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A Comparative Study on Mechanical Heart Valve and Bio-Prosthetic Valve

Dr. Anitha S[1], Hemanth Kumar G[2], Anarghya. K. S[3], Chandana. B. G[4]

[1]Professor, Department of Biomedical Engineering ACSCE, Bangalore, Karnataka, India

[2]Assistant Professor, Department of Biomedical Engineering, ACSCE, Bangalore, Karnataka, India

[3]Student, Department of Biomedical Engineering, ACSCE, Bangalore, Karnataka, India

[4]Student, Department of Biomedical Engineering, ACSCE, Bangalore, Karnataka, India

ABSTRACT

Artificial heart valves are engineered devices used for replacing diseased or damaged natural valves of the heart. Most commonly used for replacement are mechanical heart valves and biological valves. This paper briefly outlines the evolution, designs employed, materials being used, and important factors that affect the performance of mechanical heart valves and bio prosthesis valves.

Keywords : Mechanical Heart Valves, Bio Prosthesis Valves, Valve Design, Valve Performance.

I. INTRODUCTION

An artificial heart valve is a device implanted into the heart of a patient to replace a dysfunctional native heart valve The human heart contains four valves: tricuspid valve, pulmonic valve, mitral valve and aortic valve. Their main purpose is to keep blood flowing in one direction through the heart, and from the heart into the major blood vessels connected to it (the pulmonary artery and the aorta). Heart valves can malfunction for a variety of reasons, which can impede the flow of blood through the valve (stenosis) and/or let blood flow backwards through the valve (regurgitation). Both processes put strain on the heart and may lead to serious problems, including heart failure. Although some dysfunctional valves can be treated with drugs or repaired, others need to be replaced with an artificial valve. Aortic valve replacement (AVR) has been performed since the 1950s. Since then, the surgical procedure has been optimized to reduce the risk of procedure-related complications.Technical advances in the design of valves have significantly improved long-term prognosis. After the initial use of mechanical ball-caged valves, numerous monoleaflet and bileaflet valves have been introduced and evaluated. Prosthetic heart valves which are used for the definitive treatment of disease and dysfunctional native heart valves came to use since the mid 1960s. They are broadly divided into mechanical heart valves (MHVs) and bio prosthetic heart valves (BHVs). MHVs are made of synthetic material (e.g., polymers, metal, and carbon), where as BHVs are made of biologic tissues which are mounted on a fabric covered plastic frame, called a stent. MHVs are more durable, but their thrombogenicity and need for long-term anticoagulant therapy make them unsuitable for patients in some age groups especially older age groups. In contrast, BHVs are safe to implant, functionally similar to the native aortic valve, do not require long-term anticoagulant therapy, and are hence associated with reduced risk of haemorrhage.

As they were introduced in the mid 1960s. Many tissues and different animal species aortic valves have been tried with varying results. Today, the most commonly used BHVs are those from porcine aortic valves and from calf pericardium. While the use of BHVs are done according to patient's age and other considerations, the trend in the United States and Europe has been towards greater use of tissue rather than mechanical valves. Currently, mechanical valves are preferred except in elderly patients or those who cannot be put under anticoagulant therapy, like women who may still wish to bear children, or hemolytic patients.

II. Classification of heart valves

There are mainly three types of artificial heart valves: (a) mechanical heart valves (b) bio prosthesis heart valves (c) tissue-engineered valves. But tissue engineered valves are not used much. Bio prosthetic heart valves are used most commonly in US, UK, and the European union. Whereas mechanical heart valves are preferred in Asia and Latin America

A. Mechanical heart valves

Mechanical heart valves are made from materials such as titanium and carbon. They usually consist of two leaflets and a metal ring surrounded by a ring of knitted fabric, which is sewn onto the heart in place of the original valve. There are several different models available for aortic and mitral replacement surgeries. The main advantage of mechanical valves is that they are very durable. However, these valves provide a surface on which blood clots can form easily. As a result, anyone who has been implanted with a mechanical valve needs to be on lifelong blood-thinning medication, such as warfarin, to prevent the development of blood clots that can cause heart attack or stroke. These valves should be avoided in women of child-bearing age, as warfarin is not for use in pregnancy, and those with a high risk of falls or bleeding.

B. Bio prosthetic heart valves.

Tissue valves, also known as biological or bio prosthetic valves, are composed of animal or human tissue. The valves are derived from animal tissue such as porcine (pig), bovine (cow) and equine (horse) models, and then fixed with a preserving solution that may be mounted on a flexible frame to assist in deployment during surgery. As with mechanical valves, the bottom of a tissue valve is often surrounded by a ring of knitted fabric that is sewn onto the heart. In addition to animal-derived valves, a human tissue valve from a donor human heart, known as an allograft or homograft, may also be used as a replacement valve. Tissue valves can be used in open heart surgery or in a minimally invasive aortic operation known as transcatheter aortic valve implantation (TAVI). Advantages of tissue valves compared to mechanical valves include the avoidance of lifelong warfarin therapy to prevent the development of blood clots. A disadvantage is their relatively poor durability compared to mechanical valves, with many requiring a re-operation in 10 to 20 years.

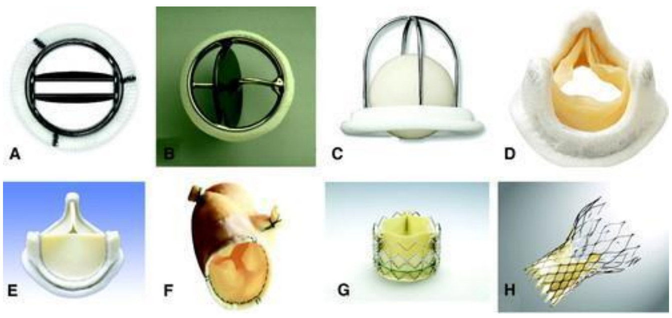

Fig 1 : Different types artificial heart valves.

III. Types of mechanical heart valves.

A. Caged ball valves

The first artificial heart valve was the caged ball valve, in which a ball is housed inside a cage. When the heart contracts and the blood pressure in the chamber of the heart exceeds the pressure on the outside of the chamber, the ball is pushed against the cage and allows blood to flow. When the heart finishes contracting, the pressure inside the chamber drops and the ball moves back against the base of the valve forming a seal. In 1952, Dr Charles Hufnagel, Professor of Experimental Surgery at Georgetown Medical Center in Washington, DC, implanted the ball valve as in the figure 1. In the late 1940s, Dr. Hufnagel experimented in an animal preparation with methacrylate tubes for arterial replacement; this led to animal implants with a ball valve similar to that depicted in Figure 1 [4]. The methacrylate chamber containing the methacrylate ball could be inserted in the descending thoracic aorta during a brief cross-clamp period because of ingenious fixation rings (Fig 1). The methacrylate ball was subsequently replaced with a hollow nylon ball coated with silicone rubber to reduce valve noise.

The below are the different types of cage ball valves:

i. Hufnagel Ball Valve
ii. Harken-Soroff Ball Valve
iii. Starr-Edwards Ball Valve
iv. Magovern-Cromie Ball Valve
v. Smell off-Cutter Ball Valve
vi. DeBakey-Surgitool Ball Valve
vii. Braunwald-Cutter Ball Valve

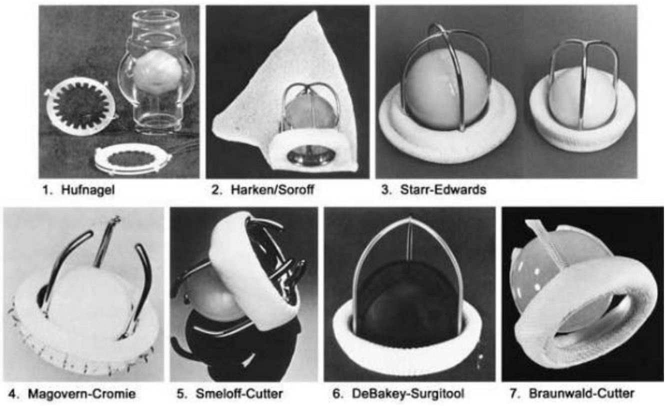

Fig 2 : Types of caged ball valves.

B. Tilting Disc Valves

Introduced in 1969, the first clinically available tilting-disc valve was the Bjork-Shiley valve. Tilting-disc valves are made of a metal ring covered by an ePTFE fabric. The metal ring holds, by means of two metal supports, a disc that opens when the heart beats to let blood flow through, then closes again to prevent blood flowing backwards. The disc is usually made of an extremely hard carbon material (pyrolytic carbon), enabling the valve to function for years without wearing out.

The below are the different types tilting disc valves:

i) Bjork-Shiley Flat Disc Valve
ii) Bjork-Shiley Convexo-Concave Tilting Disc Valve
iii) Lillehei-Kaster Tilting Disc Valve
iv) Omniscience Tilting Disc Valve
v) Hall-Kaster and Medtronic-Hall Tilting Disc Valves

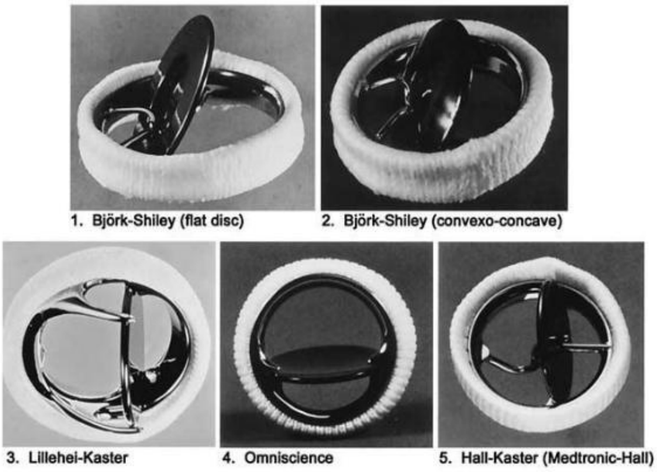

Fig 3 : Types of tilting disc valve.

C. Bileaflet Valves.

Introduced in 1979, bileaflet valves are made of two semicircular leaflets that revolve around struts attached to the valve housing. With a larger opening than caged ball and tilting-disc valves, they carry a lower risk of blood clots. They are vulnerable to blood backflow. The below is different types of Bileaflet Valves:

i) Gott-Daggett Bileaflet Valve
ii) Kalke-Lillehei Bileaflet Valve
iii) St. Jude Medical Bileaflet Valve
iv) Carbomedics Bileaflet Valve

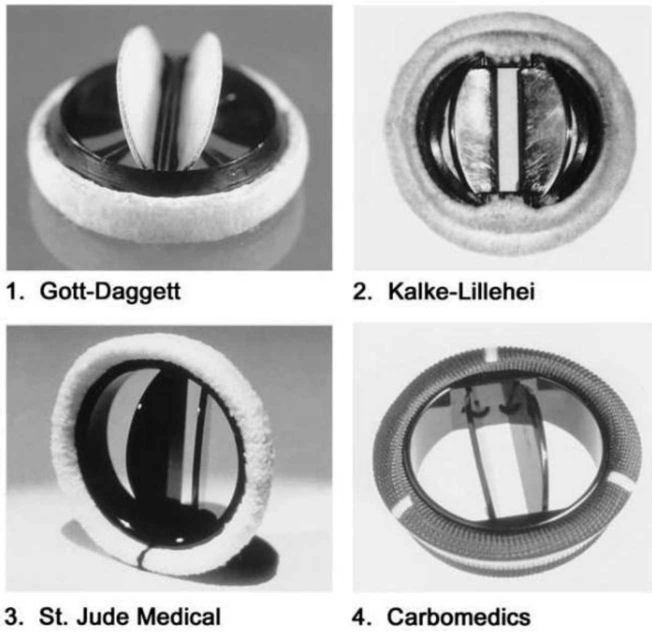

Fig 4 : Types of Bileaflet Valves.

D. Bileaflet Valves.

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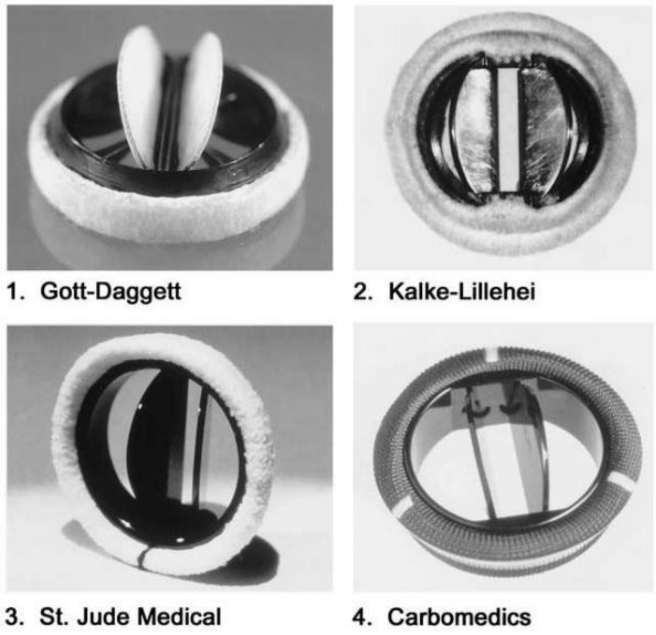

Fig 5 : Types of Bileaflet Valves.

IV. Disadvantages of Mechanical heart valves

One of the major drawbacks of mechanical heart valves is that they are associated with an increased risk of blood clots. People with mechanical valves need to take anticoagulants.

Some patients with mechanical valves can hear clicks as their valve closes, which some find disturbing.

Cavitation is the rapid formation of vaporous microbubbles in a fluid due to a local drop of pressure below the vaporization pressure at a given temperature. Cavitation in the blood can lead to mechanical heart valve failure.

V. Advantages of Mechanical heart valve

The major advantage of mechanical valves over bio prosthetic valves is their greater durability. Made from metal and/or pyrolytic carbon, they can last 20–30 years.

VI. Classification of Bio – prosthetic heart valve.

Bioprosthetic valves are usually made from animal tissue (heterograft/xenograft) mounted on a metal or polymer support. Bovine (cow) tissue is most commonly used, but some are made from porcine (pig) tissue.The tissue is treated to prevent rejection and calcification.

A. Homograft.

These are derived from cadaveric (human) aortic valves. They are cryopreserved and are implanted into the aortic root without a stent. Autograft. Patient's own valve was taken from one site (pulmonary) and implanted at another site, for example, pulmonary valve grafted into the aortic site. This predominately occurs in children with diseased native aortic valves.

B. Xenograft or Heterograft. These are developed from animal tissues the most common being the porcine aortic valve followed by calf (bovine) pericardium. Porcine aortic valve. In porcine BHV, the valve tissue is sewn onto a fabric covered metal wire stent, made from a cobalt-nickel or another alloy. A Dacron fabric covers the entire stent and a sewing skirt is fashioned and attached to the base of the wire stent. Contemporary models of these valves are durable and last for 10–15 years.

C. Bovine Pericardial Valve. Similar in design to porcine valves in that they imitate the tricuspid aortic valve, except that the metal cylinder joining the ends of stent wire is located in the middle of one of the stent post loops. At 10 years after implantation, the hemodynamics and durability of pericardial valves are equal to or greater than the porcine valves

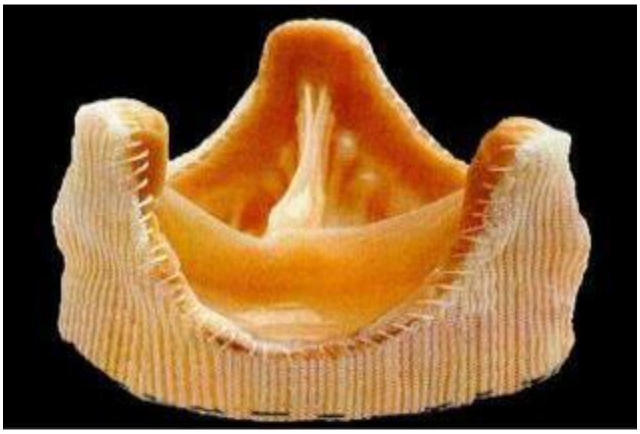

Fig 6 : Bio-prosthetic heart valve

VII. Types of Bio – prosthetic heart valve.

A. Stented Bioprostheses

The design of bioprostheses purports to mimic the anatomy of the native aortic valve Porcine bioprosthetic valves consist of 3 porcine aortic valve leaflets cross-linked with glutaraldehyde and mounted on a metallic or polymer supporting stent. Pericardial valves are fabricated from sheets of bovine pericardium mounted inside or outside a supporting stent.

B. Stentless Bio - prostheses

In an effort to improve valve hemodynamic and durability, several types of stentless bio-prosthetic valves have been developed. Stentless bio - prostheses are manufactured from whole porcine aortic valves or fabricated from bovine pericardium.

C. Percutaneous Bio - prostheses

Percutaneous aortic valve implantation is emerging as an alternative to standard aortic valve replacement (AVR) in patients with symptomatic aortic stenosis considered to be at high or prohibitive operative risk .The valves are usually implanted using a percutaneous transfemoral approach. To reduce the problems of vascular access and associated complications, a transapical approach through a small thoracotomy may also be used. At present, the procedure appears promising, but it remains experimental and is currently undergoing further investigation.

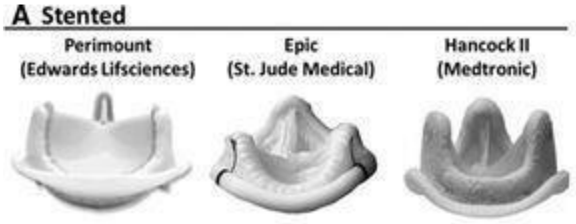

Fig 7 : Image of stented bio-prosthesis.

Fig 8 : Image of stentless bio-prosthesis.

VIII. Disadvantages of Bio – prosthetic heart valve.

Tissue valves are less durable than mechanical valves, typically lasting 10–20 years.

Bioprosthetic valves tend to deteriorate more quickly in younger patients.

IX. Advantages of bioprosthetic heart valves

Bioprosthetic valves are less likely than mechanical valves to cause blood clots, so do not require lifelong anticoagulation.

people with bioprosthetic valves have a lower risk of bleeding that those with mechanical valve.

X. CONCLUSION

From the comparison done in the paper we can conclude that the usage of Mechanical heart valves are more are more useable then Bio-prosthetic heart valve. As mechincal heart valves are more durable.

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