Eight Types of Interchangeable Prosthetic Heart Valve: A Mini Review

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Abstract

Introduction: Bioprostheses are prone to structural degeneration and have limited durability. Implantation of a prosthetic heart valve is risky when subsequent reoperation is required to replace the worn prosthetic valve. Methods: A review of interchangeable prosthetic heart valve models between 1984 and 2022. Results: Eight types of bioprostheses with interchangeable mechanisms, intended for heart valve prosthesis implantation and rapid substitutions during reoperations, aim to describe their framework’s mechanical structure and increase knowledge of their coupling mechanisms. These are intended to reduce the surgical risks associated with the excision of the old, worn bioprosthesis and shorten the reoperation time. Conclusion: These new experimental paradigms should prove the operability of the removal mechanism of all types of interchangeable bioprostheses and the effectiveness of the new quick connector and its perfect locking parts during heart valve reoperation, which should facilitate the reoperation operation, faster and safer.

Index terms—heart valve diseases, heart valve prosthesis implantation, biological heart valve, bioprosthesis, reoperation.

1 Introduction

Since 1968, the introduction of biological heart valves has involved a tremendous amount of work and research that has utilized effective valve replacement therapy to treat valvular heart disease. [1] The future of heart valve treatments discusses improving valve structure and degradation of bioprostheses and compares pericardial heart valves to porcine valves. In addition, implantation of a prosthetic heart valve (PHV) can be considered a risky surgery and may aggravate if subsequent reoperation is required to replace the worn prosthetic valve. This mechanical bioengineering approach encompasses the coupling and uncoupling mechanisms of their components.

2 II.

3 Methods

Relevant literature databases on eight types of i-BHVs were searched on PubMed and MEDLINE from 1984 to 2022. Martin J.R. et al. (1984) developed the first i-BHV, which consisted of three parts: the sewing ring, the i-BHV, and the retaining ring. The sewing ring mounts onto the high-profile support ring, which has an internal stop for docking with the i-BHV support structure and an inner channel for attaching the retaining ring. The support framework for the i-BHV has on its underside a small flap that forms a step protruding from the outside, intended to track the inner circular stop of the ring that supports the sewing ring. They implanted the prototype in the tricuspid position. At the follow-up operation, which took place after eight months, the valve was changed in 8 minutes. The ring supporting the sewing ring in situ facilitated the procedure. They reported no thrombotic phenomena or periprosthetic leaks. The wound healed, and growth of fibrotic pannus and underlying tissue less than 1 mm thick was found. Finally, the authors propose another new project to optimize the reduction of the
attachment between the catheter and the e-T A VI framework should be tight enough to allow its removal through
news bond-coupling constraints between the electromagnets and the ferromagnets in the cladding simulations,
followed by the immediate placement of a new valve. The experimental research revealed the need to define
e-T A VI, a novel e-T A VI electromagnetic vascular catheter was developed to remove and retrieve a failed e-T A VI,
system called exchangeable-T A VI (e-T A VI). To facilitate the minimally invasive removal and replacement of an
components: A retention device that could be surgically implanted or attached to a catheter and a novel valve
(2022) described a novel transcatheter aortic valve implantation (T A VI) with a valve system consisting of two
In three patients, the i-BHV set behaved like conventional bioprostheses. Performance was excellent, and it was
pass the horizontal bars of the i-BHV support framework, the two parts lock and return to their rest positions.
the hemodynamic effects of i-BHV in acute experiments on three sheep. All experiments efficiently performed
the sewing ring. There are no animal studies in the literature. (6) Fukamachi et al. (1992) proposed an
i-BHV consisting of the sewing ring and the i-BHV. The researchers incorporated a magnetic metal ring into
the sewing ring and another into the support framework of the i-BHV. The model used the magnetic attraction
between two magnetic rings to couple and lock between the parts. The prototype met the target in vitro tests
and withstood the separation force in a pulsating pneumatic ventricle simulator. In vivo testing demonstrated
the mechanical coupling between the parts. The three struts of the top can be
coupling between the pieces takes place at these three points. The forced engagement between the parts is only
possible due to the deformability of the plastic material of the two parts. The three struts of the top can be
compressed internally while the tortuous support structure of the bioprosthesis expands. After the coupling hooks
pass the horizontal bars of the i-BHV support framework, the two parts lock and return to their rest positions.
Ebner et al. (5) proposed an i-BHV that consists of two parts: the
sewing ring and the i-BHV. Both frameworks were made of plastic material, giving them enough malleability to
allow for the mechanical coupling between the parts. The shape of the ring that supports the sewing ring went
through modifications, and its framework has three ascending bars with hooks at the ends designed to couple
to the i-BHV’s support framework. The i-BHV’s support structure is sinuous and circular. And it has three
horizontal bars added to its three ascending is a quick coupling mechanism between the two parts. The three
hook bars at the ends of the ring that supports the sewing ring penetrate the interior of the i-BHV’s sinuous
support framework and are connected to its three horizontal bars by quick-connect couplings. Therefore, the
coupling between the pieces takes place at these three points. The forced engagement between the parts is only
possible due to the deformability of the plastic material of the two parts. The three struts of the top can be
compressed internally while the tortuous support structure of the bioprosthesis expands. After the coupling hooks
pass the horizontal bars of the i-BHV support framework, the two parts lock and return to their rest positions.
In three patients, the i-BHV set behaved like conventional bioprostheses. Performance was excellent, and it was
easy to insert the first surgical implant. The coupling lasted 3 to 6 minutes intraoperatively. (8) Eren et al.
(2022) described a novel transcatheter aortic valve implantation (TAVI) with a valve system consisting of two
components: A retention device that could be surgically implanted or attached to a catheter and a novel valve
system called exchangeable-TAVI (e-TAVI). To facilitate the minimally invasive removal and replacement of an
e-TAVI, a novel e-TAVI electromagnetic vascular catheter was developed to remove and retrieve a failed e-TAVI,
followed by the immediate placement of a new valve. The experimental research revealed the need to define
news bond-coupling constraints between the electromagnets and the ferromagnets in the cladding simulations,
suggesting that another physical coupling mechanism is required to realize the e-TAVI concept. Moreover, the
attachment between the catheter and the e-TAVI framework should be tight enough to allow its removal through
the catheter pathway.
4 Discussion

The innovative i-BHV is ahead of its similar, not interchangeable, not enhancing its durability or performance, but rather the ease and the security of detaching and then replacing it with the next i-BHV when reinserted in the next operation.

Therefore, the perspectives and limitations of these reviews, with multicenter publications and a small number of cited surgeries, make it difficult to generalize the results.

The engagement and decoupling between parts are possible thanks to these innovations. Fukamachiet al. (7) report the desirable advantages of an i-BHV, such as:

1. Simple surgical fixation of the sewing ring together or not with the i-BHV. 2. Reduction of operational risks related to removing the bioprosthesis's old, worn-out sewing ring. 3. Ease and safety in removing the i-BHV during reoperation. 4. Hermetic sealing between parts. 5. No growth of fibrotic tissue at the internal junction interface between the pieces. 6. The optimized lumen-to-ring ratio is to obtain the largest possible area of the valve opening, despite the addition of the coupling mechanism between the parts. 7. The sewing ring frameworks and the framework that stents the valve prosthesis leaflets must be made of medical grade material, malleable, and fatigue resistant. 8. Durability and security of the coupling and locking mechanism between the parts. 9. Absence of long-term fragility or mechanical stress fractures due to structural changes in the bioprosthesis support framework and sewing ring.

Due to the degeneration of bioprosthetic heart valves, the interchangeable bioprosthetic heart valve (i-BHV) describes new paradigms based on the innovative hypothesis of heart valve surgery to improve reoperations, supposedly making them safer and faster. (10)
Figure 2: Figure 2:
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[1] Lyra et al., R M; Lyra, A A; Leirner, P. Pomerantzeff.


