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A REVIEW OF ORIGAMI-APPLICATIONS IN MEDICAL HEALTHCARE INDUSTRY

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ABSTRACT

Origami, the art of folding paper has been used to make medical tools that help surgeons perform surgeries with the least amount of cutting and achieve faster healing. It is achieved by folding so that doctors can insert small devices into the body through tiny openings, which upon entering, unfold to aid in treatment or fixation. Origami design structures are also used in making flexible catheters, robotic surgical tools, and heart stents that help reduce pain and enable quicker recovery. Some origami tools even change shape when exposed to electricity or heat-allowing them to adapt within the human body. The special materials used to make these devices include shape-memory alloys, which change shape to perfectly fit the body. Origami is also used in developing wearable health devices that monitor everything in one's body, such as a heart rate or blood sugar level, without having to undergo painful tests. Origami in medicine will assist doctors in bringing recovery to their patients faster, reducing large incisions, and increasing the effectiveness of treatments. These tools are certain to become even smaller, smarter, and more effective in healing the body over time.

Keywords: Origami, Medical Tools, Surgeries, Minimal Cutting, Faster Healing, Devices.

I. INTRODUCTION

Ancient art of folding paper, origami, inspires medical people with innovative ideas and gives birth to new developments in the medical field, especially in surgeries that don't require large cuts, commonly known as minimally invasive surgeries (MIS), which cause less pain and ensure quicker recovery times for the patients. Scientists now use origami folding techniques to create very small instruments suitable for being inserted into the human body through a small opening in their body. Once inside, these tools open up or expand to do their work, just as a paper shape unfolds.

Origami-inspired designs have been used to design medical devices such as catheters, surgical robots, and even stents which help open blocked arteries. For example, origami-inspired catheters are flexible and can be easily fitted into the blood vessels. Origami-inspired surgical robots may be sharper and more flexible; thus, surgery is more likely to be safe. Some are flexible enough and bend without exerting influence upon crucial diagnostic medical scans, such as MRIs. Others can become suitable for treating wounds by attaching themselves to tissue, thereby ensuring faster healing. One of the most exciting applications of origami in medicine includes the creation of artificial muscles. Such as the ability to make robots move, assist in surgeries, or even help a person who needs artificial limbs. Another nice innovation is wearable health devices inspired by origami. These flexible, tiny devices can be stuck onto the body like a sticker, and it can track heart rate or sweat without hurting the person.

Origami-based designs do not only make surgeries easier but also lead to shorter recovery times, reduced pain, and decreased risks for patients. Many of these devices are smart as well, capable of adjusting to the body and even monitoring health in real-time. These technologies need to be more affordable, efficient, and widespread, allowing doctors to take better care of patients with fewer complications. These origami-inspired tools will be even more essential in the future to revolutionize and make medical treatments better. They will make healthcare more accessible, efficient, and less invasive. Researchers are working continuously to improve these technologies so they are safe, reliable, and can be used on an everyday basis in health care-all over the world that benefits patients.

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II. METHODOLOGY

2.1 Origami applications in minimally invasive surgical procedures

Minimally invasive surgeries were a type of surgeries that involves making smaller incisions or no incisions at all, and using specialized tools to perform the procedure.

MIS (minimally invasive surgeries) is generally safer and more tolerable than traditional surgery, and can result in: less tissue damage, fewer complications, minimal pain and scarring, a shorter hospital stay, and a faster recovery. It is a specialized technique of mechanisms that are being using in medical field as an alternative and also as a only option for many surgeries.

We know every day a new study will be introduced; this MIS is changing through new methods and applications that are getting used by leaving the traditional procedures. And now we are going to discuss the applications which are introduced by the researchers for MIS are:

Applications

1. **Origami-Based Catheters:** It offers pliability in reaching blood vessels. While holding stiffness in navigating expanded heart chambers when the need arises.
2. **MRI-Compatible Tools**: Origami-based devices, such as joints in surgical instruments, are designed to be MRI-compatible, using smart materials like Shape Memory Alloys (SMAs) to bend without interfering with imaging.
3. **Flexible Graspers for Delicate Surgery**: These tools use origami-inspired folding mechanisms with SMA actuators, allowing surgeons to grasp and manipulate tissues.
4. **Magnetic Capsule Robots for Aneurysms**: Origami-inspired designs enable small, magnetically-controlled robots to navigate the body and treat brain aneurysms by coiling the affected area.
5. **Biodegradable Adhesive Patches for Wound Healing**: Using origami principles, researchers have developed multilayer bio adhesive patches for tissue sealing.
6. **Portable Head Injury Diagnosis Devices**: Origami-inspired structures have been used to develop portable, low-cost diagnostic devices for rapid assessment of head injuries.

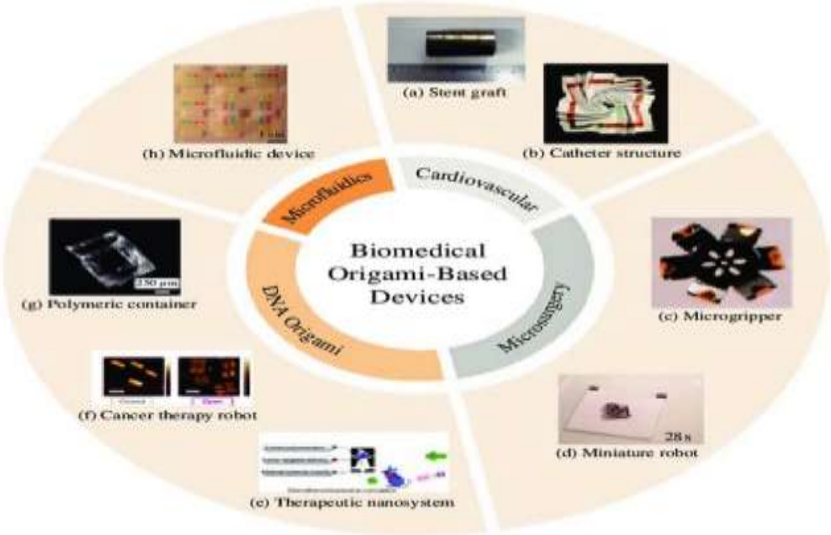

Figure 1: The above figure represents the different applications of origami in MIS.

2.2 Origami based medical devices:

Design and Functionality

A new medical tool that is inspired by the ancient technique of folding paper, also known as origami, promises to make surgeries and medical treatments easier.

Origami methods are used to design devices that can be folded up tightly and inserted through small openings inside the body. Once inside, these devices unfold or expand in order to perform precise operations, such as the opening of arteries or their assistance during surgery. For instance, origami patterns help instruments of medical robots to stay steady and safe from germs during surgery.

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There are devices made of special materials such as shape-memory alloys that can change their shapes in order to fit around body parts. These origami-inspired devices make surgeries much more precise and help heal the body with fewer complications. Origami designs in tools such as cardiac implants and surgical robots improve their functionality and reduce risks.

Origami flexibility and adaptability make it possible to come up with compact, effective medical tools that could enhance more interactive health care for patients with minimal recovery time.

Using this origami pattern. we can have a better long term uses. And faster Recovery. Such designs like: Designs

1. **Triangulated cylindrical origami pattern**: It is an origami inspired design which are mainly used in Bio-medical applications.
2. **Cardioverter defibrillator cam**: based on the heart stents.
3. **Origami based Thin Shaped films**: It is used in Brain Surgeries and implantable devices also used in medical Surgeries. It is mainly used in minimally invasive surgery, which means faster Recovery without medical Surgeries. finally, it gives a good medical Recovery.
4. **Medical robots**: Origami concepts are used in soft robotics for foldable, flexible, and adaptive robotic structures.
5. **Wearable medical devices**: Flexible origami designs allow wearables to conform to the human body for comfort and functionality.

Figure 2: It is an origami-inspired pattern known from tessellated triangles.

2.3 Origami Applications in Cardiac Stent

Origami is an art of folding paper. Nowadays, those skills are being donated to the healthcare sector as the creators make special medical tools and devices, using the technique to help in making things like stents that open blocked arteries, tiny surgical tools, and even artificial muscles.

These origami-inspired designs are quite smart as they use little material but can still perform important jobs inside the body. For instance, some of the stents open up inside blood vessels according to the temperature produced inside the human body, which is more effective and powerful compared to the previous models. Origami helps in creating soft robotics for surgery that can flexibly move and may cause less need for huge cuts within the body. Such types of robots might even be used for both surgery and rehabilitation.

Origami applied in medical practice will provide the availability of smaller, easier to use, cheaper tools and will support doctors in doing their work with higher precision. For patients, it also helps to recover faster and suffer less pain during treatments. Future designs get better and better at fitting with the body shape and then heal, thereby boosting recovery processes.

The design of stents and materials that are used by inspiring from origami are:

Design & Material

1. Origami-inspired Self-deployable Stent

Design: Origami-like foldable stent, compact when stowed, and capable of unfolding at body temperature or through super elastic properties.

Materials Used: Alloy foil, like nitinol or a similar super elastic metal, capable of expanding and adapting to the inner body environment.

2. Metallic Cardiovascular Stents

Design: Original stents with better material selection, geometry, and surface modifications for enhanced functionality and biocompatibility.

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Materials Used: Stainless steel, cobalt-chromium alloys, and other biocompatible metals, often coated with drug-eluting polymers for better healing and reduced restenosis.

3. Polymeric Bioresorbable Stent

Design: Biodegradable support stent which absorbs as time passes, hence no second procedure for its removal.

Materials: Polylactic acid (PLA), polyglycolic acid (PGA), or poly(lactic-co-glycolic acid) (PLGA), that dissolve as the vessel heals.

4. 4D Printed Stent

Design: Smart stent, adaptive one that can respond to real-time changes in flow or conditions in the vessels by changing its structure.

Material Used: Nitinol or polymer blend with changeable shape with external stimuli, like in 4D printing, using shape-memory polymers or metal alloys having adaptive properties.

5.Origami-Inspired Metal Stent for Pediatric Applications

Design: Origami-inspired design, offering unique expansion options for small and growing vessels, such as pediatric patients.

Materials: Nitinol or similar super elastic metals, which will expand to fit into the very small and often irregularly-shaped blood vessels in children.

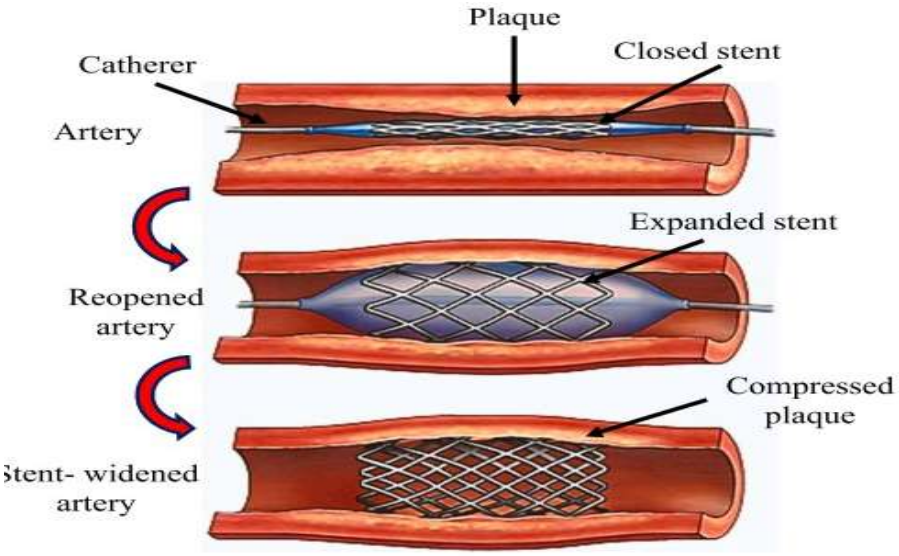

Figure 3: It is a stent placing in an artery, showing the stages of implantation of a stent.

6. Smart Stent with Health Monitoring Functionality

Design: A stent designed to monitor the patient's health, adapting to changes in the vascular system, and potentially gives back feedback for improved treatment.

Materials Used: Biocompatible metals with sensor modules and electronics able to wirelessly send data for health monitoring.

Each of these designs illustrates how origami-inspired principles and advanced materials, including metals, biodegradable polymers, and flexible materials, are reshaping the use of stents in medical healthcare.

2.4 Origami for Wearable Health Monitoring Devices

0We make those tiny foldable gadgetry by using some special folding techniques which are quite similar to origami. These gadgets may stick to your body like stickers so that you can watch your health. They are super tiny, therefore, will not bother you at all so you can carry them with you anywhere. The gadget can stretch along with you; hence it will not break whenever you move. We have materials that can sense things. You want to know how fast your heart beats, or how much you are sweating. Some gadgets have it use a barely discernible needle to check your sugar levels without poking you. Such gadgets do not need the battery because they get their energy from the air or your movement. Some gadgets can take how many pounds are on your

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skin by how hard you touch something soft. They are clever, and they can communicate with your phone or computer to let you know about your health. We are making use of special materials like thin wires and specialized paper to make them function better. These gadgets help doctors see your health state even when staying in the house.

They are soft and flexible, so they do not bother you on your skin. It can measure your health all day long and won't remind you when to look at it. This is cleverly small that one can wear even without noticing them, so you remain healthy without big machines or visits to a doctor.

The wearable health monitoring devices that are being used are:

Devices

1. **Pressure Sensors:** Some of these can even sense the pressure you are applying, such as when you gently squeeze something.
2. **Microneedles:** Some devices have tiny needles that can check your blood sugar without hurting you.
3. **Real-Time Health Monitoring**: These devices can measure anything, like heart rate or counts of steps, at any given moment and communicate the signal to your phone.
4. **Long-term wear:** They are quite strong and stretchy so you literally can wear them all day without worrying that they will break.

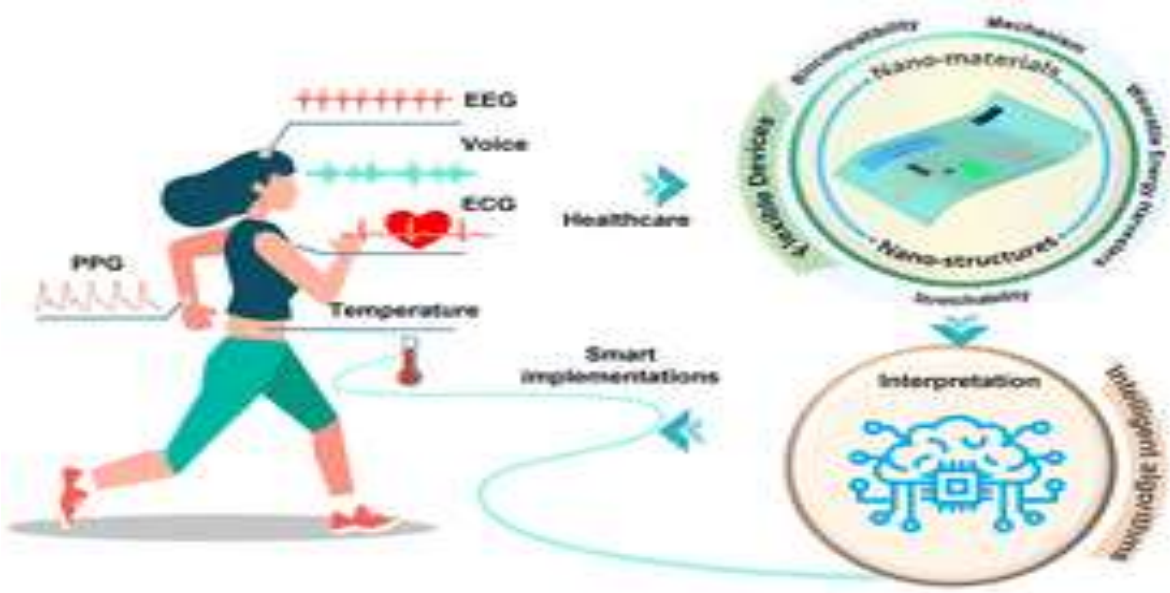

Figure 4: The above figure shows the health monitoring devices that monitors the health of a person daily.

2.5: Artificial muscles using origami

Researchers create origami-inspired muscles artificially by folding and creasing materials, such as in paper folding art, to bend and stretch. These are muscles that can move by changing their shape when they are heated or electricity is applied to them.

In the same manner as how our bodies move, researchers fold these materials in different ways so they can change direction and perform various tasks with minimal energy. Scientists make these muscles using materials like rubber, metal, or special fibers-light and so strong. They are used in robots, prosthetics, and even wearables.

Researchers study on how the folds and materials can be improved for stronger and longer-lasting performance of these muscles. These muscles can mimic the contracting and relaxing behavior of natural muscles and help create machines that can do smart tasks that require complex thinking.

The focus of the research is on making these muscles more adaptive and efficient for real-world use, including robotics and medical devices.

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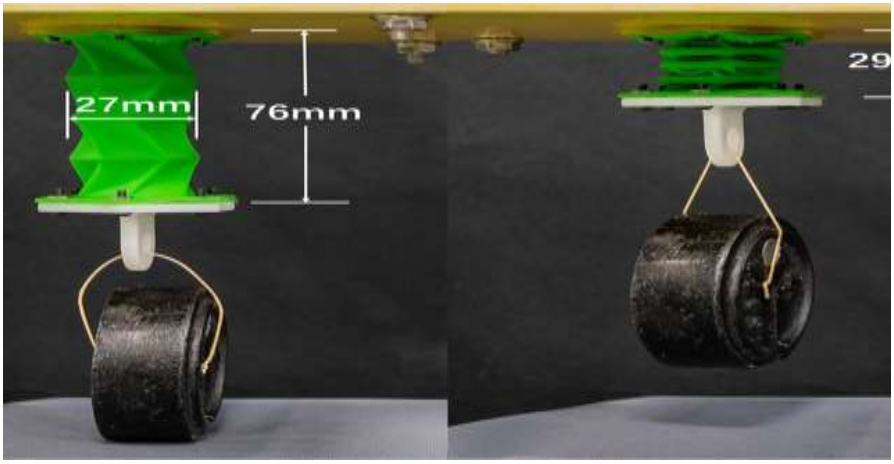


Figure 5: The above figure is a prototype for artificial muscle performing strength test.

Materials

1. **Shape Memory Alloys (SMAs):** Nickel-Titanium (Niti)
2. **Dielectric Elastomers (DEAs):** Silicone elastomers, acrylics.
3. **Hydrogels:** Superabsorbent polymers that can absorb large amounts of water, such as polyacrylamide or polyelectrolyte hydrogels.
4. **Soft Robots with Compliant Actuators:** Soft elastomers, polymers, and composites.
5. **Artificial Muscle Composites (AMC):** Combinations of active polymers, fibers, and nanomaterials.

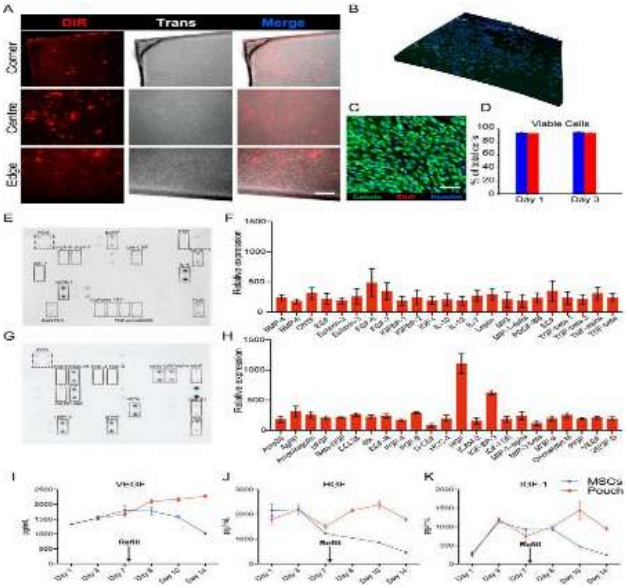
III. RESULTS AND DISCUSSION

3.1 Origami applications in minimally invasive surgical procedures

Of all the studies reviewed, origami-based designs are likely to herald a medical-device revolution for improvement in flexibility, miniaturization, and adaptability in various applications in surgery.

Solutions such as catheters, surgical robots, and tissue-healing patches emerge in superior performance owing to bending, folding, and conforming to the natural curvature of the human body. Importantly, it includes the development of soft robotic tools-a safe and precise alternative to stiff instruments that present fewer discomforts on patients and less complexity for surgical procedures. For example, magnetic origami capsules may target aneurysms with reduced invasiveness.

However, the materials have to be optimized for biocompatibility, biodegradability, and functionality under complex biological conditions.



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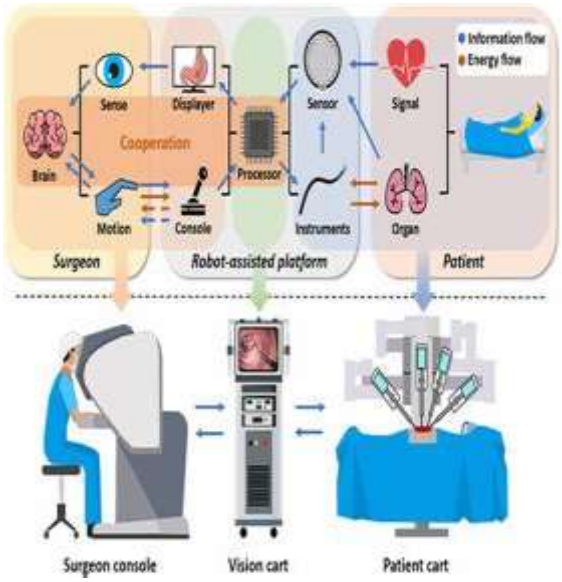

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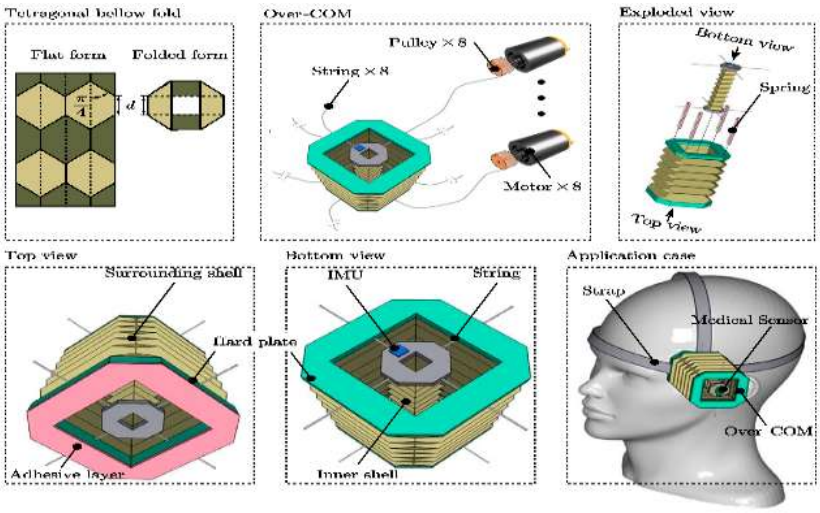


c

Figure 6: (a)This figure shows interaction between patient and robot assist-platform,(b) this figure shows the results of heart pouch that is attached in a rat for some days,(c)The Over-COM process is done using this application which located the temporal window to detect the symptoms from brain.

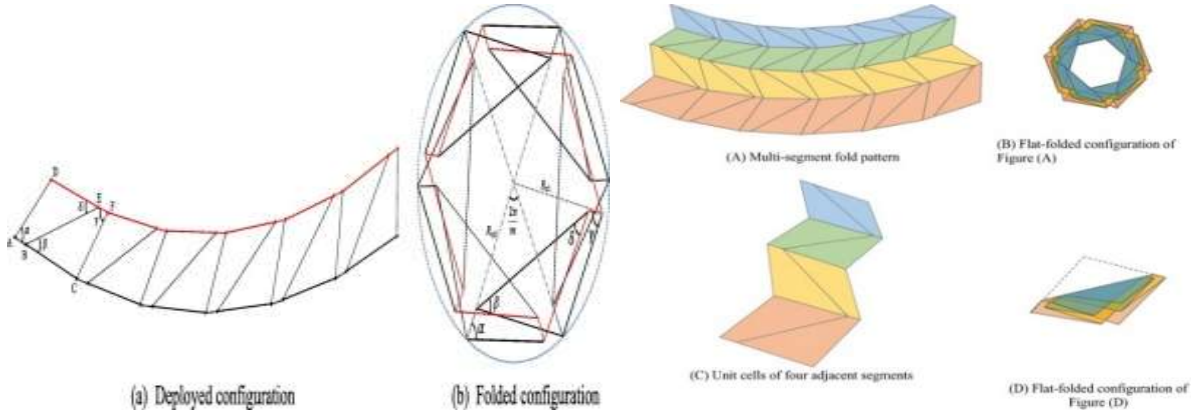
3.2 Origami based medical devices

Design and Functionality

Origami principles, particularly folding techniques, have been applied in healthcare. To this end, innovative medical tools have been developed to improve surgery and treatment results.

Folding material provides miniaturized devices that could be inserted into the body with small cuts through various parts of the body. After insertion into the body, these devices open or expand to perform various functions, which include helping arteries remain open or assisting during surgery. One advancement is that the supporting systems for medical robots are designed by origami patterns, which stabilize the instruments and keep them clean.

Another device is one made of shape-memory alloys, which adjusts its shape to fit the body better, thus being much more efficient and sensitive. Because of its flexibility, origami can create compact, efficient tools like cardiac implants and robotic surgical assistants that improve accuracy in procedures and reduce patient risks.



(a) (b)

Figure 7: (a) The deployable origami design that is used for the its high flexibility,(b)The origami structure that are being used in macro to microscopic designs.

Origami-inspired tools are promising to show a great promise in reducing recovery times, enhancing the safety of patients, and offering innovative solutions for complex medical problems. Further research is going to expand the use of origami in healthcare even more as a means for providing even more effective as well as less invasive treatments.

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3.3 Origami Applications in Cardiac Stent

Origami-inspired techniques have used the advancements in developing some brilliant pieces of medical devices, like stents, artificial muscles, and soft robotics. Because they are made of foldable alloy foil, self-deployable stents can be deployed inside arteries with the body's heat opening up arteries and hence avoiding its blockage or damage caused. They could accommodate complex shapes of blood vessels. More notably, the origami principles have given rise to foldable robots that can be used for minimally invasive surgeries. This creates procedures that turn out to be less painful and more specific. Origami-based refillable heart pouches, which will one day help in delivering stem cell therapies for heart repair, is another thought altogether.

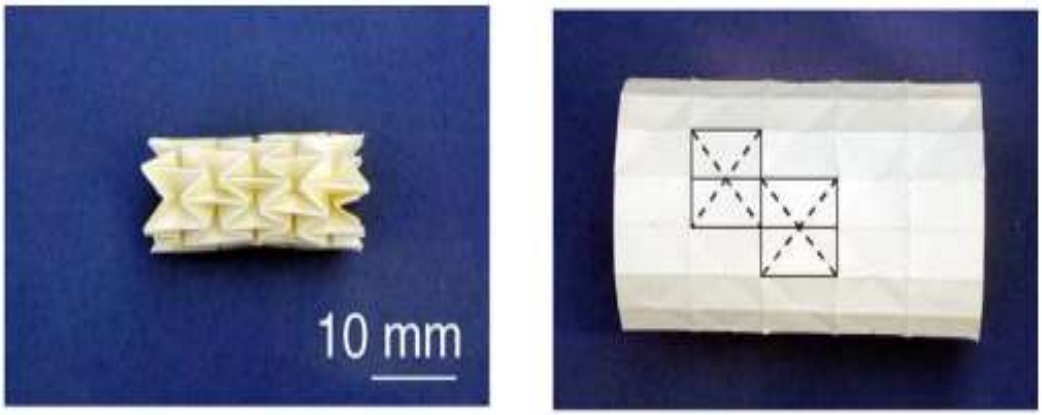

Figure 10: The origami design of stent graft made from a foldable alloy foil.

Origami-inspired designs are changing the face of healthcare through more efficient, cost-effective solutions. With the flexibility and scaling, they are able to produce small, precise, and variable medical devices in the shape of body curvatures. Origami stents and other devices reduce the amount of needed surgery, leading to quicker healing time and better patient outcomes. Origami and new technologies including 3D printing certainly continue the innovations in medical care. Future advancements should increase the safety and efficiency of treatments, leading to less invasive strategies or even superior recovery for patients.

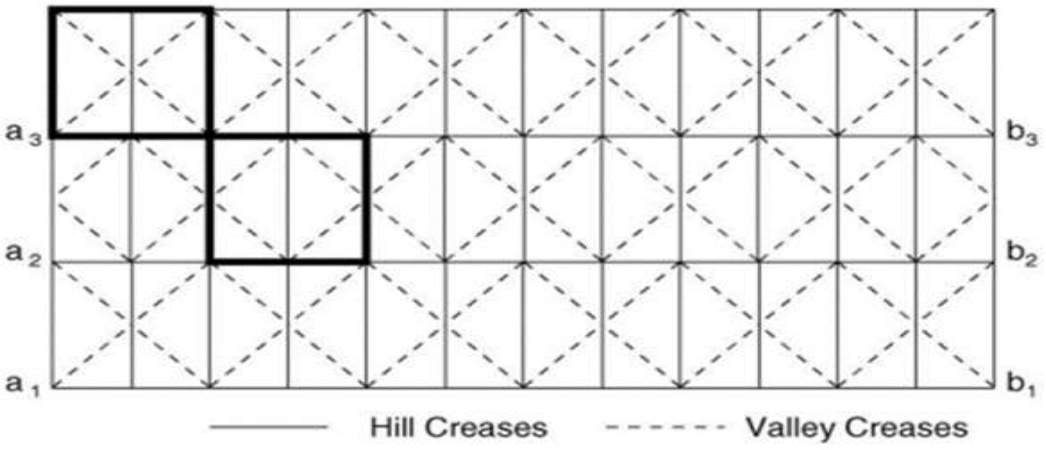

Figure 11: Ni-rich Tini shape memory alloy foil, optimizing geometric configurations for effective deployment.

3.4 Origami for Wearable Health Monitoring Devices

Well, promising results come forth: the development of small, flexible, and foldable health monitoring devices, which may provide continuous, real-time health tracking without invasive procedures. Using advanced materials in the form of wires and specially constituted papers, these devices seek to monitor heart rate, sweat levels, and even blood sugar. The devices integrate pressure sensors and microneedles, so measurements will not be invasive; also, the devices are energy-efficient, drawing power from either motion or air. The devices are stretchable, meaning users can wear them all day without a fear of it breaking. These wearable gadgets

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communicate the health data directly to the smartphones, thus enabling remote monitoring as well as minimizing frequent visits to a doctor. While promising, further work will be necessary to enhance their overall long-term stability, data accuracy, and comfort to promote widespread adoption. Future work will be geared towards the improvement of materials and deepening how their capabilities can provide more complete health tracking.

Figure 12: The wearable health monitoring devices that are located to use in a human body.

3.5 Artificial muscles using origami

The origami-inspired artificial muscles are one serious research work on advancing materials science and robotics. Here, researchers have constructed muscles by folding materials like rubber, metal, and special kinds of fibers in such a way that bend and stretch to perform complex activities with minimum energy input. These artificial muscles based on materials such as SMAs, DEAs, and hydrogels can mimic natural muscles; therefore, they operate under heat or electrical excitation to achieve movement. Such material versatility in terms of lightweight strong and flexible actuators has expanded extremely favorable applications in soft robotics, prosthetics, and wearable equipment. This study targets further developments which should improve the durability of the muscles, strength, and their efficiencies to be applicable in the real world. For example, in the case of SMA-based actuators, when heated, recover their original shape; DEAs and hydrogels provide enhanced flexibility and responsiveness. It is still a challenge to optimize all these for long-term performances with respect to environmental variances. The target objective goes toward adaptive artificial muscles that can be very efficient and reliable to accomplish complex tasks that will range from advanced robotics to prosthetic/ wearable exoskeletons in the context of medical devices.

IV. CONCLUSION

Origami, which is the art of folding paper, brought the most exciting innovations into the medical world. Medical tools can be made much smaller, more flexible, and easier to use inside the body using folding designs. This helps doctors be able to perform surgeries on patients using smaller cuts, thus making the recovery faster. Origami-inspired devices are seen in tools like heart stents, designed to keep the arteries open, or wearable gadgets that monitor health without being uncomfortable. These may even move or change shape to fit the human body better, rendering surgeries safer and more accurate. Soft robots created with origami help in delicate surgeries and assist in faster recovery. The combination of origami and new materials, such as special metals and smart polymers, makes these tools both effective and safe for patients. Future research will continue to improve these devices, helping doctors do their work with even greater accuracy and making treatments less painful for patients. These advancements promise a future with better healthcare and faster healing.

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