypothesis is proposed:

H3: There is a positive relationship between attitude toward Malaysian's awareness of 3D printed application in healthcare.

2.10 Research Framework

This study focused on the analysis of an established framework. The research model used in this study to measure which are perceived usefulness, perceived ease of use, social influence, facilitating conditions and performance expectancy. The following hypotheses are aimed at being tested and the figure of research framework is shown in Fig. 1.

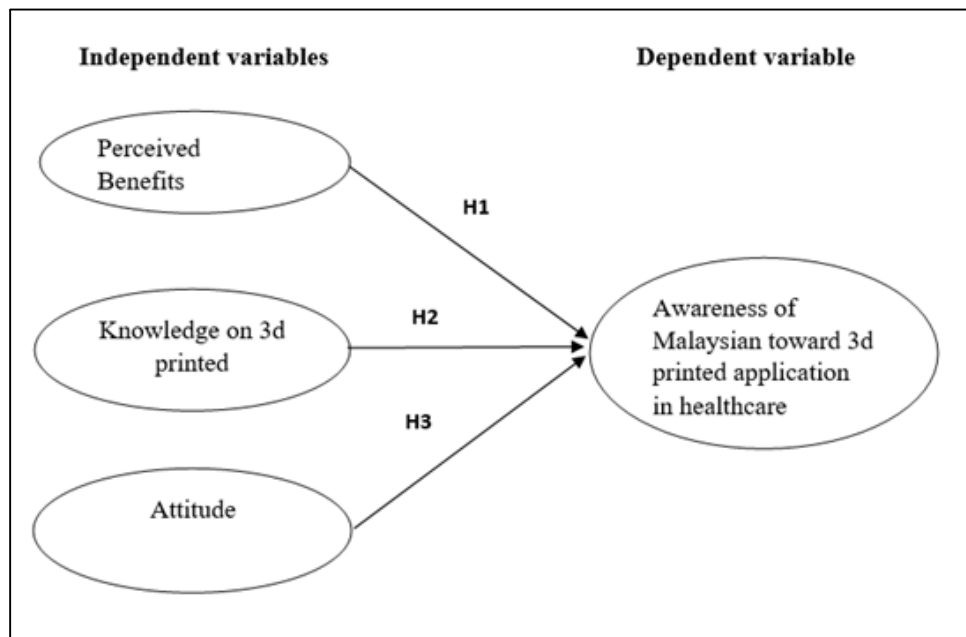


Fig. 1 Diagram adoption research framework of 3D printed application in healthcare

3. Research Methodology

3.1 Research Design

This study focused on the acceptance Malaysian toward 3D printed upper limb prosthetics. A quantitative approach is used to conduct the survey because it is easier to collect data from a larger sample size, and it is faster and easier to collect data as well (Mander, 2022). Therefore, a survey questionnaire will be developed to target on Malaysians acceptance level. Survey questionnaire can provide direct feedback from Malaysians on their perceptions and attitudes towards 3D-printed upper limb prosthetics, which is crucial for understanding their acceptance levels. Surveys are also time and cost-effective compared to other data collection methods, enabling the collection of extensive data in a shorter period. This study employs descriptive and correlational designs using a questionnaire to collect large-scale data. The questionnaire comprises three sections: demographic profiles (Section A), TAM and UTAUT frameworks (Section B), and Malaysian acceptance of 3D-printed upper limb prosthetics (Section C). It uses multiple-choice and 5-point Likert scale questions for simplicity and ease of use (Newson, 2021), facilitating efficient data collection and analysis.

3.2 Population and Sampling

The non-probability sampling technique with convenience sampling (Palinkas *et al.*, 2015) was used in this study because the population of Malaysian who have knowledge of 3D printed in healthcare was unknown, and there was no statistic. Thus, this study aims to achieve a sample size of 384 respondents using convenient sampling.

3.3 Questionnaire Development

In this study, the questionnaire was consisted of 3 sections, namely section A on demographic profile, section B on factors awareness Malaysian toward 3D printed application in healthcare and section on the awareness level. Table 1 lists the questions included in the questionnaire found in the table below.

Table 1 Questions in the questionnaire

Variables	Questions	Sources
Perceived benefits	I believe that the perceived benefits of emergency technologies to improve patient outcomes I believe 3D printing technology can enhance surgical precision	(Ng <i>et al.</i> , 2022)

	I believe 3D printing can enhance the overall quality of healthcare I believe 3D printing applications are easier and more convenient I believe that 3D printed applications can provide helpful guidance in performing tasks of healthcare	
Knowledge on 3D printed	I am familiar with the use of 3D printing technology in healthcare I am familiar with the application in various fields I believe 3D printing in healthcare sector becoming more popular in recent times I think 3D printed materials used in healthcare sector will be biocompatible and does not have any harmful side effects in patient I think 3D printing technology is ethical in healthcare	(Acharya <i>et al.</i> , 2023) (Jawahar <i>et al.</i> , 2021) (Wilk <i>et al.</i> , 2020)
Attitude	I believe that 3D printing in healthcare will have more advantage I will to obtain any updated information regarding 3D printing in healthcare I believe 3D printing technology has the potential to replace traditional methods in healthcare I believe 3D printing offers significant advancements in the development of medical devices I am confident in the use of 3D printing in healthcare	(Parikh <i>et al.</i> , 2019)
Awareness toward 3D printed	I am interested in 3D printing of healthcare I am aware about the working principle of 3d printing I am aware of the procedural expenses for 3D printed surgical guides I note the additional morphological defects or unexpected variations when 3D printed models were used in healthcare I am aware of any 3D printing techniques used in healthcare	(Tesikova <i>et al.</i> , 2022) (Ng <i>et al.</i> , 2022)

3.4 Data Collection

This study targeted Malaysians as the sample, using a survey-based approach to examine the awareness of 3D-printed applications in healthcare. The sample included individuals with and without personal experience with prosthetics, enabling a diverse and representative analysis of awareness levels. The survey explored factors such as perceived benefits, knowledge of 3D printing, attitudes, and their relationship to overall awareness. Google Forms was utilized for creating and distributing the survey, offering convenience through sharing via email, links, and messaging platforms like WhatsApp. Additionally, the data collected was automatically stored in a spreadsheet, streamlining classification and pre-analysis.

3.5 Pilot Test

In order to complete the pilot test, 30 respondents were collected. For the questionnaire's reliability, a Cronbach's alpha coefficient required at least 0.7 to expect to avoid the exclusion or elimination of any variables in the contents. The reliability results show that the survey items for all four variables demonstrate strong reliability. Perceived Benefits (PB) has the highest Cronbach's Alpha of 0.951, indicating excellent internal consistency. Awareness of Malaysians (AOM) follows with a very good reliability score of 0.870. Both Knowledge (K) and Attitude (A) have good reliability scores of 0.750 and 0.726, respectively. These results suggest that the survey items are consistent and reliable for measuring perceptions, knowledge, attitudes, and awareness of 3D printing applications in healthcare. After the variables refined, the questionnaire was achieved an acceptable reliability level, with Cronbach's alpha all greater than 0.7. There is a total 20 items, and Cronbach's alpha of each variable were in the range of 0.726 to 0.951.

Table 2 Pilot test

Variables	No. of Item	Cronbach's Alpha	Interpretation
Perceived benefits	5	0.951	Excellent
Knowledge of 3D printed	5	0.750	Good
Attitude	5	0.726	Good
Awareness toward 3D printed	5	0.870	Very Good

3.6 Data Analysis

The Statistical Package for Social Science (SPSS) version 22.0 is then used to analyse the data. Responses are totalling and analysing using the data's mean, percentage, and standard deviation for descriptive analysis. To compare and test hypotheses, inferential analytic techniques like Pearson's correlation and Spearman's correlation were employed (Bhandari, 2020). The data analysis for this study used the descriptive analysis, scale measurement, and inferential analysis methodologies.

4. Results and Discussion

4.1 Response Rate

The researcher randomly distributed 384 self-administered questionnaires to Malaysian. Within a month 5 September until 5 October 2024, 120 questionnaires are returned to the researcher from the respondents. Therefore, only 120 respondents are considered to be analyzed for this study. The rate of response for this study is 31.25%. A response rate of 31.25% is generally considered acceptable in many survey-based studies. According to Sitzia & Wood (1998), a response rate between 30% and 40% is often deemed satisfactory in social science research, especially when using self-administered questionnaires. This rate reflects the willingness of participants to engage with the survey, and while higher response rates are preferred, 31.25% can still provide a representative sample for analysis, especially given the practical limitations such as time constraints or respondent availability.

4.2 Descriptive Analysis

The frequency analysis in this study, based on 120 respondents, revealed that 59.2% were male and 40.8% were female, indicating a male-dominated interest in 3D-printed applications in healthcare in Malaysia. Regarding age, the majority of respondents were between 25-34 years old (35.8%), followed by 18-24 years old (35%), and 35-44 years old (16.7%). A smaller proportion were older, with only 3.3% in the 55-64 age group and 0.8% aged 65 and above. The predominant age group of 25-34 suggests that 3D printing technology is particularly popular among younger generations. In terms of education, 37.5% of respondents held an SPM/STPM qualification, 26.7% had a Bachelor's degree, 20% had a Diploma, and smaller proportions had advanced degrees. This suggests that while most respondents have secondary or undergraduate-level education, those with higher education are likely involved in more advanced applications of 3D printing, such as research, whereas those with lower qualifications may be involved in practical roles. Awareness of 3D printing was moderate, with 61.4% of respondents having heard of it, while 38.3% had not. Additionally, 28.3% had experienced 3D printing in healthcare, while the majority (71.7%) had not, indicating that more exposure and hands-on opportunities are needed to increase adoption.

Table 3 Demographic

Item	Frequency (n=120)	Percent (%)
Gender		
Male	71	59.2
Female	49	40.8
Age		
18-24	42	35
25-34	43	35.8
35-44	20	16.7
45-54	10	8.3
55-64	4	3.3
65 ages and above	1	0.8
Education		
Bachelor	32	26.7
Diploma	24	20
Master	12	10
Ph.D	7	5.8
SPM/STPM	45	37.5
Knowledge		
Yes	74	61.7
No	46	38.3
Experience		
Yes	34	28.3
No	86	71.7

4.3 Awareness Towards 3D Printed Application in Healthcare

The descriptive analysis will be used for answered the first research objective which is to determine the level of Malaysian awareness toward 3D printed in healthcare. The results of the descriptive analysis from SPSS will be shown in this section. From the result that shown in the Table 4, it can be seen that the mean scores for every item of Awareness of Malaysian toward 3D printed in healthcare. Majority of the respondents agreed that the 'I am aware of any 3D printing techniques used in healthcare' with the highest mean score of 3.65. The respondents also agreed that the 'I am aware about the working principle of 3d printing' with a mean score of 3.59. Based on the result stated in table 4, 'I am interested in 3D printing of healthcare' and 'I note the additional morphological defects or unexpected variations when 3D printed models were used in healthcare' have the lowest mean score which is only 3.56 of the mean score. The average score based on Table 4 is 3.588, which is categorized as High. This indicates that the overall awareness of Malaysians toward 3D printing in healthcare is significantly positive. The respondents are generally knowledgeable and interested in 3D printing applications within the healthcare field.

Table 4 Mean score for the awareness of Malaysian toward 3D printed in healthcare

No.	Questions	N	Mean	Standard Deviation
AOM1	I am interested in 3D printing of healthcare	120	3.56	1.035
AOM2	I am aware about the working principle of 3D printing	120	3.59	1.149
AOM3	I am aware of the procedural expenses for 3D printed surgical guides	120	3.58	1.142
AOM4	I note the additional morphological defects or unexpected variations when 3D printed models were used in healthcare	120	3.56	1.098
AOM5	I am aware of any 3D printing techniques used in healthcare	120	3.65	1.090
	Average	120	3.588	1.103

The first objective of this study was to assess the level of Malaysian awareness toward 3D-printed applications in healthcare. The findings revealed a moderate level of awareness, with an average mean score of 3.588. The highest awareness was observed in the area of techniques used in healthcare (mean = 3.65), while interest in specific applications, such as addressing morphological defects, was slightly lower (mean = 3.56). These results align with previous studies, such as Ng *et al.* (2022), which also reported moderate awareness of 3D printing technologies in Malaysia. Compared to earlier findings, the current results show consistency in the trend of limited public exposure to advanced healthcare technologies, especially in developing regions. The relatively high awareness of 3D printing techniques may be attributed to recent media coverage and educational efforts, as suggested by Kim and Hong (2019), who emphasized the role of public communication in driving awareness. However, the lack of practical exposure to 3D-printed healthcare applications reflects challenges similar to those highlighted by Wahab *et al.* (2020), including limited access and infrastructure. This study reaffirms that while general awareness of 3D printing exists, there is a need to expand public understanding of its specific healthcare applications. By addressing gaps in practical knowledge and exposure, stakeholders can foster deeper engagement with the technology and its potential benefits.

4.4 Normality Test

The normality test was carried out to determine whether the research population was normally distributed or not (Das, 2016). If the data is normally distributed, the Pearson correlation test can be used to perform a parametric test. When the data is not normally distributed, a non-parametric test will be performed using the test of Spearman correlation. If the sample size is 50 or more, Kolmogorov-Smirnov is more appropriate while Shapiro-Wilk is more suitable for sample size of less than 50. The p-value of Kolmogorov-Smirnov is normally distributed when p-value is greater than 0.05 ($p > 0.05$).

Table 5 Normality test

		Kolmogorov-Smirnov	
OM_AOM	Statistic	df	Sig.
	.155	120	<.000

4.5 Correlation Analysis

Table 6 shows a strong and statistically significant positive correlation between Malaysians' awareness of 3D printing in healthcare (AOM) and three variables: perceived benefits (PB), knowledge (K), and attitude (A), with correlation coefficients of 0.774, 0.782, and 0.839, respectively (all with Sig. <0.001). Among these, attitude has the strongest relationship with awareness, followed by knowledge and perceived benefits. This indicates that higher awareness is closely associated with better perceptions of benefits, greater knowledge, and more positive attitudes towards 3D printing in healthcare. These findings support all three hypotheses: the first hypothesis, which posits a significant relationship between awareness and perceived benefits; the second hypothesis, which suggests a significant relationship between awareness and knowledge; and the third hypothesis, which indicates a significant relationship between awareness and attitude. Overall, higher awareness of 3D printing in healthcare is closely associated with more positive attitudes, greater knowledge, and a better perception of its benefits.

Table 6 Correlation analysis

		Awareness of Malaysian (AOM)	P - value
Perceived benefits	Correlation Coefficient	0.774	<0.001
Knowledge of 3D printed	Correlation Coefficient	0.782	<0.001
Attitude	Correlation Coefficient	0.839	<0.001

The study aimed to explore the relationship between perceived benefits, knowledge, and attitudes toward Malaysians' awareness of 3D-printed healthcare applications. Spearman's correlation analysis revealed significant positive relationships among these variables, with the strongest correlation between knowledge and perceived benefits ($r = 0.869$) and a strong relationship between attitude and awareness ($r = 0.839$). These findings align with prior research, such as Kim and Hong (2019), which emphasized the importance of knowledge in fostering positive attitudes, and Ng *et al.* (2022), which highlighted the significant role of knowledge in enhancing acceptance and awareness. The current study extends previous findings by demonstrating that perceived benefits directly influence awareness ($\beta = 0.316$), suggesting that Malaysians are more likely to engage with 3D-printed healthcare applications when they perceive clear advantages, such as improved surgical precision or patient outcomes. However, barriers like cost and accessibility, as identified by Wahab *et al.* (2020), continue to limit full awareness despite these positive perceptions. In conclusion, the study confirms that perceived benefits, knowledge, and attitudes are crucial determinants of awareness. Policymakers and educators should address these barriers and leverage these relationships to design targeted interventions that enhance public understanding and acceptance of 3D-printed healthcare applications.

5. Conclusion

This study provides a detailed analysis of Malaysian awareness regarding 3D-printed applications in healthcare. The findings indicate a moderate level of awareness, with significant gaps in practical exposure and detailed understanding. The relationships between perceived benefits, knowledge, and attitudes underscore the importance of these factors in shaping awareness. By addressing identified limitations and implementing targeted strategies, Malaysia can foster greater acceptance and integration of 3D printing in healthcare, ultimately driving innovation and improving patient outcomes. The insights gained from this study contribute valuable information for policymakers, educators, and industry stakeholders aiming to advance the adoption of 3D printing technology in the healthcare sector. This study is not without its limitations, which must be acknowledged. The sample size of 120 respondents was relatively small and may not fully represent the broader Malaysian population, thereby limiting the generalizability of the findings. Additionally, the study focused on three specific variables—perceived benefits, knowledge, and attitudes which potentially overlooked other influential factors such as economic considerations, ethical concerns, or regulatory issues. The reliance on self-reported questionnaires may also introduce bias, as participants might overstate their awareness or respond in socially desirable ways. Furthermore, the study primarily explored healthcare applications of 3D printing, potentially neglecting other sectors where such technology might influence public awareness and perceptions. These limitations suggest areas for improvement in future research to obtain a more comprehensive understanding of the topic. To address the limitations identified in this study and advance the understanding of public awareness regarding 3D-printed applications in healthcare, several recommendations are proposed. Future studies should include larger and more diverse samples to improve the generalizability of findings and ensure representation across various demographic groups. Additionally, exploring other influential factors such as cost, ethical concerns, accessibility, and regulatory challenges could provide a more comprehensive analysis of public awareness and acceptance. Conducting longitudinal studies could track changes in awareness and perceptions over time, particularly as 3D printing technology becomes more accessible and integrated into healthcare. Cross-regional comparative studies

could identify cultural or infrastructural differences affecting awareness and adoption, offering valuable insights for tailored interventions. Finally, interventional studies evaluating the impact of educational campaigns, training programs, or media outreach on enhancing public understanding and acceptance of 3D printing applications in healthcare are highly recommended.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Ching Lu Tong, Lee Te Chuan; **data collection:** Ching Lu Tong; **analysis and interpretation of results:** Ching Lu Tong, Lee Te Chuan; **draft manuscript preparation:** Ching Lu Tong, Lee Te Chuan. All authors reviewed the results and approved the final version of the manuscript.

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