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THREE-DIMENSIONAL (3D) BIOPRINTING OF HUMAN ORGANS IN REALISING *MAQĀSID AL-SHARI'AH*

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Abstract

As three-dimensional (3D) printing evolved significantly over the past 20 years, the latest innovation of 3D human organ printing technologies gave a new dimension in modern medicine. This technology refers to the placement of various cell types into a soft scaffold fabricated according to a computer-aided design template of material using devices. Hence, will provide an alternative to fulfill the acute needs for human organs such as lungs, heart, kidney, liver, pancreas for transplantation. Meanwhile, the preservation of life (*Hifz al-Nafs*) is one of the essential values (*al-Daruriyyāt*) of *maqāsid al-Shari'ah* as defined by majority of Islamic scholars. For the sake of preserving this essential value, Islam has come out with clear guidelines, ethics, maxims, and its own principles in the application of this technology to be linear to *maqāsid al-Shari'ah.* This paper aims to demonstrate how this technology could realise *maqāsid al-Shari'ah* through in-depth analysis within Islamic perspective based on Quran and Sunnah, and data analysis from related sources. Literature analysis was the primary method of data collection and deductive method was used in data analysis. This study shows that the 3D bioprinting of human organs plays an important role in realizing *maqāsid al-Shari'ah* especially in the essential value of the preservation of life.

***Keywords*:** 3D-bioprinting; *maqāsid al-Shari'ah*; *Hifz al-Nafs*; 3D-organ printing; Islamic law; *al-Qarinah*; *al-Bayyinah*

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1.0 INTRODUCTION

With the invention of stereolithography which is a printing that enables real tangible three-dimensional (3D) material to be produced from digital data in 1984, 3D-printing has evolved extensively resulting from the advanced development of technology. 3D-printing has nowadays becomes more accessible and has been widely varied and innovated in its capabilities in printing various kinds of materials including food products, urethane, ceramic filters for power plant and even human tissue. As for these purposes, the 3D printing is expected to develop by 300% from 2012 to 2020 as mentioned by the website on 3D-printing manufacturer, Sculpteo [1]. As it keeps developing drastically, this 3D printing has now reached the time when it can be applied to the printing of human organs. It is assumed that in not less than two years from now the medical engineering will definitely enter a new horizon of advancement. At the same time, *Shari'ah* (Islamic law) is typically predicated to benefit humankind and the community, and is aimed at keeping and providing better atmosphere of human way of life on earth [2]. With that, Islamic scholars have discovered that *maqāsid al-Shari'ah* is predicated within the knowledge of the purposes that Allah (s.w.t) has mentioned in legislating laws and guidance to be practiced [3]. Scholars has categorised *maqāsid al-Shari'ah* into different categories which consist of five essential values of human life namely; the preservation of life, religion, intellect, lineage and property. One of the *maqsud* of medical treatment is to preserve the essential value of one's life [4]. Figure 1 shows the hype circle for emerging technology presented by Jackie Fenn [5]

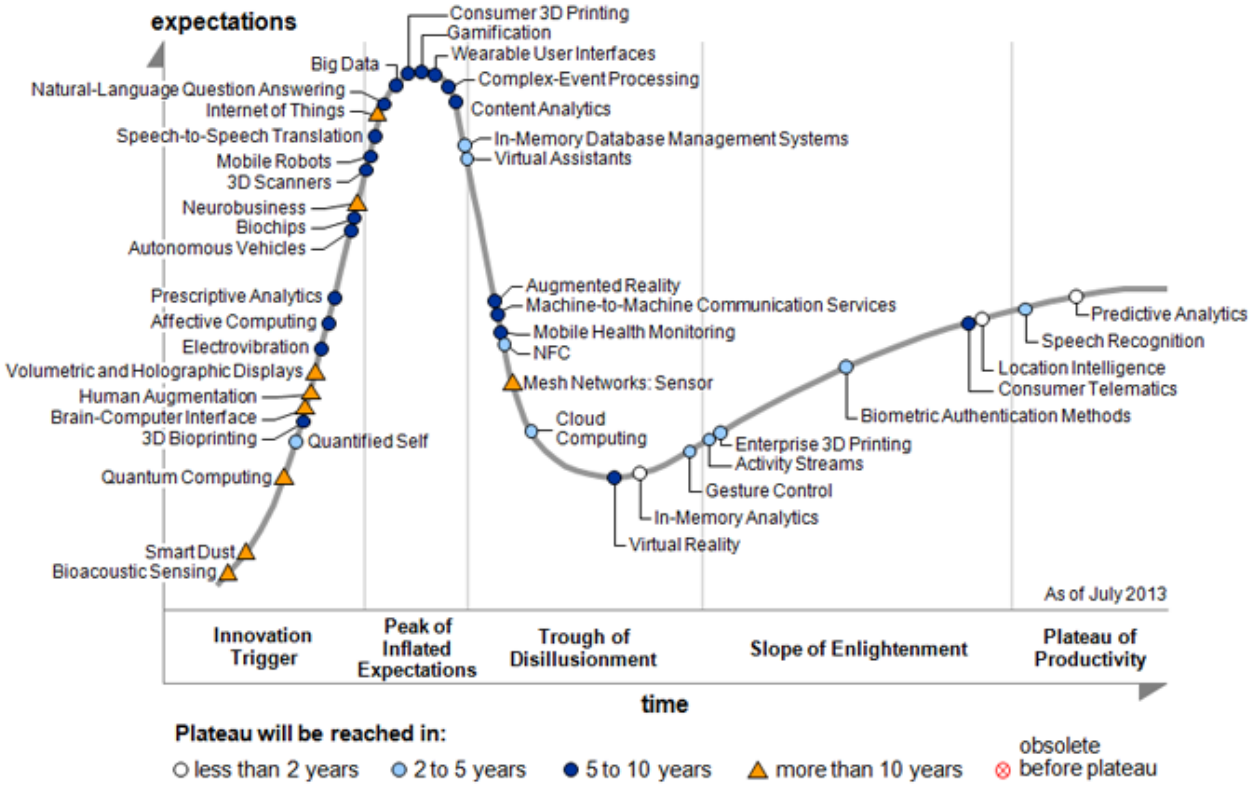

Figure 1: Hype Cycle for Emerging Technology

In the coming ten years 3D printing is expected to be gradually developed which consists of the emergence of 3D scanners, consumer, bioprinting and enterprise [6]. As enterprising 3D printing climbing slope of enlightment by its replenishment in each sort which resulted in a more realistic, cheaper, and in line with the human atmosphere.

2.0 HISTORY OF 3D-PRINTING

3D printing started in the early 1980s when Charles Hull invented a machine that allowed users to test a design before agreeing to invest in the manufacturing programs. In 1992, a layer-by-layer printing machine was developed which used viscosity and honey-colored liquid which is known as ultraviolet (UV) laser solidifying photopolymer to form a three-dimensional material that goes through a layer by layer process. The technology then evolved in 1999 when scientists at the Wake Forest Institute for Regenerative Medicine developed engineering organs, and implanted a 3D-synthetic scaffold coated

with patient cells for a urinary bladder augmentation. This technology then has remarkably developed into a much smaller functional filterable kidney which is able to produce diluted urine by removing substances from the blood in animals. These experiments had not had any rejections from the recipients either in animals or humans because they were made from the recipients' own cells. The 20th century then demonstrates a rapid development in 3D printing technology [1, 7].

In the 2000s period, starting with the engineering of a working 3D-kidney in 2002 followed by in 2005 with a 3D-printer that can print from its own components. In 2006, the first SLS (Selective Laser Sintering) machine was introduced. This machine uses a laser to fuse materials into 3D products. It then lead to the development of multivariety of materials manufactured. Below is a timeline on 3D-printing history and development.

Table 1: The Development of 3D-printing Timeline [5]

Year	Events
1984	The birth of 3D printing
1992	Building parts, layer by layer
1999	Engineered organs bring new advances to medicine
2002	A working 3D kidney
2005	Open-source collaboration with 3D printing
2006	SLS leads to mass customization in manufacturing
2008	The first self-replicating printer, do it yourself (DIY) co-creation service launched, and major development for prosthetics using 3D started
2009	DIY kits for 3D printers enter the marketplace, From cells to blood vessels
2011	World's first 3D printed robotic aircraft, printed car, and 3D printing in silver and gold
2012	3D printed prosthetic jaw implantantion

3.0 3D-BIOPRINTING OF HUMAN ORGANS

This 3D printing is a series of action to create a 3D material from a digital prototype using some additional manufacturing concept which requires a layer by layer material blend process. Coatney [7] says that 3D printing has boosted up the advancement of dental fabrication and prosthetics manufacturing. Moreover, it is also said to be a significant value towards the achievement of new discoveries and development in the field of bone printing, tissues and organ replacement. As a result, the development of this field has come to the days when it has been adopted in various fields and commercialized intensively including in tissues and organ building. Illustrated below is the basic process required to be completed in order to develop and build living tissues, combined and fused, to grow into a new organ.

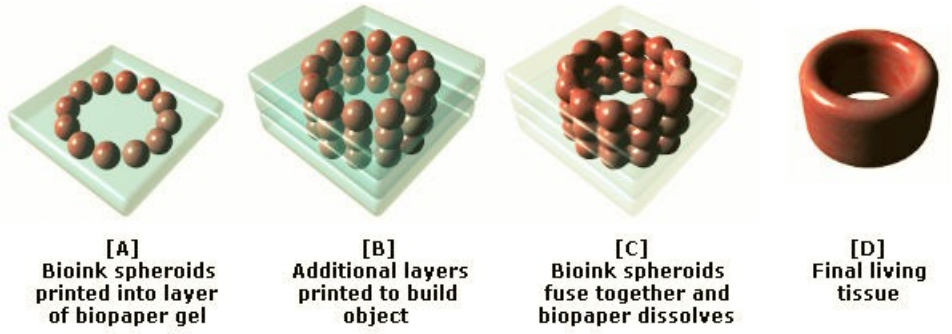

Figure 2: Flowchart of 3D Organ Printing [8]

In this flow, [A] represents a bio-printer which contains bio-ink spheroid which aggregately restrains large number of cells (amounting to millions). The light blue 3D layer square is a water-based bio-sheet made from gelatin, collagen or other hydrogels. The bio-ink spheroids will then be injected into this material as shown provided in the flow above in [B]. As in [C], the process is continued by adding more layers in order to finish the final object or material. Thus, the spheroid coalesces and bound together naturally whilst the bio-sheet dissolves away or is fadely removed. A living tissue as in [D], either a body part or other organ, has been developed. This process is a form of natural capabilities which then the structure of cells known to configure themselves into complicated organs. 3D printing

machine is only the platform to construct and give pattern towards cells to arrange themselves and put together into some form of configuration [9].

4.0 THE PRESERVATION OF HUMAN LIFE (*HIFZ AL-NAFS*) IN ORGAN-PRINTING

Kamali [10] says that *Shari'ah* (Islamic law) is a general concern of benefits to both community and individual, which intents to maintain and protect essential values thus providing a more desirably condition of human life. *Maqāsid al-Shari'ah* generally is the knowledge of the objectives or the goals that Allah (s.w.t) has mentioned in the same way in formulating the laws of Islam. It also presents the values that come out from the legislation and on the harms that are removed when Allah (s.w.t) legislate a particular legislation. It is a crucial branch of knowledge for all Islamic jurists which bases of these *maqāsid al-Shari'ah* are indicated from a clear and detailed scripts from the Qur'an and al-Sunnah [10]. As for the purpose of preserving human life, Islam has provided a clear guideline towards fulfilling this aspect. For example, Islam has strictly forbidden the act of killing humans from many verses in Qur'an and Sunnah such as in Surah al-Isra' verse 33 [11] and al-An'am verse 131 [12]. Preventing anything that could lead towards killing a soul through the method of *Sadd al-Dharai'* (blocking the means), al-Qisas (the Law of Equality in punishment), compulsoriness of providing evidence in killing accusation, and forgiving (al-'afwu) in *al-Qisas* are also parts of the method to preserve *Hifz al-Nafs* [13, 14].

5.0 SHORTAGE OF ORGAN DONOR, REJECTION OF DONATION AND MEDICAL EXPENSES

Everyday 18 people on the organ transplantation waitlist stop living and end their lives before they receive the organ donated. There are over 115,000 people on this list alone with many more in need of a transplant but do not have enough or sufficient money to cover medical expenses. In addition to expenses, organ transplantation is a neatly skilful process due to the stuation that can expose them to the danger of having organ rejection. Due to this condition, there are many different approaches to creating a replacement organ, from creating a fully mechanical one to growing a new organic one in a lab. With ~~a~~ the recent breakthrough, 3D organ printing might be a feasible option in the future. As

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mentioned in the National Kidney Foundation report, 89000 patients are currently in the queue of receiving organ donations and 4000 of them are struggling with death every month in United States [15]. Iran, Saudi Arabia, Pakistan, Malaysia and Turkey are Muslim majority countries which have their own model in organizing organ transplantation activities. LURD model of Iran [16], the formation of Saudi Center of Organ Transplantation (SCOT) [17], SIUT model of Pakistan, are some of transplantation models and formation established to encourage organ donation. Besides, these countries are also among the members of Middle East Society for Organ Transplantation (MESOT) established in Turkey in 1987. It shows the urgent need of organ donation specifically in muslim majority countries [18]. Some research studies relate that ethical consideration of religion has been one of the main reasons of organ donation shortage in muslim majority countries [19]. In fact that it is reported that transplant waiting list is about 16 000 per year compared to less than 50 kidneys donated in Malaysia.

Also, the other issue related is the rejection of donation. It is when the immune system of recipients rejects any tissue or organ being transplanted which it considers as a 'foreigner', to put it simply. This happens in three stages; hyperacute, acute and chronic stage. When recipients received the organ from donour, they have to ensure that they are clean from any rejection from immune system. As rejection can occur due to the wrong type of blood and unstable condition of organ, immune system will react with the organ/tissue as soon as the organ is transplanted and in hyperacute rejection stage, the organ needs to be removed from the recipient right away to prevent him from dying. In this case, 3D organ printing can overcome the situation. Studies around the globe from the eastern countries [20] to the west [21] have shown the crucial need of organ transplantation as it is a never-ending review to be written here.

6.0 3D-BIOPRINTING AND *MASALIH AL-MURSALAH*

Maslahah is a 'vehicle' of legal change in contemporary world which every single book or written material will give reference to it, that is what Felicita Opwis said in her book regarding introduction of *Maslahah* Opwis [22]. In general, *Masalih* is a plural form of *maslahah* which means a cause of benificial, utility, good [13] or interest [23, 24], while *al-Mursalah* means unregulated, not mentioned and unrestricted in any script (of Islam) [25]. The categorization of the *al-Maslahah* is basically divided into three different parts namely; *al-Masalih al-Mu'tabarah*, al-*Masalih al-Mulghah*, and *al-Masālih al-Mursalah*. The admissibility of it is not a consensus. This different views of classification can be concluded through the chart below:

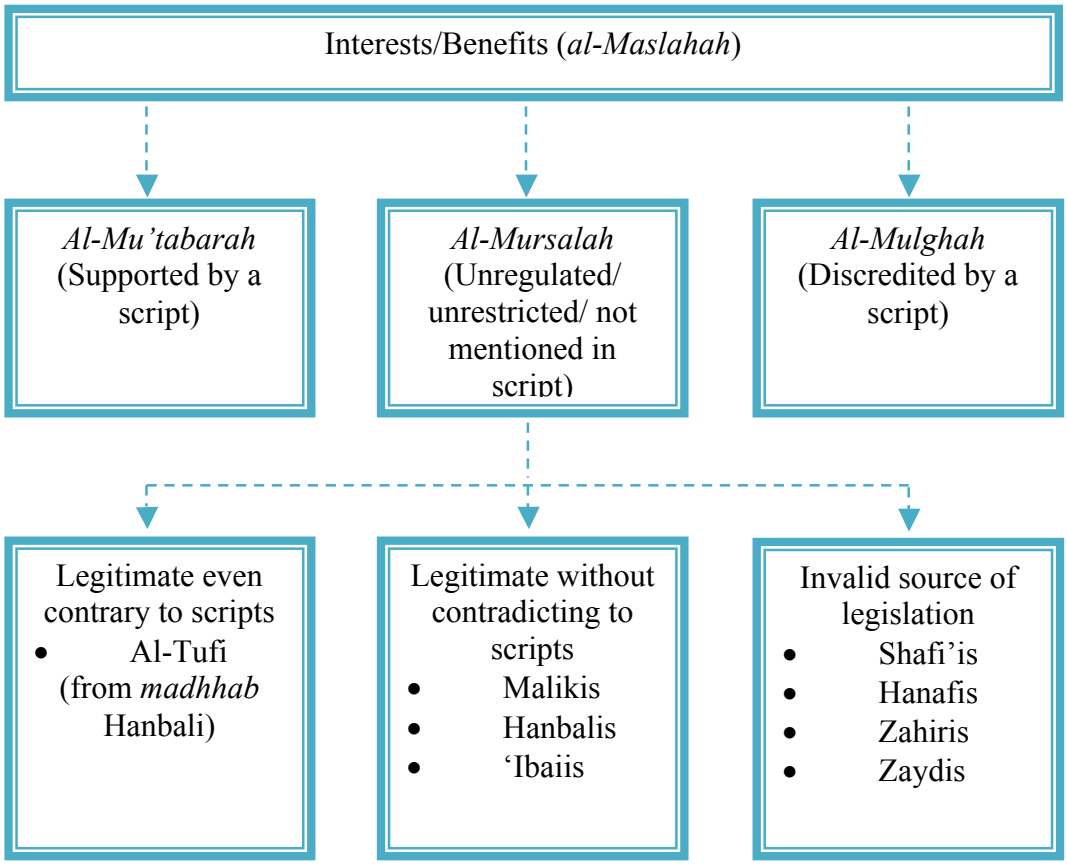

Figure 3: Classification of Interests/Benefits and Difference of Opinion over *al-Maslahah al-Mursalah* adapted from Abu Zahrah (1958: 275), Auda (2010: 120-121)

Disregarding the numerous discussions and *al-Ikhtilaf* (argumentation) on this topic as it is classified into the 'disputed source' and referring to the views agreed upon on the admissibility of *al-Maslahah*, scholars have agreed to add certain regulations in adapting this *al-Maslahah* as a source of *shari'ah*:

1. The *al-Maslahah al-Mursalah* must, in general, benefit all *muslimin* and absolutely certain in providing goodness within the boundary of *al-Daruriyyat al-Khamsah*.
2. It must be suitable and linear to the concept of *maqāsid al-Shari'ah* and does not bring chaos.
3. The level of *al-Maslahah al-Mursalah* to realise *maqāsid al-Shari'ah* must be certain or at the minimum beyond the reasonable doubt.
4. There is no contradiction to any specific script and must fall within the subject of *al-Mu'amalat* (worldly dealing) and of *'adat* (customs) excluding *al-'Ibadat* (worship).
5. The *al-Masālih al-Mursalah* must result in a higher level of purpose or interest from the *maqsud* (goal) that is mentioned is relevant script (Auda, 2010).

Considering that 3D-bioprinting of human organs is one of *al-Masālih al-Mursalah*, in order to be acknowledged, it must first fulfil those regulations stated and it is believed that this 3D-bioprinting on human organs fully complies with the regulations of being part and used in this contemporary society based on *al-Masālih al-Mursalah* rationale as it gives general benefit to ummah, certainly provide goodness in preserving essential values of *al-Dharuriyyat,* does not bring bizzare, has no contradict to any script and yet it results in higher achievement of *maqsud* especially in preserving life and property.

7.0 RELATED ISLAMIC LEGAL MAXIMS (*QAWA'ID AL-FIQHIYYAH*)

First of all, the principle of *al-Maqsad* that derived from a renowned Prophetic Hadith on the authority of 'Umar al-Khattab [26] which sourcing the maxim of *al-Umur bi maqasidiha* (matters are judged by intentions). 3D-bioprinting of human organs are purposely to print new skin, print cartilage and bones, replace tissue and organs, print stem cells and absolutely for the purpose of cosmetic. As for the

principle of *al-Maqsad* which judges every act or order based on the intention, it is simple to relate that in this 3D-bioprinting issue, if the purpose of the printing is for the sake of human life such as to reconstruct damaged/burned skin, to rebuild damaged tissue or replace organs, it is permissible. Consequently, all of these positive purposes are to ward off harm and to preserve the essential value of human life. These purposes are in line with the maxim of *al-Dararu yuzal* **(**harm shall be warded off) which regards that it is an obligation to remove any kind of harm that is prohibited in religion [27]. Being so, it is binding to forbid it so as not to be incurred. As for this case, when it comes to the harm of death due to the risk of rejection from organ transplantation, shortage of organ donor and costly medical expenses to maintain mechanical/organic organ, the alternate way is to use the 3D-bioprinting which can remove the harm in a definite way. With regards the side effect from the derivation of stem cells as basic substance for the 3D-bioprinting process, stem cells can be obtained from three important sources of autologous (obtained from the same individual-one's own body) adult stem cells which are from; 1. Bone marrow (extraction by procedure called 'harvesting'), 2. Lipid cells (extraction by 'liposuction' procedure), 3. Blood (extraction through apheresis procedure). Moreover, it can also be taken from blood of the umbilical cord after birth. Under the principle of injury (using the maxim of *al-Dararu yuzal*) any process to derive stem cells should be done in lesser degree than the original injury due to one maxim which is *al-Dararu la yuzal bi mithlih* (harm cannot be warded off with same degree of it). As for this case, if one of those three processes to obtain the stem cells could cause a bigger potential to injure the body, it should be avoided.

As in a Hadith narrated by Ibn Mas'ud:

ما أنزل اللهُ عز وجل مِنْ داءٍ إلا أنزل معه شفاءً

'*Allah will not send an illness without sending with it cure'*

Verily, Allah has created illness and provided the cure of that illness. Some scholars used this hadith as an indicator on the prescribition of curing any illness. As in this scenario, 3D bio-printing is a way to cure the illness. Hence, it is a prescribed method sourced from the hadith.

Moreover, using the principle of motive (*al-Qasd*) the determination of intention/motive to have 3D-bioprinting on human organs has to be clear. If the 3D printing planned to be done for the sake of human medical treatment such as replacing and repairing broken organ, developing new tissues and other medical benefits that have no intention to disobey Shari'ah guidance then the 3D printing is permissible. With the maxim of *al-Umuru bi maqasidiha* and *al-Aslu fi al-Ashyā' al-Ibāhah* should be applied in this case, means that if there are intentions to be against Shari'ah principle such as to build new organs and print just to alter Allah's creation, replace any part of the body that need no replacement but just to attain beauty, gain attractiveness, showing off and to lie on one's actual appearance. Allah said in Surah al-Isra' verse 70:

> *"And We have certainly honored the children of Adam and carried them on the land and sea and provided for them of the good things and preferred them over much of what We have created, with [definite] preference"*

and in verse 30 Sūrah al-Rūm:

> *"... No change should there be in the creation of Allah. That is the correct religion, but most of the people do not know."*

which prohibit the altering of the creation without any reasonable purpose. With that Ibn Kathir [28] says in his famous exegesis of Qur'an *Tafseer Ibn Kathir*, these two verses show on how Islam has honoured mankind and preventeds human from doing lies and cheating about their appearance. In fact, as for this principle of *maqsad*, any intention to change any character on body without any acceptable reason and also for the beauty purposes to fabricate on the appearance it is not allowed. 3D printing on skin can change the appearance of someone and his characteristic. Regarding this matter, 3D printing of skin without any acceptable reason, such as to cure diseases or rebuild part of organ loss specific ethics, rules and regulations should be applied [29]. The main point is if the 3D printing of skin for the purposes of fabricating the appearance and change the original creation on body characters, it is forbidden due to the scripts mentioned in the maxim of *maqsad.*

While *al-Aslu fi al-Ashyā' al-Ibāhah* means 'the norm in regard of things is permissibility' which is sourced from verse 29 Surah *al-Baqarah* shows that anything which is not prohibited in Islam through any scripts of *dala'il al-Hukm* is considered permissible. As for this situation, the norm of printing human organs is not prescribed in any scripts and sources of *dala'il al-Hukm*. With that, the judgement of this act is through the underlying motive, for example if the motive is towards the goal of treating a disease so it is allowed because treating diseases is a *sunnah* in Islam. Even if we take a look at the principle of *sadd al-Dharai'*, this 3D human organ printing is a way to stop criminal commercial exploitation of selling 'original' organ which is against human norms and stops the exploitation of innocent people. This act is actualy leading towards the preservation of human life and dignity and also in line with the Quranic verse 70 in Surah *al-Isra'* which honoured sons of Adam and conferred the special favours above a great part of the creation [12].

8.0 3D-PRINTING, FORENSIC EVIDENCE AND *AL-QARINAH*

Significantly, 3D printing has an extraordinary value towards the forensic science field. As we know forensic science and the field of *al-Qarinah* in Islamic law have a great integration. Forensic experts can be considered as a part of the law which prescribes them as expert witnesses (*al-Ra'yu al-Khabir*). In certain cases, their testimonies can be considered as *al-Bayyinah* while in other cases we can just consider them as *al-Qarinah.* In fact, *al-Qarinah* means circumstantial evidence and has a big role especially in solving complicated cases. In civil law, forensic science has been widely used as important clues to solve cases.

8.1 Facial Reconstruction and Footprints Identification

Skull reconstruction helps in determining the age, gender, and some human identity. With the reconstruction of skull, face can be reconstructed according to the skeleton of the face bone to at least build probable identity of the deceased. This is the role of 3D printing. Once the deceased has been identified through probable face pattern and traits, race, age, gender and even the true identity of the deceased can be discovered. Facial reconstruction is not limited to face bone but it also covers the tooth arrangement and dental record. Once the skeleton is found, 3D printing can reconstruct exact

dental composition to match the skeleton structure. This dental composition will then be matched with any dental records kept by dentists. Also, utilising the skull can lead to crime solving. In certain crime cases there were attacks on the head of victims which killed the victims. Thus reconstruction of skull and skeleton helps in giving clues to solve related cases. Moreover, forensics analysis on footprints and footwears can be observed and analysed with regards to events that may have occurred at crime scene that could assist in determining situation and giving extra information in providing the details of human height from the foot length. The issue is everything changes with the passage of time-which is also a basic forensics principle- the tracks and marks of footprints will be affected by weather, human-beings, animals and vegetable growth, for example. By transferring image data into a replica using advanced 3D printing software will then give accurate and dense surface model to be analysed. Just imagine how the replica can be interpreted more than a stun static picture [30]. This technology can assist on a virtual recognition process of identification.

In light of the perfection of Islam, *al-Qarinah* of 3D facial reconstruction will provide more precise and accurate analysis to support any witneses testimonials. Islamic law consists of *al-Hudūd, al-Qisas, al-Diyat* and *al-Ta'zir*. Towards solving cases using Islamic law, this 3D technology will ascertain more on the evidencing section. Moreover, the level of *al-Shubhah* could be decreased thus increasing the reliability towards *al-Yaqin* which is a part of the basis of the law. The evidence will be as good as it being explained orally. Historically, in the pre-Islamic era Arab citizens have widely recognized the use of *al-Qaif* (tracer) which comes from the word *al-Qiyafah* (physiognomy). They have some tribes which have been recognised by other tribes as experts in determining either *Qiyafah al-Bashar* (human likeness) or *Qiyafah al-Athar* (leaved traces). There are also a few Hadiths related to *al-Qiyafah* which demonstrate how the Prophet and companions agreed on the admissibility of tracers. What the tracers did were analising the footprints and ascertain who the owners were, where they went, how old the owners were, gender and also could determine if the rowners of the footprints were pregnant of not [31]. Just imagine what 3D printing can remarkably do in this era by seeing past suceessful achievement with the limitation of technology.

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8.2 Fingerprint Examination and Forensic Pathology

Solving problems that occur based on the trace of fingerprint requires experts to be extraordinarily keen in this field as the fingerprint collected in mirror side, has its own characteristic [32]. To be more precise and faultless 3D printing may capture fingerprint in 3D. As a high resolution image, the fingerprint will be photographed or scanned thus resulting in a comprehensive 3D model of fingerprint which can be measured and analysed in more details. Replica could also be brought to court with some colour coding of fingerprint feature and it will help a judge in considering the truth of any cases as circumstantial evidence in civil court, or as *al-Qarinah* in Shari'ah court. Virtopsy which is derived from the word 'virtual' and 'autopsy' used as likely the same method of 3D imaging for autopsy purpose and seeking the truth on someone's death [33]. It is an alternative to standard method of autopsy which benefits for time consuming, more precise in diagnosis and in sync with sentiment of one's beliefs and religion especially for Islam. From virtopsy, all details could be known including bullet trajectories, bone fragments, and of course could lead to the cause of death in less time than standard cadaver. In imaging concept of autopsy, the interpretation from autopsy photography could be much more easier to be told in court.

9.0 CONCLUSION

In conclusion, 3D printing on human organs opens up a new horizon to advanced technology relating to human lives. Its massive benefits towards mankind could be used either for negative or positive purposes. In fact it is a wordly matter that Allah has blessed humans through the guidance of *'Aql*, and could be a disaster without any complete reference to the detail principles and standards of Shari'ah. This study is only an early review of this field as it is new to the world and in its trial phase. It is suggested that further review on this topic be carried out so as to ensure 3D printing on human organs becomes stable and fully developed.

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