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CASE REPORT

INTERMEDIATE

DAVINCI CORNER

Insights Into Interaction Between Clip Device and the Mitral Valve Apparatus in the Human Heart

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ABSTRACT

Precise appreciation of the 3-dimensional relationship between the edge-to-edge clips and mitral valve apparatus remains clinically challenging. We demonstrate the images of clips observed in situ 4 years after implantation. Detailed observation from this case helps improve our understanding of 3-dimensional clinical cardiac anatomy related to transcatheter edge-to-edge mitral valve repair. (**Level of Difficulty: Intermediate.**) (J Am Coll Cardiol Case Rep 2023;22:101999)

Intraprocedural transesophageal echocardiography is the gold standard for guidance of transcatheter edge-to-edge mitral valve repair.[1,2] Transesophageal echocardiography, however, provides very limited understanding of the location and interaction of the mitral chordae tendineae with the mitral leaflets. Thus, manipulation of the transcatheter edge-to-edge mitral valve repair device in the left ventricle is essentially blind to the chordae tendineae. We herein share the images of edge-to-edge clip device (MitraClip, Abbott Laboratories) observed in situ 4 years after implantation.

LEARNING OBJECTIVES

- To appreciate the undistorted anatomy of clip device–mitral valve apparatus interactions.
- To visualize the 3-dimensional anatomy of the chordae tendineae connections to the mitral leaflets.
- To recognize that the distance between the clip arms is reduced in the setting of a single-leaflet capture.

CASE REPORT

We received the heart of a 58-year-old man that was rejected for transplantation. Medical history included an old myocardial infarction, atrial fibrillation, coronary artery bypass graft surgery (11 years ago), and transcatheter edge-to-edge mitral valve repair (4 years ago). This patient died as a result of nonoperative extensive bilateral frontal and temporal parenchymal hemorrhage. Before dissection, the heart was pressure-perfused and fixed to maintain the pathophysiological morphology.[3] Two clips, central and medial, had been implanted at the A2-P2 scallops of

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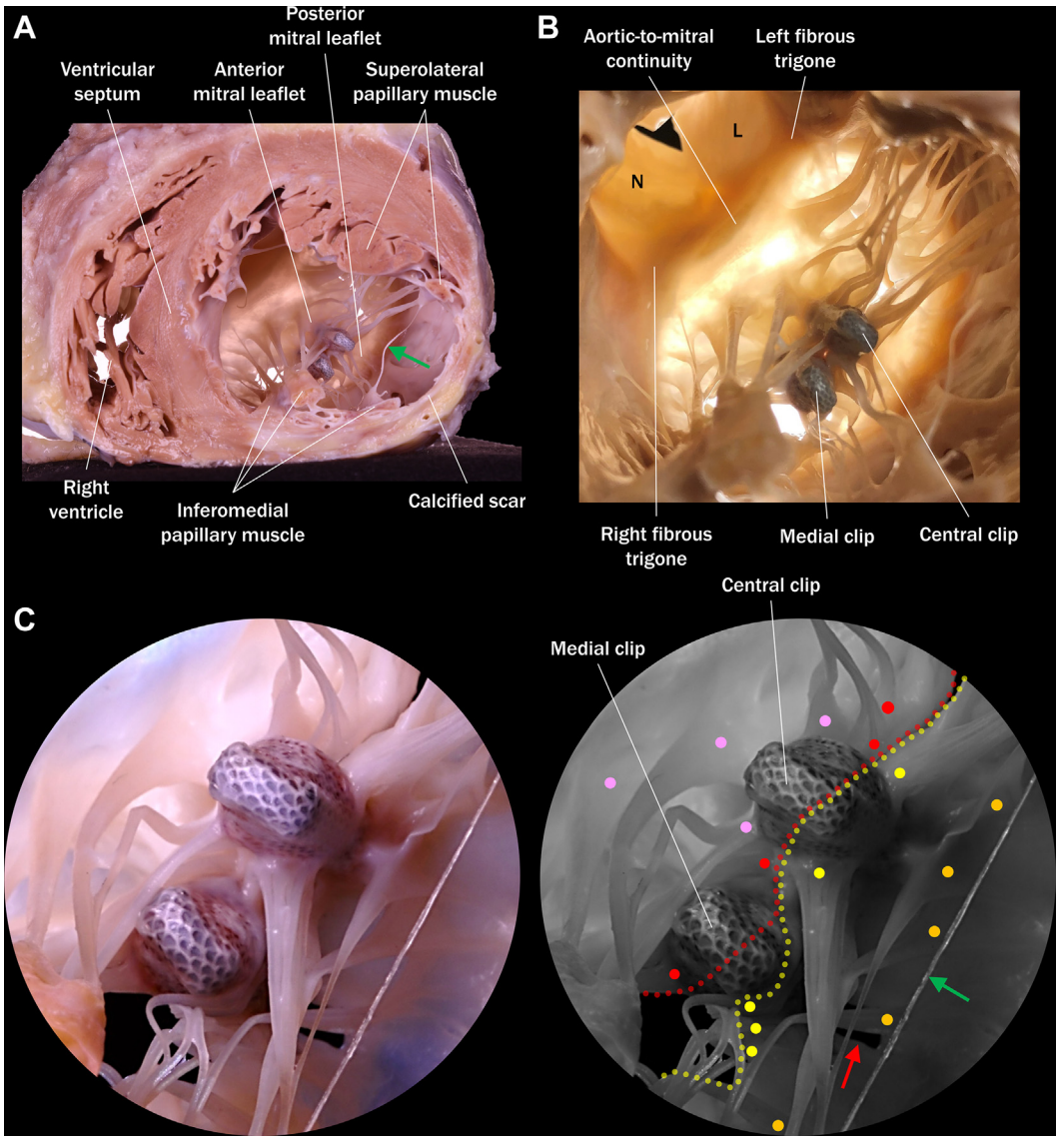
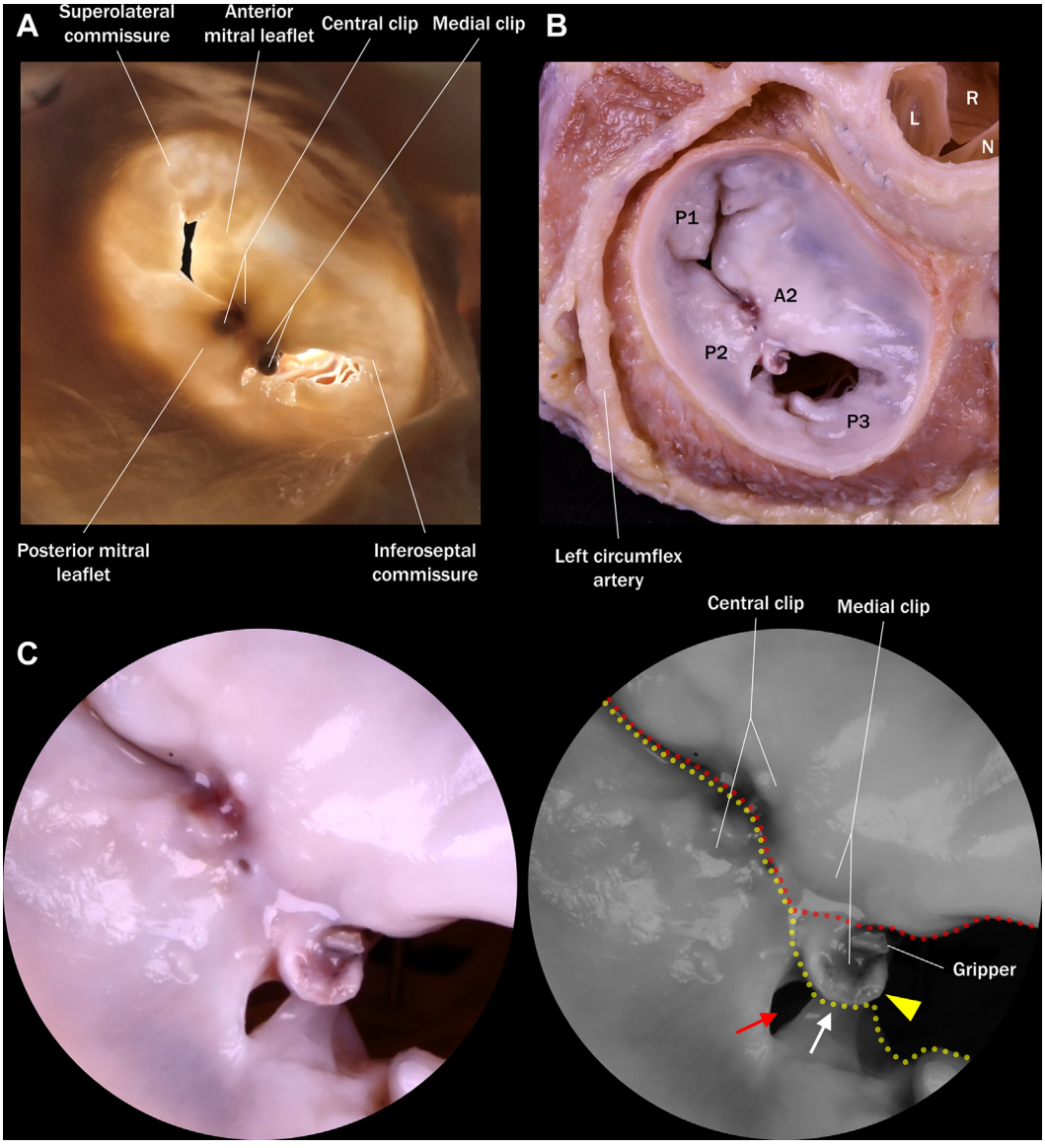
FIGURE 1 Mitral Valve Viewed From the Left Ventricle



Extensive calcified infarction scar is noted at the inferolateral left ventricular wall **(A)**. The inferomedial papillary muscle and part of the superolateral papillary muscle are also involved, suggesting ischemic mitral regurgitation as the potential mechanism **(A)**. Magnified image with transillumination **(B, C)** shows that the chordae-free zone is very narrow in both mitral leaflets, where it is appropriately grasped by the central clip. Both clips apparently grasp multiple first-generation chordae (rough zone chordae) attaching to the edge of the leaflets **(red and yellow circles)**, together with the leaflets. Partial endothelialization and/or fibrous adhesion around the clips are also evident. Multiple second-generation chordae (strut chordae) attaching to the ventricular surface of the leaflets **(pink and orange circles)** are not affected by the clips. The medial clip is surrounded by numerous chordae tendineae originating from the inferomedial papillary muscle **(B, C)**, suggesting the limited working space and increased risk of clip entanglement. A tiny tear in the posterior mitral leaflet **(red arrow)** and thin single chordal connection between the papillary muscles **(green arrows)** are noted. **Red and yellow dotted lines** denote the free margin of the anterior and posterior mitral leaflets, respectively **(C)**. Although it is difficult to appreciate from this direction, the posterior mitral leaflet is not grasped by the medial clip, but shows the adhesion on its inferior surface. L = left coronary aortic leaflet; N = noncoronary aortic leaflet.

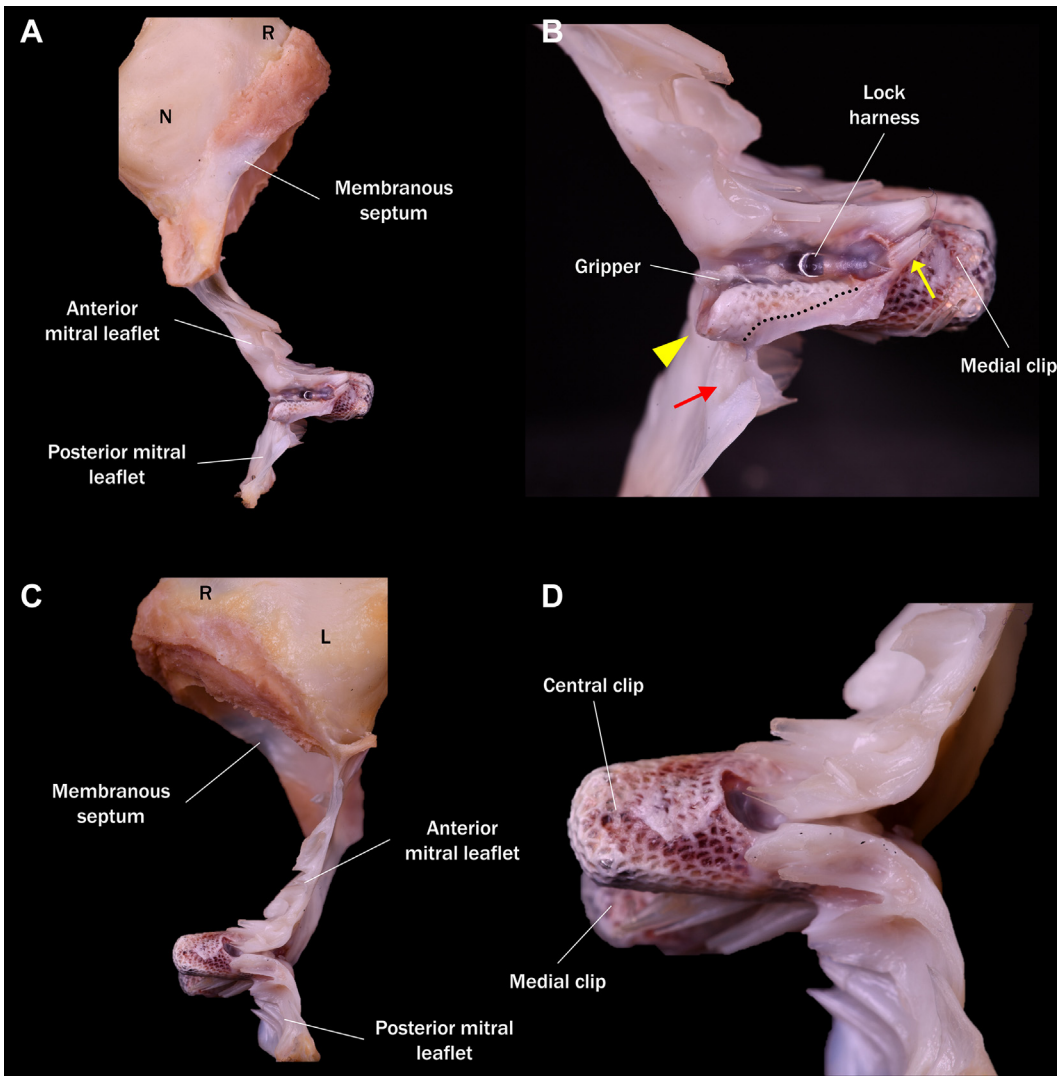
FIGURE 2 **Mitral Valve Viewed From the Left Atrium**



Surgical view with transillumination **(A)** shows that the inferior arm of the medial clip looks bare without coverage by the posterior mitral leaflet. Image after removal of the left atrium **(B)** and magnified image of the middle scallops **(C)** confirm the bare inferior arm of the medial clip **(yellow arrowhead)**, failing to grasp the posterior mitral leaflet. Both arms of the central clip and the superior arm of the medial clip are covered by the leaflets, indicating the successful capture of the leaflet. A tiny tear in the posterior mitral leaflet **(red arrow)** and adhesion of the posterior mitral leaflet to the inferior surface of the inferior arm of the medial clip **(white arrow)** are noted. **Red and yellow dotted lines** denote the free margin of the anterior and posterior mitral leaflets, respectively **(C)**. R = right coronary aortic leaflet; other abbreviations as in Figure 1.

the mitral leaflets (Figures 1 and 2). Subsequent progressive dissection of the heart was then performed focusing on the relationship between the clips and the mitral valve apparatus. Direct observation of the left ventricular wall and the interaction between the clips and the mitral valve apparatus (particularly the chordae tendineae) revealed insightful anatomical nuances that would be impossible to visualize using clinical imaging modalities. These observations include the partially infarcted papillary muscles (Figure 1), the topographic relationship between each clip and the chordae tendineae/mitral leaflets

FIGURE 3 Magnified Image of the Clips



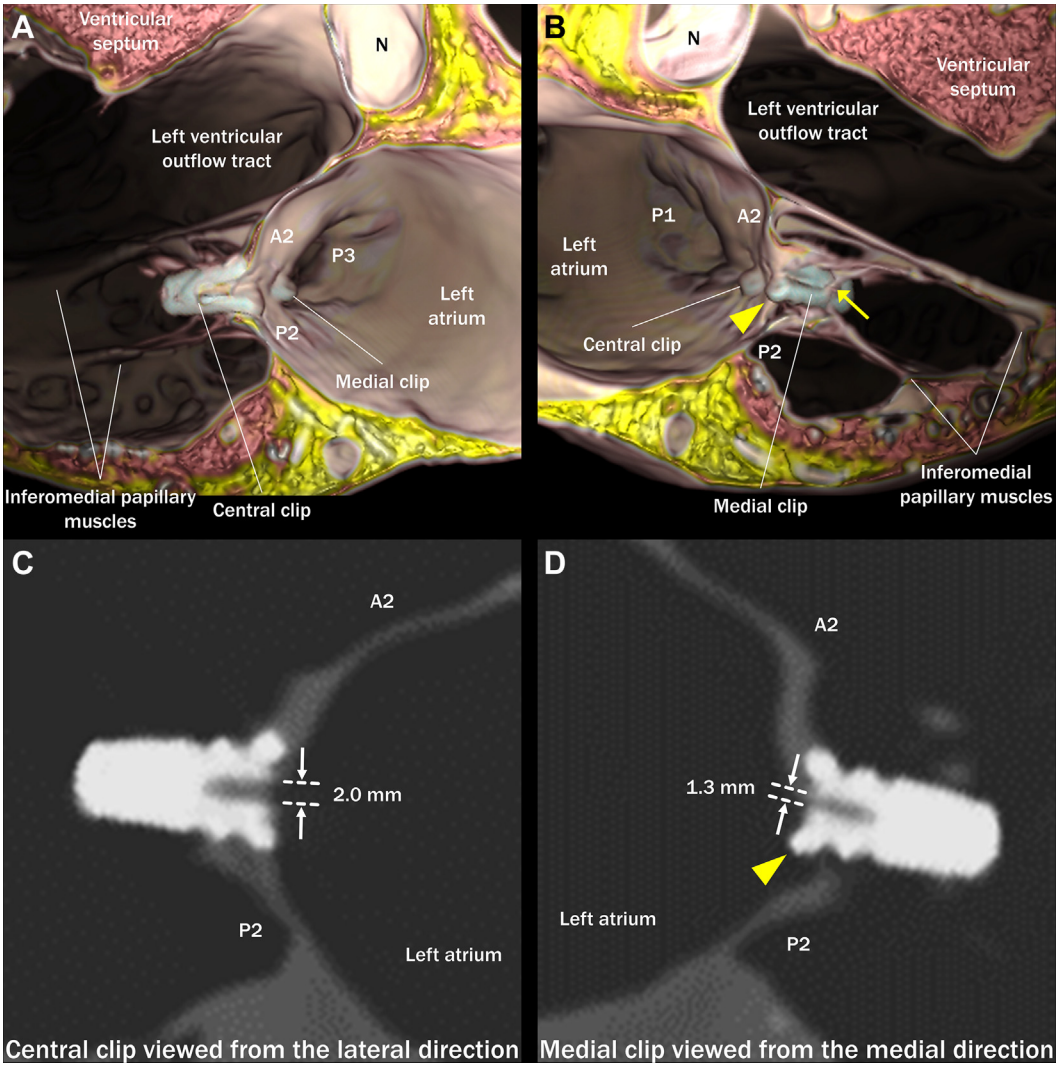
Close-up images of the medial clip viewed from the medial side **(A, B)** and central clip viewed from the lateral side **(C, D)** in similar fashion with Figure 4 revealed that the inferior arm of the medial clip fails to capture the posterior mitral leaflet. Thus, the inferior arm looks bare **(yellow arrowhead)** without coverage by the leaflet, and the leaflet is not sandwiched between the gripper and the inferior arm **(B)**. A tiny tear in the posterior mitral leaflet **(red arrow)** and adhesion of the posterior mitral leaflet to the inferior surface of the inferior arm of the medial clip **(black dotted line)** are confirmed. **Yellow arrow** denotes the first-generation chorda tendinea of the anterior mitral leaflet captured by the medial clip. On the other hand, the central clip clearly shows dual-leaflet capture **(D)**. Note a physiological angulation between the aortic and mitral valvar orifice **(A, C)**. Abbreviations as in Figures 1 and 2.

(Figures 1 to 4), the tiny tear at the posterior mitral leaflet (Figures 1 and 2), the adhesion of the posterior mitral leaflet to the medial clip surface (Figures 2 and 3), the capture of the first-generation chordae tendineae by the clips (Figures 3 and 4), the chordal connection between both papillary muscles (Figure 1), the 3-dimensional relationship between the mitral and aortic valves (Figures 1 and 3), and the single-leaflet capture by the medial clip (Figures 1 to 5) with the observed difference in the extent of opening distances of the clips (Figures 4 and 5).

DISCUSSION

Typically, the superolateral and inferomedial left ventricular papillary muscles project chordae

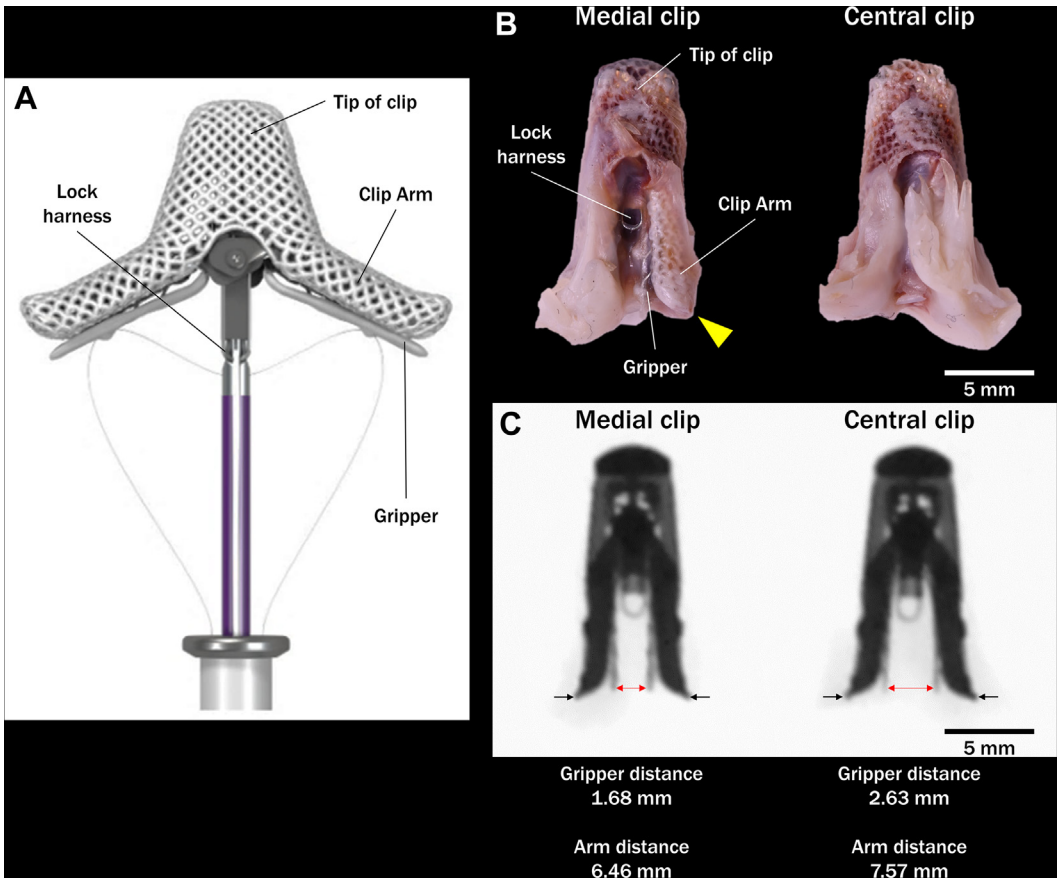
FIGURE 4 **Virtual Dissection of the Clip and Mitral Valve Apparatus**



Virtual dissection images **(A, B)** and multiplanar reconstruction images **(C, D)** of the central clip **(A, C)** and medial clip **(B, D)** corresponding to Figure 3 are reconstructed with computed tomographic scanning (SOMATOM Definition AS, Siemens Healthcare). The medial clip does not grasp the posterior mitral leaflet **(D)**. Thus, the inferior arm looks bare **(yellow arrowheads)** without coverage by the leaflet, and the posterior mitral leaflet is not sandwiched by the medial clip **(D)**. Distance between the arms of the clip is shorter in the medial clip **(C, D)** than in the central clip. **Yellow arrow** denotes the first-generation chorda tendinea of the anterior mitral leaflet captured by the medial clip as shown in Figure 3. Abbreviation as in Figure 1.

tendineae to the superolateral and inferomedial aspects of the mitral leaflets,[3,4] respectively, sparing the central leaflets edges. Thus, the central segments of the anterior and posterior mitral leaflets are considered chordae-free zone.[5] The presence and extent of chordae-free zone is highly variable in both normal hearts and hearts with mitral valve prolapse.[6,7] In the current case, chordae-free zones were very narrow in both mitral leaflets, which were appropriately grasped by the central clip (Figure 1). Even when the noncentral zone outside the chordae-free zone is targeted, transcatheter edge-to-edge mitral valve repair has been reported to be a safe and effective treatment for mitral regurgitation.[5] However, complications during the procedure may occur, such as clip entanglement/entrapment in the chordae tendineae, resulting in chordal rupture.[8] The dense chordae network surrounding the medial clip

FIGURE 5 Comparison of 2 Clips



(A) The structure of MitraClip (with permission from Abbott Laboratories). Real photograph **(B)** and corresponding fluoroscopic image **(C)** demonstrate the en face images of 2 clips (Figure 4). The distance between the grippers **(red arrows)** and the arms **(black arrows)** is shorter in the medial clip with single-leaflet capture than that in the central clip with dual-leaflet capture. Note that the inferior arm of the medial clip looks bare **(yellow arrowhead)**, and nothing is sandwiched between the gripper and that arm. This provides evidence of single-leaflet capture.

(Figure 1) can complicate device manipulation, and potentially lead to chordae tendineae capture, which can increase the risk of shallow leaflet capture, single-leaflet capture, or capture failure of both leaflets.

Single-leaflet capture is reported in 1.5% of transcatheter edge-to-edge mitral valve repair.[9] It can be clinically silent and may be overlooked if the chordae tendineae is captured close to its attachment to the noncaptured leaflet. A detailed observation of clip morphology using fluoroscopy, computed tomography, and direct macroscopic examination revealed that the distance between the 2 arms of the clip with single-leaflet capture is shorter than that of the dual-leaflet capture (Figures 4 and 5). This observation is clinically relevant because it may assist operators in diagnosing a potential single-leaflet capture before release of the clip. Further investigation in the clinical setting is needed to evaluate the relationship between the distance between the clip arms and single-leaflet capture using intraoperative and postoperative transesophageal echocardiography (3-chamber view), intraoperative fluoroscopy (deep right anterior oblique and caudal angulation), and postoperative cardiac computed tomography.

CONCLUSIONS

In this case report, we demonstrate rare images of a mitral valve clip device in a postmortem heart 4 years after implantation. The insights provided with regard to the interaction between the clips and the chordae

tendineae and the morphologic features of single-leaflet capture can improve the interventionalist's understanding of 3-dimensional interaction between the clip device and the mitral valve apparatus.

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