MORPHOLOGY AND MORPHOMETRIC ANALYSIS OF THE HUMAN MITRAL VALVE COMPLEX

Dissertation submitted for

M.S.ANATOMY

BRANCH V DEGREE EXAMINATION

**THE TAMILNADU
Dr.M.G.R. MEDICAL UNIVERSITY
CHENNAI, TAMILNADU**

September - 2006

CERTIFICATE

This is to certify that the Dissertation on **"MORPHOLOGY AND MORPHOMETRIC ANALYSIS OF THE HUMAN MITRAL VALVE COMPLEX"**, is a bonafide work, carried out in the Upgraded Institute of Anatomy, Madras Medical College, Chennai - 600 003, during 2003 - 2006 by **Dr.M.Kavimani**, under my Supervision and Guidance in partial fulfillment of the regulation laid down by the Tamilnadu Dr.M.G.R. Medical University, M.S.Anatomy Branch-V Degree Examination to be held in September 2006.

DEAN
Madras Medical College
Chennai - 600 003.

Prof.Dr.CHRISTILDA FELICIA JEBAKANI M.S.,
Director and Professor,
Upgraded Institute of Anatomy ,
Madras Medical College,
Chennai - 600 003.

ACKNOWLEDGEMENT

I wish to express my sincere gratitude to my most beloved and respected teacher and guide, **Prof. Dr. CHRISTILDA FELICIA JEBAKANI, M.S.**, Director and Professor, Upgraded Institute of Anatomy, Madras Medical College, Chennai, who has motivated me to conduct this study and provided all the guidance and facilities available in the Institution. But for her untiring and enthusiastic support and valuable suggestions this study would not have been possible.

My sincere thanks to **Dr.KALAVATHI PONNIRAIVAN, B.Sc., M.D.**, Dean, Madras Medical College, Chennai for permitting me to avail the facilities in the Institution during the course of my study.

I express my sincere thanks to Director and Professor, Institute of forensic medicine, Madras Medical College, Chennai for permitting me to collect the specimens from the Institute of forensic medicine for my study.

I wish to thank **Dr.RAJA SANTHOSAM**, Director and Professor, Institute of Cardiothoracic Surgery, Madras Medical College, Chennai for his excellent guidance and unflinching support showed me the right path to complete this work.

I am profoundly thankful to **Dr.SOLOMON VICTOR**, Cardiothoracic Surgeon for his helpful suggestions to conduct and complete this study.

I am extremely thankful to cardiothoracic surgery postgraduate students **DR.RAMAKRISHNAN, Dr.PONNUSWAMY, Dr.GOPAL, Dr.GIRISH**, for their help to conduct the clinical studies.

I am grateful to **Prof.Dr.T.R.KALAVATHY, M.S.**, (Rtd.), Director and Professor, Upgraded Institute Anatomy, Madras Medical College, Chennai for her constant encouragement and support during the study.

My sincere thanks to **Dr.I.JEYARAJ, M.S., Tmt.M.S. THENMOZHI, Tmt.M.C.INDIRAKUMARI, Dr.CHEZIAN** for their appreciation and encouragement throughout my dissections.

I am thankful to **Dr.IWAN JAMES, Dr.A.SHARMILA, Dr.V.SATHIALAKSHMI, Dr.M.VIJAYALAKSHMI, Dr.A.SENTHAMIL SELVI, Dr.S.SUMATHILATHA** for their constant support and encouragement.

I wish to thank **Dr.P.MURUGESAN, Dr.SATHISH, Dr.KARTHIK** for their constant support.

I am thankful to **Dr.PREETHI, Dr.JAYANTHI NANADEEPAM, Dr.JAYANTHI, Dr.ANITA** for their supportive and encouraging throughout my study.

I express my sincere thanks to **Mr.JABBAR, P.DEVARAJAN, G.ANKIAH, Mr.SUGENDRAN**, who helped with making arrangements for dissections.

I am thankful to the workers in the Forensic Medicine Department who helped me in collecting specimens

I am very grateful to my wife **Dr. M. SARASWATHI M.V.Sc., (Surgery)** and my parents **Mr.G.MOGANARANGAN** and **M.VASANTHA, Dr.M.LATHASARATHY, Dr.MURUGASARATHY** and **Dr.M.ANBUMALAR**, who made this study a reality.

CONTENTS

INTRODUCTION

The Search for TRUTH is in one way hard
And in another easy

For it is evident that no one can master it fully
Nor miss it entirely

But each adds a little to our knowledge of Nature
And from the facts assembled

There arises grandeur

- Aristotle (384 – 322Bc)

The opening of a new field of surgical endeavor often arouses interest in the detailed study of the anatomy of the involved part of the body.

As a result of such studies, current notions may be so changed and extended so as to understand better the morphologic structures of the organ and to provide a scientific basis for its function.

The impetus given to mitral valve surgery in the course of the last few years has prompted a thorough revision of our knowledge concerning the anatomy of the normal mitral valve.

In my present study (which included adult and foetal cadaveric study and clinical study) the morphology and morphometric analysis of mitral valve complex were studied and then compared and analysed with the works of many eminent scientists in this field.

Normal anatomy of mitral value complex

The mitral value complex includes mitral annulus, leaflets of the mitral valve, chordae tendineae and papillary muscles. Mitral annulus – the mitral annulus consists of a collagenous ring where the lamina fibrosa of the valve leaflets are attached.

Leaflets of the mitral valve – The leaflets of the mitral valve are two, anterior and posterior hence called bicuspid valve. These leaflets are separated by two deep indentations are known as commissures, namely anterolateral and posteromedial commissures.

The base of anterior leaflet is attached to the anteriomedial margin of the annulus and extends between right and left fibrous trigones. The anterior leaflet consist of a thick rough zone close to the free margin and a thin clear zone extending upto the annulus (Basal zone is absent in this leaflet).

The free margin and the ventricular surface of the rough zone provide attachments to free chordae and rough zone chordae. The anterior leaflet presents two peculiar and strongest strands of rough zone chordae derived from anterolateral and posteromedial papillary muscles. These are called strut chordae.

The base of the posterior leaflet is attached to the posterolateral margin of the annulus. So that it possesses wider attachment than the anterior leaflet. The free margin of the leaflet presents usually two clefts which divide the leaflet into three scallops.

The clefts and commissures give attachment to fan shaped chordae. Each scallop of the posterior leaflet consists of three zones – rough, clear and basal. Ventricular surfaces of the rough and basal zones are connected to the chordae tendineae.

Chordae tendineae – There are endothelial covered collagenous threads. The chordae are classified according to their attachments to the leaflets as follows – commissural, cleft, rough zone, strut and basal chordae.

The commissural and cleft chordae are fan shaped, and are attached to the indentations and margins of adjacent leaflets or scallops. The rough zone chordae attached to close to the free margin. Strut chordae is two peculiar and strongest strands of rough zone chordae. Basal chordae extend from the ventricular wall to the basal zone of the leaflets.

Papillary muscles

These are conical muscular projections, usually two in number – anterior (anterolateral) and posterior (Posteromedial). The base of the anterior papillary muscle is attached to the sternocostal surface. The posterior papillary muscle is attached to the inferior wall of the left ventricle.

The apical third of the papillary muscles provides attachments to the chordae tendineae to the anterior and posterior leaflets. The chordae tendineae of each papillary muscle are connected to both leaflets of the mitral valve.

AIM OF THE STUDY

Normal mitral valve function depends upon the anatomic and mechanical integrity of the atrioventricular ring, the valve leaflets, chordae tendineae and the papillary muscles.

While there is no dispute in accepting that the mitral valve forms a continuous skirt hanging down from the mitral annulus, there is no consensus as to how many leaflets are in the valve or as to what constitutes the point of separation of one leaflet from the other.

Advances in echocardiography, invasive cardiology (including balloon mitral valvuloplasty) and surgical reconstruction of mitral valves necessitate an appreciation of the many variations in the anatomy of the mitral valve.

The classical description of the mitral valve found in the textbooks of anatomy is inadequate for the need of the cardiac surgeon. Similarly the importance of the valvular structures and the myocardium in the mechanism of valve closure requires a new appraisal in view of recent observations.

The aim of the present study is to analyse the morphologic and morpho metric details of the human mitral valve complex.

This study will also be of much help for mitral valve procedures such as mitral commissurotomy, commissuroplasty, valvuloplasty and artificial chordae tendineae replacement and prosthetic valve replacements.

REVIEW OF LITERATURE

MITRAL ANNULUS

Henry Gray (1858) said that the mitral annulus is not a simple fibrous ring, but comprises elements varying greatly in consistency, with which the valvular laminae fibrosae become continuous. These variations are of the greatest functional significance, allowing major changes in the annular shape and dimensions at different stages of the cardiac cycle, ensuring optimal efficiency in valvular actions of the mitral complex and its equally important role in controlling inflow / outflow patterns through the left ventricle.

MC Alpine WA (1975) disfavoured the term annulus, preferring to describe the sheetlike fibrous area as the aortoventricular membrane that extended around the subvalvar region.

A.K.Datta (1986) described that the mitral annulus consists of a collagenous ring where the lamina fibrosa of the valve leaflets are attached.

Hutchins GM et al., (1986) reported that the floppy mitral valve is associated with disjunction at the mitral annulus. A separation between the atrial wall - mitral valve junction and the left ventricular attachment is known as disjunction.

Angelini A, et al., (1988) studied about mitral annular circumference and demonstrated pronounced variations not only from heart to heart but with in the same heart.

They traced prongs of fibrous tissue from each of the fibrous trigones which were not continuous around the orifice. They also say that the mitral annulus opposite the area of valvar fibrous continuity tends to be "weaker" in terms of lacking a well formed fibours cord. This is the area affected in "annular dilatation" and also most often involved in calcification of the mitral annulus. With severe dilatation, the minor axis of the valvar orifice becomes so distended that the leaflets which are of fixed lengths, become unable to approximate each other.

Kitzman DW, Edwards WD (1990) found that with advancing age there are significant increases in heart weight, ventricular septal and probably left ventricular free wall thickness and in valve circumferences. In the myocardium there are increases in fat, collagen, elastin and lipofuscin. The geometry of the heart changes as well, due to decreasing base to apex dimension, right ward shift and dilatation of the aortic root, and left atrial dilatation. The aortic and mitral valves thicken and become fibrotic along their oppositional surfaces, and their mitral annuli are the sites of collagen degeneration, lipid accumulation and calcification.

Tirone E, David M.D., (1994) described that the interactions between the mitral valve and left ventricle are complex and not yet completely understood. However, continuity between the papillary muscles and the mitral annulus is probably the most important factor in this relationship because severance of the chordae tendineae in experimental animals causes a significant drop in left ventricular systolic function as assessed by load independent parameters. This deterioration in ventricular function is even more marked in dilated hearts due to chronic mitral regurgitation. There is strong clinical evidence that maintenance of papillary muscle - mitral annular continuity during mitral valve surgery is beneficial to left ventricular function and clinical outcome. That is one of the reasons why the mitral valve should be repaired rather than replaced in patients who need mitral valve surgery. If replacement is necessary, the chordae tendineae should be preserved. If preservation of chordae tendineae is difficult because of calcification, fibrosis or for other reasons it is possible to resuspend the papillary muscle with expanded tetra fluoroethylene sutures. Preservation of chordae tendineae during mitral valve replacement is also important because it prevents spontaneous rupture of the posterior wall of the left ventricle, a rare but dreaded complication of this type of surgery.

Gerda L. Van Rijk-Zwikker, M.D. et al., (1994) viewed mitral valve from left atrium and described the mitral annulus consisting arbitrarily of two areas - Anterior and posterior to the commissures. The anterior commissure is also called the anterolateral or superior commissure (SC) Starting at the superior commissure and rotating clockwise, the annulus (and left atrium) is adjacent to a small part of the left ventricular free wall (LVFW), the left fibrous trigone (LFT) and the left coronary cusp of the aortic valve (LCC). The non-coronary cusp (NCC) is the next structure that borders the annulus, then the right fibrous trigone (RFT), the interventricular septum and the posteromedial or inferior commissure (IC) (Fig.1).

Tetsuro Sakai et al., (1999) measured the distance from the tip of the papillary muscle to its corresponding mitral annulus in 57 normal cadaveric hearts for a guide to the resuspension procedure in mitral valve replacement. They came to a conclusion that in normal hearts, the mitral annulus - papillary muscle distances of the mitral apparatus are similar in 2, 4, 8 'O' clock positions and correlate with the mitral annular diameter (Fig.2).

Syho (2002) reported that the mitral annulus marking the hinge line of the valvar leaflets is more D shaped than the circular shape portrayed by prosthetic valves. The straight border accommodates the aortic valve allowing the latter to be wedged between the ventricular septum and the mitral valve. In this region, the aortic valve is in fibrous continuity with one of the two leaflets of the mitral valve. Expansions of fibrous tissues at either extreme of the area of continuity form the right and left fibrous trigones. The atrioventricular conduction bundle passes through the right fibrous trigone. Although the term mitral annulus implies a solid ring-like fibrous cord to which the leaflets are attached, this is far from the case. In the area of aortic - mitral fibrous continuity, the distal margin of atrial myocardium over the leaflet defines the hinge line. When viewed from the ventricular aspect however the hinge line is indistinct since the fibrous continuity is an extensive sheet (Fig.3).

Skandalaki's Surgical Anatomy (2004) said that the mitral valve leaflets insert on the left atrioventricular fibrous mitral annulus.

COMMISSURES

Henry Gray (1858) said that the two deep indentations which are regularly positioned and receiving unique fan shaped commissural chordae tendineae are anterolateral and posteromedial commissures. Mitral commissures are positionally named.

Rusted.I.E., et al., (1952) emphasized the localizing importance of the anterior muscle in "Commissurotomy" (Valvulotomy) for mitral stenosis, stating that in only 1.5 percent of their specimens was the muscle atypical and a poor guide to the commissure between the CUSPS, as determined both by inspection and palpation. A single muscle points directly toward the commissure, either by a well defined apex, by a groove upon it or by an imaginary line projected along it (Fig.4). When the muscle is double, a line along the posterior aspect of the more anterior muscle points toward it and when triple the middle of the three muscles points toward it. The chordae from this muscle may also serve as a guide to the commissure (since they go to both anterior and posterior cusps), for in more than half the cases a distinct, hammock like groove leading to the commissure could be palpated (the chordae of the posteromedial muscle were rarely (10%) a good guide to the commissure). They suggested that the chordae from the anterior muscle might be especially useful as a guide in those cases of mitral stenosis. He presented further anatomical data including measurements of the normal bicuspid valve.

They emphasized also the difference between the normal commissures or areas of fusion at the bases of valves and the pathological commissures produced by further fusion of the edges of the valves. In their material the normal commissures averaged about 0.7 to 0.8 cm in length, so that a commissure which upon palpation is much greater than 1 cm long can be supposed to be formed in part by abnormal fusion. They also pointed out that thickening of the chordae tendineae may interfere with the function of the valve, persons with this lesion constituting a minor group in which valvulotomy cannot be expected to relieve valvular stenosis.

Michele A. Chiechi et al., (1956) studied 105 normal human hearts and stated that the posterior portion of the mitral valve is the least gifted with valvular tissue and therefore the weakest part of the valve. the preponderance of valvular incompetence at the region of the posterior commissure is probably due to this shortage of valvular tissue in this region. The posterior junctional tissue could be destroyed by a rheumatic process more easily than the anterior which is richer in valvular tissue. They came to a conclusion that no commissurotomy should ever reach the mitral ring, because of the importance of maintaining a cuff of valvular tissue to insure closure of the orifice. By splitting the valvular tissue upto the annulus a fatal regurgitation might be produced. It is well known that a posterior commissurotomy more often is followed by a surgically produced valvular incompetence there is an anterior separation. If the operation had been adequate that is if the division has been in the line of the commissure, the production of incompetence could be explained only by the fact that the junctional tissue has been divided along with the commissure. This is much more easily done posteriorly because the posterior commissure is usually less deep than the anterior and the atrioventricular annulus is reached promptly by a stroke of the finger or of the knife.

Hollinshed (1957) reported that both mitral valve leaflets are continuous with each other at their bases, and accessory leaflets may sometimes be found in the angles at which they meet. These angles are again known as commissures.

Davila J.C. Palmer T.E. (1962) described the commissures as junctional zones of valvular tissue.

DU Plessis LA. Marchand P (1964) reported that commissures are points of attachment of the mitral annulus to the fibrous trigones.

Ranganathan N, et al., (1970) described the commissures as indentations at either end of the anterior leaflet or aortic leaflet.

Lam JHC. et al., (1970) stated that the areas of leaflets covered by typical commissure chordae have been considered as the commissural area which would include adjacent leaflet tissue.

Yacoub M. (1976) considered the commissural scallops as separate leaflets and states that mitral valve has four leaflets and is a quadricuspid valve.

Anderson R.H., Becker A.E. (1980) described about clefts separating anterior and posterior leaflets.

A.K.Datta (1986) reported that the two leaflets of mitral valve are separated by two deep indentations, anterolateral and posteromedial commissures.

Wilcox B.R, Anderson RH, (1992) defines commissure as the space between identifiable components of the skirt of leaflet tissue.

Solomon Victor, Vijaya M.Nayak (1994) reported that the junctions between the two leaflets commonly called commissures.

Syho (2002) stated that the anterior and posterior leaflets meet to form an arc shaped closure line and each end of the closure line is referred to as a commissure. They are designated as the anterolateral and posteromedial commissures. It is worth noting however, that the indentations between leaflets do not reach the annulus.

MITRAL VALVE LEAFLETS

Henry Gray (1858) described the anterior leaflet of mitral valve as large, triangular with no marginal indentations. Its lamina fibrosa is peripherally continuous, beyond the margins of the fibrous sub-aortic curtain with the mitral aspects of the right and left fibrous trigones, between there with fibrous curtain itself and beyond the trigones with the trigonal roots of the fila coronaria. The posterior leaflet has usually two minor indentations or clefts. Clefts divide the posterior leaflet into a relatively large middle scallop and smaller anterolateral commissural and posteromedial commissural scallops.

T.Walmsley (1929) states that Andreas Vesalius was the person who first suggested the picturesque term "mitral" to describe the left atrioventricular valve owing to its resemblance to a plan view of the bishop's mitre.

Harken (1948) described anteromedial leaflet as the aortic baffle because it is the only dividing structure between the mitral and the aortic orifice. Directly inferior to the aortic canal, it constitutes an integral part of the outflow tract of the left ventricle. Due to this anatomic location a considerable portion of its function is believed to be the direction of the flow of blood toward the aorta.

In other words the leaflet apparently acts as a watershed which deflects the blood toward the aorta in the ejection phase of the ventricular contraction.

He reported that 26 of 35 hearts had two additional or commissural leaflets which are the scallops just behind commissural line.

Hollinshed (1957) stated that bicuspid valve consists only of an anterior and posterior leaflets, the anterior being the larger of the two; as in the case of the tricuspid valve.

Zimmerman J (1966) studied about prongs of fibrous tissues from each of the fibrous trigones which are expansions of fibrous tissue at either end of the area of aortic and mitral valvar continuity.

Ariela Pomerance (1967) studied ageing in 805 human hearts and observed the following changes in the mitral valve.

Anterior leaflet or anterior cusp - nodular thickening at the free edge, which when marked is generally referred to as senile sclerosis, and lipoid deposition nearer the attached part.

Atheromatosis of the anterior cusp of the mitral valves is also considered to be related to age and results of his study confirm this view. He found 4 changes in posterior cusp or leaflet that is -

(1) The most striking change with age was the rise in incidence of mitral ring calcification.

(2) Small puckered scars were seen in about 5 percent of men over 65 and 3 percent of women.

(3) A more constant finding particularly in the female, was diffuse opacity of the cusp.

(4) The cusps became thickened opaque and voluminous resembling a parachute.

N. Ranganathan, et al. (1970) studied fifty normal mitral valves from adults and observed the following:

Commissures which are identified by the commissural partition the mitral valvular tissue into anterior and posterior leaflets.

The posterior leaflet is further divided into scallops by cleft in its tissue and the posterior leaflet which is partitioned this way there was triscalloped in 46 hearts.

In 42 hearts a large middle scallop was present with two smaller scallops on either side. They also state that rough and clear zones can be defined on the anterior leaflet and rough, clear and basal zones on the posterior leaflet.

A.K. Datta et al. (1984) studied morphology and morphometry of the mitral valve in 30 normal human hearts collected from postmortem room (Fig.5a,b,c).

Precise demarcation of mitral leaflets subdivision of posterior leaflet into three scallops, rough and clear zones of both leaflets and pattern of chordal attachments are observed and their age changes are noted by them and they quote that the morphometry reveals that the basal width of the posterior leaflet is distinctly more extensive than that of the anterior leaflet. The height of the anterior leaflet, however is comparatively more than that of the posterior leaflet. Further in the anterior leaflet the rough zone is significantly shorter in central height than its clear zone, whereas in the middle scallop of posterior leaflet the height of the rough zone is slightly longer than the clear zone. Their findings provide morphological evidence of the mechanism of closure of the normal mitral valve.

Carpentier A. et al., (1971) who did a new reconstructive operation for correction of mitral and tricuspid insufficiency state that free edge of the mural leaflet is often divided into three or more scallops or segments described as lateral, middle and medial or assigned terms like, P_1, P_2 and P_3 (Fig.6).

Perloff JK, and Roberts WC (1972) emphasized the important role of the atrial wall though it was not a part of mitral apparatus since left atrial enlargement can contribute to mitral regurgitation.

The continuity of the atrial myocardium over the atrial surface of the mural (posterior) leaflet makes this leaflet vulnerable to being displaced when the atrial chamber enlarges.

Bulkley B.H. and Robert W.C. (1975) stated that in deformation of the mural leaflet, the middle scallop is most often affected. This is thought to be a consequence of mitral annular dilatation in this region.

Solomon Victor, Vijaya M. Nayak (1994) studied one hundred human hearts from autopsies to clarify controversies in the literature about commissures, slits, chordae and leaflets of the mitral valve. They have designated perpendiculars drawn from the annulus to the free edge at the shortest height of the mitral veil on either side of the aortic leaflet as the anterolateral and posteromedial commissural lines. These lines divide the mitral veil precisely into aortic and mural leaflets. Slits in the leaflets were easily identified by the dipping in of the free edge into the cusp tissue. There was no slits in the aortic leaflet. Ninety eight hearts had slits in mural leaflet, in the anterolateral halves in 81, posteromedial halves in 76, and in the centre in one. The number of slits in the mural leaflet varied from one to five but was commonly two. Unlike the relatively static and straight annulus of the aortic leaflet, the curved annulus of the mitral leaflet contracts and changes in contour during systole. Hence slits are necessary in the mural leaflet to help it fold and adapt to the reduced orifice during systole and unfold during the diastole. In addition to this coarse adjustment of the mural leaflet, both leaflets are pleated due to "Hooding up" of the leaflet tissue between chordal attachments during systole, providing the fine tuning to enable the leaflets to adapt themselves to the reduced systolic orifice (Fig.7a,b,c).

The nodular appearance of the line of apposition of the leaflet is evidence of this pleating mechanism during valve closure. Slit lines which they have designated as perpendiculars drawn from the summit of the slits to the annulus, were used arbitrarily to divide the mural leaflet into 2 to 6 scallops. When slits are absent there are no scallops. The slits and scallops are best serially numbered counter clockwise from the surgeon's view through the atrium. The scallops immediately behind the commissural lines, customarily labelled as the commissural scallops, are best defined as mural leaflet tissue between the anterolateral or posteromedial commissural line and the closest anterolateral or posteromedial slit line. Anterolateral commissural scallops were seen in 81 hearts and posteromedial commissural scallops in 76 hearts. There is no consistent fan shaped chordae pattern at the commissural lines or at the slits. However the chordae arising from each papillary muscle group in toto form a fan, reaching out to the corresponding adjacent halves of the two leaflets, restraining their splaying out in diastole and upward bulge during systole. This findings are relevant to the pathogenesis of mitral valvular disease and reparative procedures.

Gerde L van Rijk - Z Wikker, MD et al., (1994) reported that the edge of the anterior leaflet is smooth and the edge of the posterior leaflet often has multiple indentation or clefts bridged by fan like chords. Just as in the actual commissures the indentations never reach the mitral annulus itself, otherwise the valve would be incompetent. The same applies to mitral valve commissurotomy where the incision intended to open the commissures should not reach the mitral annulus itself but leave at least 2 mm of valve tissue. In diastole the combined surface area of the two leaflets is 1½ to 2 times the surface area of the functional mitral orifice, while in systole than anterior leaflet alone may cover the effective mitral orifice.

Therefore in mitral valve incompetence in conjunction with mitral annular dilatation, the extent of reduction of the annulus to obtain a competent valve can be estimated from the size of the anterior leaflet, which has to cover the mitral orifice at the annulus level. The redundancy of valvular tissue indicates that the mitral valve will not rapidly become incompetent with mitral annular dilatation alone.

He also state that the atrial side of the valve leaflets has a smooth surface. One half of two thirds of the ventricular surface is irregular, in particular, the area where the chords insert into the valve leaflets over some distance. The smooth part of the ventricular surface of the anterior leaflet is the continuation of the aorto mitral membrane and is roughly one third of the total surface. The site of insertion of the chords on the ventricular surface called the rough zone of the leaflets, serves as a fibrous re-enforcement of the leaflets. Although there is considerable variation, the rough zone is larger in the anterior leaflet, because the chords insert over a large area in the central part of the leaflet. The rough zone is smaller in the posterior leaflets, tapers off toward the clefts in the leaflet and toward the commissures, and is absent in the commissural areas. The absence of chordal support and the relative immobility of the mitral annulus in the commissural areas makes reconstruction of the valve in these areas more difficult.

Cheng To et al., (1997) studied the mitral valve by echo cardiography and stated when the closed mitral valve is seen in profile, the major part of the closure line lies below the plane of the atrioventricular junction rising toward the commissures at the peripheral ends so that the atrial surface of the leaflet has a saddle like configuration. Being tethered by the tensor apparatus, the line of coaptation in a normal valve does not extend above the level of the junction during ventricular systole.

Syho (2002) described that the aortic leaflet which is in fibrous continuity with the aortic valve has a rounded free edge and occupies a third of the mitral annular circumference, whereas the other leaflet is long and narrow, lining the remainder of the circumference. The aortic leaflet hangs like a curtain between the left ventricular inflow and outflow tracts. When the valve is closed, this leaflet appears to form the greater part of the atrial floor but is approximately equal in area to the mural leaflet. It meets the mural leaflet to form an arc shaped closure line, or zone of apposition, that is obliquely situated relative to the orthogonal planes of the body. With the leaflets meeting, the view of the valve from the atrium resembles a smile.

Skandalaki (2004) in his book of Surgical Anatomy reported that two leaflets guard the opening forming the mitral valve. The anterior leaflet is large and triangular in shape. The smaller posterior leaflet is known as the Merklin leaflet. The leaflets insert on the left atrioventricular fibrous annulus. Their free margins are attached by chordae tendineae to the papillary muscles. The scalloped margin of the posterior leaflet gives the impression of indistinct minor leaflets, often at opposite sides of the valve.

CHORDAE TENDINEAE

Henry Gray (1858) reported that the false chordae interconnect papillary muscles, extend from the latter to a point on the ventricular wall or interconnect two points on the ventricular walls. They are ignored in many accounts and when mentioned considered of little or no functional significance.

True chordae of the mitral valve complex may first be divided into inter leaflet or commissural chordae and varieties of leaflet chordae. Of the latter those of the anterior leaflet are rough zone chordae, including special strut chordae. Those of the posterior leaflet include rough zone chordae, cleft chordae and basal chordae (Fig.8a).

Most true chordae divide into branches from a single stem soon after its origin from the apical third of a papillary muscle, or proceed as single cords dividing into multiple fine cords near their attachment.

Anterolateral and posteromedial commissural chordae arise near the tips of papillary muscles by a single stem fanning out at once into radiating strands attached to the smooth free margin of the commissure.

Tandler J. (1913) suggested most commonly used classifications of chordae tendineae into three orders.

Ist order - chordae tendineae inserted into the leaflet's edge.

IInd order - chordae tendineae inserted 6 to 8 mm beyond the free margins.

IIIrd order - chordae tendineae inserted into the basal portion of the ventricular aspect of the posterior leaflet.

Quain's elements of Anatomy (1929) distinguishes three orders of chordae tendineae according to the site of attachment to the leaflets.

Ist order - chordaes are those inserted on the free edge. They are numerous, delicate and often form networks near the edge.

IInd order chordaes insert on the ventricular surface of the leaflets beyond the free edge forming the rough zone. These are thicker than first order chordaes.

IIIrd order - chordaes attach only to the mural leaflet since they arise directly from the ventricular wall or from small trabeculations. They insert to the basal portion of the leaflet and run only a short distance toward the free margin.

Lam JHC et al., (1970) did a study on chordae tendineae from 50 normal mitral valves and they distinguished "four main types by their mode of insertion" (Fig.9).

1. Commissural chordae inserted into the commissures between anterior and posterior leaflets.

2. Rough zone chordae inserted into the ventricular aspect of the distal rough portion of the anterior and posterior leaflets.

In this rough zone chordae two of the anterior leaflet rough zone chordae are thicker than the others and are called strut chordae.

3. Cleft chordae inserted into the clefts between the scallops of the posterior, leaflet.

4. Basal chordae are single strands that arise from the posterior ventricular wall and inserted into the basal zone of the posterior leaflet.

They say that this classification gives clear definition of mitral valve anatomy and forms a sound basis for functional studies of chordae tendineae.

Becker A.E. and DW Wit APM (1980) studied 100 hearts and showed that uniformity of the chordal attachment was uncommon. Normal valves have a spectrum of chordal support and this lack of uniformity could lead to leaflet prolapse, particularly in older individuals.

A.K. Datta et al. (1984) studied thirty human hearts and observed the following (Fig.10a,b,c):

The rough zone chordae are attached to the free margin and the adjoining ventricular aspect of both leaflets of the mitral valve. Each rough zone chordae on approaching the leaflet splits into three strands : one is attached to the free margin, the other to the junction of rough and clear zones, and the third to a point between them.

Two rough zone chordae known as strut chordae are thicker than the rest and are attached to the anterior leaflet on either side of the tip, one arising from the apex of anterior papillary muscle and other from the posterior papillary muscle.

The basal chordae are observed only in the posterior leaflet of all age groups but are more prominent in the third age group. These are attached along a narrow basal strip close to the mitral annulus.

Vander Bel. Kahn J, Becker A.E. (1986) did a study on a series of floppy valves revealed pronounced derangements in chordal branching and in their attachments to the leaflets, leaving part of the affected leaflet less well supported.

Solomon Victor, Vijaya M. Nayak (1995) reported that there is no consistent fan-shaped chordal pattern at the commissural lines or at the slits. However the chordae arising from each papillary muscle group, in toto, form a fan, reaching out to the corresponding adjacent halves of the 2 leaflets, restraining their splaying out in diastole and upward bulge during systole

(Fig.11).

Syho (2002) described that the tendinous cords are string like structures that attach the ventricular surface or the free edge of the leaflets to the papillary muscles. The tendinous cords of the mitral valve are attached to two groups of papillary muscles or directly to the posterio inferior ventricular wall to form the tensor apparatus of the valve. Cords that arise from the apices of the papillary muscles attach to both aortic and mural leaflets of the valve. Since cords usually branch distal to their muscular origins, there are five times as many cords attached to the leaflets as to the papillary muscles. Normally there are only two commissural cords, one supporting each free margin of the commissural region. These cords arise as a single stem but branch like the struts of a fan that, on closing and opening, allow the adjacent leaflets to coapt and to move apart:

According to him leaflet cords are of several forms. The most numerous are rough zone cords. Rough zone cords in the mural leaflet are generally shorter and thinner than those found in the aortic leaflet. Among the rough zone cords of the aortic leaflet two are the largest and thickest, termed strut cords. They arise from the tip of each papillary muscle and are thought to be the strongest. Basal cords are unique to the mural leaflet.

Another type of cord, the cleft cord, is found only in the mural leaflet. Each is a miniature version of a commissural cord whose branches insert into the free margin between adjacent segments while the main stem runs into the rough zone.

He says, according to Toronto classification, the strut cords and parts of the rough zone and cleft cords correspond to second order cords.

Parts of the rough zone cords, cleft cords, and the commissural cords that insert to the free edge of the leaflets correspond to first order cords.

Yoav Turgeman MD (2003) says that Tandler's classification of chordae tendineae into Ist order, second order, and third order based on the site of insertion of chordae tendineae into the valvular leaflet is simple to use and it neither emphasizes the morphologic differences between chordae tendineae nor relates their sites of insertion to their function.

Papillary muscles

HenryGray (1858) stated that the two left ventricular papillary muscles vary in length and breadth and may be bifid. The anterior papillary muscle arises from the sternocostal mural myocardium, the posterior from the diaphragmatic region.

Chordae tendineae arise mostly from the tip and apical third of each muscle, but sometimes near its base. They diverge and are attached to corresponding points on both mitral leaflets.

Rusted I.E. (1951) did an elaborate study of papillary muscles in 200 hearts found that the anterior muscle (anterolateral) was single, though most frequently grooved lengthwise in 76.5 percent, double in 12 percent, triple in 9.5 percent, and more than triple in 4 percent.

The posterior (posteromedial) papillary muscle was found to be single in

30 percent, double in 26.5 percent, triple in 37 percent, and there were more than three in 6 percent. They emphasized the localizing importance of the anterior (anterolateral) papillary muscle in commissurotomy for mitral stenosis since incidence of atypical anterior papillary muscle is less.

Brock R.C. (1952) says that the papillary muscles normally arise from the apical and middle thirds of the left ventricular wall.

N.Ranganathan M.D. and G.E. Burch M.D. (1969) studied the gross morphologic characteristics of the anterolateral and posteromedial papillary muscles of the left ventricles in the ten hearts and classified the papillary muscles into 3 broad categories.

1. Completely tethered papillary muscle i.e. a papillary muscle fully adherent to the subjacent ventricular myocardium and protruding very little into the ventricular cavity with a few trabecular attachments.

2. Finger like papillary muscle. (ie) papillary muscle with one third or more of the body protruding freely into the ventricular cavity with a very few or no trabecular attachments.

3. Mixed type papillary muscle (ie) a papillary muscle with part of the body protruding freely into the ventricular cavity, but also with considerable trabecular attachments and tethering.

Tirone E.David M.D. (1994) stated that the interactions between the mitral valve and left ventricle are complex and not yet completely understood. However, continuity between the papillary muscles and the mitral annulus is probably the most important factor in this relationship because severance of the chordae tendineae in experimental animals causes a significant drop in left ventricular systolic function as assessed by load independent parameters. This deterioration in ventricular function is even more marked in dilated hearts due to chronic mitral regurgitation. There is strong clinical evidence that maintenance of papillary muscle - annular continuity during mitral valve surgery is beneficial to left ventricular function and clinical outcome. That is one of the reasons why the mitral valve should be repaired rather than replaced in patients who need mitral valve surgery. If replacement is necessary, the chordae tendineae should be preserved. If preservation of chordae tendineae is difficult because of calcification, fibrosis or for other reasons it is possible to resuspend the papillary muscle with expanded tetrafluoroethylene sutures. Preservation of chordae tendineae during mitral valve replacement is also important because it prevents spontaneous rupture of the posterior wall of the left ventricle, a rare but dreaded complication of this type of surgery.

Gerda L. Van Rijk - Zwikker, MD (1994) described that the two papillary muscles supporting the chords of the mitral valve have a variable configuration and size. Both muscles are located at the posterior free wall of the left ventricle.

The anterolateral muscle is usually single, can be distinguished from the posterior muscle, because it is larger and is located at the posterior and left side of the left ventricle, underneath the obtuse margin.

The function of the papillary muscles is closely related to the function of the left ventricular wall and proper coaptation of the valve leaflets requires the amount of tension exerted by the papillary muscles to remain within strict limits.

Transient mitral prolapse and incompetence caused by myocardial ischemia result from the inability of the papillary muscle to contract and maintain adequate coaptation of the valve leaflets. Infarction of the ventricular wall in the vicinity of the papillary muscles will also cause mitral incompetence due to either elongation of the infarcted papillary muscle or outward motion of the ventricular wall. The first will lead to prolapse of the mitral valve. The second causes incomplete coaptation of the leaflets because of retraction. Surgical correction of the mitral incompetence based on papillary muscle dysfunction is often unsuccessful due to the dynamic character of this part of the subvalvular apparatus.

Solomn Victor, Vijaya M. Nayak (1995) studied the papillary muscles of the mitral valve in 100 human autopsy hearts and state that a mid-mitral plane passing through the middle of the aortic and mural leaflets divides the chorda papillary support of the mitral valve into anterolateral and posteromedial halves (Fig.12a,b,c,d). The anterolateral papillary support had 1 belly in 67 hearts, 2 in 27, 3 in 4, 4 in 1, and 5 in 1 heart. Likewise, the posteromedial papillary support had 1 muscle belly in 50 hearts, 2 in 36, 3 in 11, and 4 in 3. The single papillary muscles were conical, mammillated, flat topped, grooved, stepped, wavy, arched, sloped or saucerized. When there were two bellies they presented a two tiered, interlinked parallel or arched, V, Y or H configuration. Three papillary muscles formed a parallel, interlinked or arched arrangement or two bellies were interlinked or formed a two tiered arrangement with the third belly separate. When four or five bellies existed, they were parallel or interlinked. In the anterolateral and posteromedial group, the papillary muscle bellies were mostly intraluminal in 14% and 11%, mostly intraluminal with the tip anchored in 19% and 28%, equally sessile and intraluminal in 54.5% and 41.5% mostly sessile in 12.5% and 19.5%, respectively. In the anterolateral group 19% of papillary muscle bellies arose from the upper third of the ventricle, 79.5% from middle third and 1.5% from lower third. The corresponding figures for posteromedial group are 6%, 92.5%, and 1.5%, respectively. Four to 22 chordae originated from the anterolateral papillary group, ending in 14 to 72 chordal insertions into the corresponding half of the valve. Likewise, 2 to 18 chordae arose from the posteromedial papillary group ended in 12 to 80 leaflet insertions. The chordae in each group are best considered in toto as a fan. The configuration of the fan is unique in each heart. Imaging techniques need to be refined to outline those variations more precisely.

Petra W. Oosthoek et al. (1998) did a study in normal hearts at between 5 and 19 weeks of development of papillary muscles with immunohistochemistry, three dimensional reconstructions, and gross inspection. Scanning electron microscopy was used to study human hearts. In embryonic hearts a prominent horse shoe shaped myocardial ridge runs from the anterior wall through the apex to the posterior wall of the left ventricle.

In the atrioventricular region this ridge is continuous with atrial myocardium and covered with cushion tissue. The anterior and posterior parts of the trabecular ridge enlarge and loosen their connections with the atrial myocardium. Their lateral sides gradually delaminate from the left ventricular wall, and the continuity between the two parts is incorporated in the apical trabecular network. In this way the anterior and posterior parts of the ridge transform into the anterolateral and posteromedial papillary muscles, respectively. Simultaneously, the cushions remodel its valve leaflet and chordae. Only the chordal part of the cushions remains attached to the developing papillary muscles. The conclusion is that the disturbed delamination of the anterior or posterior part of the trabecular ridge from the ventricular wall, combined with underdevelopment of chordae, seems to be the cause of asymmetric mitral valves. Parachute valves however develop when the connection between the posterior and anterior part of the ridge condenses to from one single papillary muscle (Fig.13).

Syho (2002) stated that the cords arise from the tips of the papillary muscles. Alterations in the size and shape of the left ventricle can distort the locations of the papillary muscles, resulting in valvar function being disturbed.

The papillary muscles normally arise from the apical and middle thirds of the left ventricular wall. Described in most text books as two in number, however there are usually groups of papillary muscles arranged fairly close together. At their bases, the muscles sometimes false or have bridges of muscular or fibrous continuity before attaching to the ventricular wall. Extreme fusion results in parachute malformation with potential for valvar stenosis.

MATERIAL AND METHODS

Study material

The study material consists of

(a) 45 normal human hearts (40 Adult [25 male 15 female] and 5 Full term Foetuses)

(b) 5 clinical cases

Methods of study

I. Conventional dissection method

(a) In adult hearts

(b) Foetal hearts

II. Clinical study of 5 cases

I. CONVENTIONAL DISSECTION METHOD

Collection of specimens

45 fresh adult human postmortem heart specimens were from taken at autopsy from the Institute of forensic Medicine, Madras Medical College, Chennai, within 24 hours from the time of death.

The postmortem specimens were collected from 25 male and 15 female adults and who had died due to non-cardiac causes mostly from Road and train traffic accidents. There was no evidence of cardiac disease. Full term foetal specimens were collected from the institute of obstetrics and Gynacology, Egmore, Chennai.

The autopsies had been carried out by the conventional 'I' shaped incision from the hyoid bone to the pubic symphysis. The thoracic cage was opened by cutting through the costochondral junctions and the heart had been removed.

The heart thus removed was emptied of blood inside, washed thoroughly in running tap water. It was then transported in closed plastic containers to the Institute of Anatomy, Madras Medical College, Chennai for further dissection.

Dissection of specimens

Position and orientation of the heart and its chambers was confirmed.

Left atrium wall was then opened by an incision through the right and left inferior pulmonary veins and the upper part of left atrial auricle was dissected and the mitral valve was inspected from above.

Out flow tract of the left ventricle was opened by an incision on the sternocostal surface of the heart extending from the apex, parallel and close to the interventricular septum upto the aortic orifice (Fig.14, a,b).

In each heart a detailed examination was made of the mitral valve annulus, commissures, valve leaflets, chordae tendineae and papillary muscles.

The collected specimens were immersed in the following specific preservative solution - 10 litres of normal saline, 1 litre of 10% formalin, 50 ml of glycerine, 5 gms of powdered thymol.

The following morphological features of mitral valve complex were studied namely

1.	Mitral valve annulus	-	(a)	Shape
			(b)	Circumference
			(c)	Age and sex differences
2.	Commissures	-	(a)	Number of Commissures
			(b)	Position of Commissures
3.	Mitral valve leaflets	-	(a)	Number of Leaflets and position of leaflets
	In posterior leaflet	-	(a)	Number of slits or clefts
			(b)	Number of scallops -
4.	Chordae tendineae	-	(a)	Types of chordae i) Rough Zone chordae ii) Strut chordae iii) Commissural chordae iv) Cleft Chordae v) Basal Zone Chordae
			(b)	Number of chordae at origin
			(c)	Number of chordae at insertion into leaflets
5.	Papillary muscles	-	(a)	Number of papillary muscles
			(b)	Spatial orientation
			(c)	Pattern (shape) of papillary muscles
			(d)	Site of origin
			(e)	Extent of protrusion of papillary muscles into the left ventricular cavity.

MORPHOMETRIC ANALYSIS OF MITRAL VALUE COMPLEX

Measurements were taken with the help of a divider, thread and a millimeter scale under the following parameters:

1. Circumference of Mitral Annulus was taken by keeping a thread in the sulcal margin and the point is marked where it meets the beginning of the thread and this distance in the thread is measured with millimeter scale (Fig.15).

2. Commissures

    (a) Length of anterior commissure

    (b) Length of posterior commissure

are measured from the annulus to the commissure with a divider and millimeter scale as shown in Fig. 16.

Using divider and millimeter scale

3. Mitral value leaflets :

    (a) The height of each single valve leaflet measured by perpendicular line from the annulus to the centre of the free edge of the leaflet.

    (b) The breadth of the single valve leaflet at the line of insertion at the valve ring (Fig.17).

    (c) Vertical height of Rough zone is measured which is the distal rough portion on the ventricular aspect of the anterior and posterior leaflets.

(d) Vertical height of clear zone is measured which is identified towards the annular side as a smooth and membranous area without any chordal attachment on the ventricular aspect of the anterior and posterior leaflets.

4. Length of chordae tendineae is measured from tip of papillary muscle to insertion in the leaflet using divider and millimeter scale (Fig.18).

II. CLINICAL STUDY

Clinical study was done on 5 patients having mitral valve disease. These patients were diagnosed and taking treatment at the cardiology department, Government General hospital, Chennai – 3. They included 4 male and 1 Female patient of age ranging from 45 to 60 years with the following diagnosis.

S. No.	Name	Age	Diagnosis
1.	Ramanathan	48 years	Mitral stenosis
2.	Govindan	55 years	Mitral regurgitation
3.	Parvathy	45 years	Mitral valve prolapse
4.	Ganeshan	58 years	Mitral stenosis
5.	Kumar	60 years	Mitral regurgitation

In all the above 5 cases, imaging (echocardiogram) of the mitral valve complex was studied.

DEVELOPMENTAL ANATOMY

MITRALVALVE COMPLEX

Mitral valve is formed by proliferation of connective tissue under the endocardium of the left atrioventricular canal.

The atrioventricular valve develops as shelf like projections from the margins of the atrioventricular orifice, directed as almost complete conical sheets towards the ventricles, their advancing edges continuing, initially as trabecular ridges, deep into the ventricular cavity. With continued differential growth and excavation on their ventricular aspects, each sheet develops two marginal indentations, defining the principal valve leaflets and minor marginal indentations (clefts) subidividing some leaflets into scallops. Each leaflet develops functionally significant regional variations in surface texture. Its core condenses as a collagenous lamina fibrosa. The latter blends at its atrioventricular base with the inappropriately named fibro areolar valve "annulus" - each a part of the complex, functionally crucial, fibrous skeleton of the heart. The papillary muscles are the ventricular ends of the original trabeculae and, whilst free throughout their length, their mural ends are confluent with mural ventricular musculature and receive a dense population of its nerves and specialized conducting tissues.

Degenerating ventricular muscle forms chordae tendineae, thick stringy attachments which connect the valve leaflets to the papillary muscles of the ventricular wall and blend with their connective tissue frame work.

OBSERVATION

The findings observed in 45 hearts (40 adult (25 male & 15 female) + 5 foetus) and clinical case study are analysed.

45 human hearts collected are arranged in four age groups 0-1, 1-20, 21-40, above 40 years and studied.

In each heart a detailed examination was made of the mitral annulus, commissures, valve leaflets, chordae tendineae and papillary muscles.

Measurements were taken with the help of a divider, thread and a millimeter scale for morphometric analysis of mitral valve complex and the following details were observed.

MITRAL ANNULUS

The peripheral margin of the mitral annulus is represented by a sulcal margin. The shape of the mitral annulus is D shaped in all 45 specimens (Fig.19a).

The superomedial part of the mitral annulus gave attachment to the anterior leaflet in 45 specimens (Fig.19b,c).

Rest of the mitral annulus provides attachment to the posterior leaflet in all the 45 hearts.

Circumference of the mitral annulus was studied with the help of a thread and millimeter scale. An increase in the mean value of the circumference with advancing age was observed. The circumference of the mitral annulus in the age group of 0-1 year ranged from 0.3-0.5cm with a mean value of 0.32 ± 0.07, in the age group of 1-20 years ranged from 6.5 - 9.6cm with a mean value of 8.11 ± 1.25, in 21-40 years ranged from 9.1-10.8cm with a man value of 9.79 ± 0.43, and above 40 years it ranged from 10.2 - 11.8 cm with a mean value of 10.76 ± 0.46.

Sex differences the circumference of the mitral annulus is consistently smaller in female than the male subjects. The circumference of annulus in the age group of 0-1 year in male is 0.4-0.5 cm and in female is 0.3-0.4 cm. Between the age group of 1-20 in male it is 7.1-9.4 cm and in female 6.5-9.3 cm, between 21-40 years of age in male it is 9.4-10.8 cm and in female is 9.1-10.1 cm. Above 40 years in male circumference is 10.4-11.8 cm and in female is 10.2-11.6 cm.

These measurements and statistical analysis are shown in Table-1(a,b).

COMMISSURES

Commissures are junctional areas between the leaflets. Two commissures were seen in all the specimens.

Position of commissures were observed as anterolateral commissure and posteromedial commissure in all age groups.

Commissures are identified by the fan shaped attachment of the chordae and these chordae are known as commissural chordae (Fig.20). Anterolateral and posteromedial commissures are clearly distinguishable in all the 45 specimens.

The length of the commissures are measured using divider and millimeter scale. The length of Anterolateral and posteromedial commissures in 0-1 year 0.2-0.3 cm and 0.2-0.4 cm, in 1-20 years 0.4-0.6 cm and 0.5-0.6 cm, in 21-40 years 0.5-0.7 cm and 0.6-0.8 cm and above 40 years it is 0.6-0.8 cm and 0.7-0.9 cm. The mean value of the commissural length increases with advancing age. Measurements are shown in Table-2(a).

MITRAL VALVE LEAFLETS

Number of leaflets in all 45 hearts is two i.e. Anterior and posterior leaflet.

Anterior Leaflet

It is triangular in shape in all the 45 specimens.

Anterior leaflet receive the chordae tendineae from both papillary muscles (Fig.21).

The edge of the anterior leaflet is smooth and there is no slit or cleft. The height and width of the anterior leaflet was measured. The height of the leaflet was measured as the perpendicular distance from the annulus to the free edge of the leaflet. The width of the anterior leaflet was measured along the annulus between the points of attachment of the leaflet.

The mean value of the width of anterior leaflet shows sharp increase with the advancement of age. The findings of the mean height of the anterior leaflet suggests a slow increase with the increment in age. The measurements and statistical analysis are shown in Table-3(a,b).

Each anterior leaflet presents a rough zone and clear zone

The clear zone of the leaflet is identified towards the annular side as a smooth and membranous area without any chordal attachment on the ventricular surface.

The rough zone is visualised towards the apex of the leaflet as a crescentic area, which is thicker on palpation and presents attachments of chordae tendineae on the ventricular surface.

Central height of the clear zone was measured. The central height of clear zone between the age group of 0-1 years is 0.5-0.9 cm, 1-20 years 1.2-2.0 cm, 21-40 years 1.4-2.1 cm and above 40 years 1.4-2.5 cm. It is shown in Table No.4.

The height of rough zone in anterior leaflet is in 0-1 year 0.2-0.5 cm, 1-20 years 0.3-0.6 cm, 21-40 years 0.5-0.8 cm and above 40 years 0.6-1.0 cm. Measurements are shown in Table No.4.

Central height of the rough zone was found to be smaller than the central height of clear zone in the anterior leaflet. Further the mean value of rough and clear zones of the anterior leaflet suggests gradual increase with the progress of age.

The ridge separating the rough zone and clear zone of anterior leaflet is distinct in the IIIrd (i.e. 21-40 yrs) age group and IVth (i.e. above 40 years) age groups (Fig.22).

In all age groups the basal measurements of the anterior leaflet are distinctly shorter. Atheromatic changes and nodular thickening at the free edge were observed above 50 years age group in anterior leaflets in 10 specimens (Fig.23).

POSTERIOR LEAFLET

Morphology of Posterior Leaflet

It is rectangular in shape in all the four age groups. Clefts or slits divide the posterior leaflet into scallops (Fig.24). Clefts or slits are identified by the fan shaped attachment of cleft chordae at the slits.

The free margin of the posterior leaflet showed two clefts and 3 scallops in 43 of 45 hearts (95%). The middle scallop is the largest in all specimens. The two lateral scallops (also called as anterolateral and posteromedial scallops) were present in all specimens but much smaller.

Two specimens in the age group of 1-20 years, showed 4 clefts and 5 scallops in the posterior leaflet (Fig.25). Even in these, the middle scallop was the largest.

Each scallop of the posterior leaflet presents rough zone, clear zone and basal zones in 43 hearts (95%). In 2 hearts the basal zone was absent since there was no basal chordae.

The rough zone is smaller in the posterior leaflet compared to anterior leaflet. The rough zone tapers off towards the clefts and is absent in the commissures.

In 10 out of 15 specimens in the age group of above 40 years, a ridge was clearly identified between the rough and clear zone of the posterior leaflet. In the younger age group, such a ridge was absent signifying its occurrence as age advances.

Below 40 years in all 35 hearts the demarcation between rough and clear zone is not well marked.

Morphometry of Posterior leaflet

The height and width of the posterior leaflet were measured. The mean value of the basal width of the posterior leaflets shows sharp increase with the advancement of age.

The findings of the mean height of the posterior leaflet suggest a slow increase with the increment in age. The measurement and statistical analysis are shown in Table No.3.

Central height of the clear zone in the middle scallop of the posterior leaflet is 0.2-0.5 cm between 0-1 year, 0.3-0.5 cm between 1-20 years, 0.3-0.5 cm in 21-40 years and above 40 years it was 0.4-0.6 cm.

Central height of the rough zone was found to be larger than the central height of clear zone. Central height of rough zone was measured in posterior leaflet and it was 0.3-0.6 cm in 0-1 year, 0.4-0.6 cm in 1-20 years, 0.5-0.8 cm in 21-40 years and 0.5-0.8 above 40 years.

In the middle scallop of the posterior leaflet the central height of the clear zone was found to be smaller compared to the rough zone.

The mean value of both rough and clear zones increase with age. It is shown in Table No.4(c).

Basal zones of each scallop of the posterior leaflet are identified by the attachment of basal chordae tendineae in 43 hearts. Whereas in 2 hearts the basal chordae was absent. Chordae arising from the ventricular wall and attached to posterior leaflet are known as basal chordae (fig.26).

Age related changes are noted in above 50 years age group in the posterior leaflet of 10 specimens which are mitral ring calcification and small puckered scars in posterior leaflet.

Comparison of anterior and posterior leaflets

The central height of clear zone was found to be larger in anterior leaflet than in the posterior leaflet.

The central height of rough zone is larger in anterior leaflet than the posterior leaflet.

In all age groups the basal measurement of the anterior leaflet are distinctly shorter than the basal measurement of posterior leaflets.

CHORDAE TENDINEAE

Ventricular aspect of the mitral leaflet was inspected to observe the patterns of insertion of the chordae tendineae into the leaflet in all age groups.

The valvular insertion of chordae fans out in several small chords.

Types

Rough zone chordae are attached to the free margin and the adjoining ventricular aspect of both leaflets of the mitral valve (Fig.27). Each rough zone chordae on approaching the leaflet splits into three strands. One is attached to the free margin. The other to the junction of rough and clear zones and the third to a point between the Ist and IInd attachment. This type of rough zone chordae are observed in all the 45 hearts studied. Amongst these rough zone chordae, two rough zone chordae known as strut chordae are thicker than the rest and are attached to the central part of the anterior leaflet. They (Strut chordae) are seen arising, one from the apex of anterior papillary muscle and the other from the apex of the posterior papillary muscle as observed in all the 45 specimens.

Commissural chordae are inserted into the free margin of the commissural area in a fan shaped manner in all 45 hearts(100%).

Commissural chordae arise as single strands from the apex of the anteromedial and posterolateral papillary muscles, but divide to form various branching patterns at insertion into the commissures.

Commissural chordae shows following varied configuration. Symmetric fan type commissural chordae was observed in 25 (56%) specimens. Asymmetric fan type chordae was seen in 5 (11%) specimens. Palmate type of commissural chordae was seen in 3 (7%) specimens. Cribriform type of commissural chordae was observed in 2 (4%) specimens. Mixed type of commissural chordae was seen in 10 (22%) specimens.

Similar to commissural chordae fan shaped chordae are observed to insert in the clefts between the scallops of the posterior leaflet. These are called as cleft chordae and are seen in all the 45 hearts.

Basal chordae are chordae tendineae which arise directly from the ventricular wall (and not from the papillary muscle), to get inserted in the posterior leaflet. Such basal chordae were seen in all age groups of 43 hearts, except in 2 specimens where basal chordae are absent.

Average length of the chordae tendineae of all 5 subtypes are measured. It is shown in Table No.5.

Number of chordae at origin (Fig.28, Table No.6)

1-3 chordae originate from anterolateral group of papillary muscle in two (4%) specimens and this is not observed in posteromedial group.

4 to 6 chordae originate from anterolateral group of papillary muscle in 11 (24%) specimens and posteromedial group of papillary muscle in 10 (22%) specimens. 7 to 9 chordae arose from anterolateral group of papillary muscle in 13 (29%) specimens and from posteromedial group of papillary muscle in 13

(29%) specimens. 10 to 12 chordae took their origin from anterolateral group of papillary muscle in 10 (22%) specimens and posteromedial group of papillary muscle in 13 (29%) specimens.

13 to 16 chordae arose from anterolateral group of papillary muscle in 5 (11%) specimen and posteromedial group of papillary muscle in 7 (16%) specimens. 17 to 20 chordae originate from anterolateral group of papillary muscle in 2 (4%) specimen and posteromedial group of papillary muscle in 2 (4%) specimen. 21 to 23 chordae originate from anterolateral group of papillary muscle in 2 (4%) specimen.

Number of chordae at insertion (Fig.29, Table No.6(a))

10 to 20 chordae are inserted into the anterior and posterior leaflets from anterolateral papillary muscle in 3 (7%) specimens.

21 to 30 chordae are inserted into both the leaflets from anterolateral papillary muscle in 13 (29%) specimens.

31 to 40 chordae are found to be inserted into both leaflets from antero lateral papillary muscle in 10 (22%) specimens.

41 to 50 chordae are attached to both the leaflets from anterolateral papillary muscle in 12 (27%) specimens. 51 - 60 chordae are attached to both leaflets from antero lateral papillary muscle in 3 (7%) specimens. 61 to 70 chordae are inserted into both the leaflets from anterolateral papillary muscle in 2 (4%) specimens. 71 to 80 chordae are inserted into both the leaflets from anterolateral papillary muscle in 2 (4%) specimens.

10 to 20 chordae are inserted into the anterior and posterior leaflets from posteromedial papillary muscle in 5 (11%) specimens.

21 to 30 chordae are observed to get inserted into both leaflets from posteromedial papillary muscle in 11 (24%) specimens.

31 to 40 chordae are attached into both leaflets from posteromedial papillary muscle in 12 (27%) specimens.

41 to 50 chordae are inserted into both leaflets from posteromedial papillary muscle in 10 (22%) specimens.

51 to 60 chordae are inserted into both leaflets from posteromedial papilary muscle in 3 (7%) specimens.

61 to 70 chordae are found to be attached to both the leaflets from posteromedial papillary muscle in 2 (4%) specimens.

71 to 80 chordae inserted into both leaflets from posteromedial papillary muscle in 2 (4%) specimens.

PAPILLARY MUSCLES

Number and spatial orientation

2 papillary muscles were seen in the ventricular chambers of all 45 hearts. According to spatial orientation, the 2 papillary muscles observed are classified as anterolateral and posteromedial in all age groups.

Pattern of papillary muscles (Fig.30 (a,b,c,d,e))

Number of papillary muscles bellies in each group of papillary muscle namely anterolateral and posteromedial were found to vary from 1 to 6.

When single belly is present, the shape of the muscle belly varied and they are classified into conical, mamillated, flat topped, grooved, step, wavy arched, sloped, saucerized patterns. Single belly of anterolateral papillary muscle was observed in 28 (68%) hearts. Single belly of posteromedial papillary muscle was observed in 22 (49%) specimens.

In this single belly type, conical pattern is seen in the anterolateral group of papillary muscle in 14 (31%) specimens and in posteromedial group of papillary muscle in 9 (20%) specimens.

Mamillated pattern is seen in anterolateral group of papillary muscle in 5 (11%) specimens and in 8 (18%) specimens mamillated papillary muscle is observed in posteromedial group.

In anterolateral group of papillary muscle flat topped pattern is seen in 5 (11%) specimens and in 3 (7%) specimens this type was found in posteromedial group.

Grooved pattern is seen in anterolateral group in 4 (9%) specimens and in 2 (4%) specimens this pattern is observed in the posteromedial group.

Stepped pattern, wavy pattern, arched pattern, sloped pattern, saucerized patterns are not seen in either anterolateral group or posteromedial group of papillary muscle in the present study.

Two bellied papillary muscle was observed in anterolateral group in (29%) 13 hearts and in posteromedial group in 19 (42%) hearts.

When two bellys are found in the papillary muscle, they are classified into two tired, interlinked, parallel, arched, V, H, Y shape patterns. Two tired pattern is seen in the anterolateral group of papillary muscle in 6 (13%) specimens and in 7 (16%) specimens the same pattern is observed in posteromedial group. Interlinked pattern is seen in 2 (4%) specimens in the anterolateral group and in 4 (9%) specimens in the posteromedial group of papillary muscle. Parallel pattern is seen in the anterolateral group in 2 (4%) specimens and in 2 (4%) specimens it is found in posteromedial group. In posteromedial group of papillary muscle the arched pattern is seen in 2(4%) specimen.

V shaped pattern is seen in anterolateral group in 1 (2%) specimen and in 2 (4%) specimen the V pattern is observed in posteromedial group. Y shaped pattern of papillary muscle of anterolateral group is seen in 1(2%) specimen and in 1(2%) specimen Y pattern of posteromedial group of papillary muscle was seen.

H shaped pattern of anterolateral group of papillary muscle is seen in 1(2%) specimen and in 1(2%) specimen this type is seen in posteromedial group.

Three bellied papillary muscle was observed in 2 (4%) specimens. In this three papillary muscle group, parallel pattern is seen in 1(2%) specimen in the anterolateral group and in 1(2%) specimen in posteromedial group.

Interlinked or two interlinked patterns are not seen in anterolateral or posteromedial group in the present study.

Arched pattern and two tired pattern are also not seen in any of the 45 hearts.

Four bellied papillary muscle was observed in 3 (7%) specimens and in this the parallel pattern is seen in 1 (2%) specimen in anterolateral group and in 1(2%) specimen in posteromedial group. Interlinked pattern is seen in 1(2%) specimen in anterolateral group.

Five bellied papillary muscle was observed in 2 (4%) specimens. In this five papillary muscle group the scattered pattern is seen in 1 (2%) specimen of anterolateral group and it is found in 1(2%) specimen of posteromedial group.

Six bellied papillary muscle was observed in only 1 (2%) specimen in posteromedial group Table No.7.

Site of origin of papillary muscle (Fig.31)

Papillary muscle arising from middle third of the left ventricle was seen in 24 (53%) specimens in the anterolateral group and in 30 (67%) specimens in the posteromedial group.

Papillary muscle originating from upper third of left ventricle was seen in 18 (40%) specimens in the anterolateral group and in 12 (27%) specimens in posteromedial group.

Papillary muscle arising from lower third of left ventricle was seen in 3 (7%) specimens in the anterolateral group and in 3 (7%) specimen in posteromedial group Table No.8.

Extent of protrusion of papillary muscle (Fig.32(a,b))

The papillary muscles varied in the extent of protrusion into the ventricular cavity and adherence to the ventricular wall. The observed types were intraluminal, intraluminal with tip anchored and sessile types. This is shown in Table No.9

Mostly intraluminal in 11 (24%) specimens of anterolateral group and in 9(20%) specimens of posteromedial group.

Mostly intraluminal with tip anchored was observed in 10 (22%) specimens in anterolateral group and in 13 (29%) specimens in posteromedial group.

Equally sessile and intraluminal was observed in 22 (49%) specimens in the anterolateral group of papillary muscle and in 20 (44%) specimens in the posteromedial group of papillary muscle.

Mostly sessile papillary muscle was found in 2 (4%) specimen in anterolateral group and in 3 (7%) specimens in posteromedial group.

I(a) Foetal study

Full term five foetal specimens were collected from the institute of Obstetrics and Gynaecology, Egmore, Chennai.

In each heart a detailed examination was made of the mitral annulus, commissures, valve leaflets, chordae tendineae and papillary muscles.

Measurements were taken with the help of a divider, thread and a millimeter scale for morphometric analysis of foetal mitral value complex.

Circumference of the mitral annulus in foetal heart is smaller than the adult.

Two commissures, two leaflets and five types of chordae tendineae were seen. 6 papillary muscles observed (Fig.33-39).

II CLINICAL STUDY

For clinical study, five clinical cases (4 male + 1 Female) were selected from cardiology department, Government General hospital, Chennai -3 between the age group of 45 to 60 years with the history of chest pain, dyspnoea, orthopnoea for the past 1 year. They were diagnosed as mitral stenosis, mitral regurgitation and mitral value prolapse.

S.No.	Name	Age	Diagnosis
1.	Ramanathan	48 years	Mitral stenosis (Fig.40)
2.	Govindan	55 years	Mitral regurgitation (Fig.41)
3.	Parvathy	45 years	Mitral valve prolapse (Fig.42)
4.	Ganeshan	58 years	Mitral regurgitation (Fig.43)
5.	Kumar	60 years	Mitral valve prolapse (Fig.44)

For the above cases as an investigative procedure Echocardiography is taken.

Imaging of the mitral valve complex are studied and showed in the figures.

Medical Management- for the 5 Clinical cases

1. T. Isordil 10 mg IBD
2. T. Lasix 40 mg OD
3. T. Cifran 500 mg IBD
4. T. Ranitidine 150 mg IBD
5. Multivitamin IBD
6. T. Deriphylline retard 150 IBD

Specific Surgical Management

1. Mitral stenosis - Open mitral valve commissurotomy is done
2. Mitral stenosis - Percutaneous balloon valvuloplasty is done
3. Mitral regurgitation - Valve repair were done
4. Mitral regurgitation - Valve replacement were done
5. Mitral Valve Prolapse - Valvuloplasty were done

DISCUSSION

MITRAL ANNULUS

Silverman, Hurst, Robert W.C., Perloff, T.Sakiris A.G., Strum RE, Wood EH, Ormiston JA, Shah P.M., Tei C., Police C.Piton M, Filly K, Van Rij K, Zwikker GL, SY H.O. (2002) stated that the annulus marking the hinge line of the valvar leaflets is more D shaped than circular shape.

In the present study (2006) in all the 45 hearts the mitral annulus is represented by the sulcal margin and the shape of mitral annulus is D shaped which coincides with the study of the above scientists.

A.K. Datta (1984) measured the circumference of mitral annulus in various age groups and found the circumference of mitral annulus between 1-20 years of age is 6.9 - 9.6 cm, 20 - 40 years it is 9.9 - 10.9 cm and above 40 years 11.3 - 12.1 cm. And he came to a conclusion that the mitral circumference increases in advancing age.

Kitzman DW, Edwards WD (1990) found that with advancing age there are significant increases in heart weight, ventricular septal and probably left ventricular free wall thickness and valve circumferences.

In the present study (2006) the mitral annulus circumference in various age groups is measured and this shows that there is increase in the circumference with the advancing age and this present study (2006) coincides with A.K. Datta and Kitzman DW, Edwards W.D. as shown in Table No.1

N. Ranganathan et al. (1970) studied 50 hearts from 15-85 years and found that the mean circumference of mitral annulus in males - 9.0 cm, Females 7.2 cm

A.K. Datta (1984) observed sex difference in circumference of mitral annulus and he found that the circumference of mitral annulus in females (9.7 cm) is lesser than in males (10.3 cm).

Gerda L. Van Rijk - Z Wikker M.D. (1994) reported that the mitral annulus mean circumference in Males - 10 cm, Females - 9 cm.

In the present study (2006) (2006) the mitral annulus circumference in male and female is measured in both sexes. Sex difference shows that circumference of the mitral annulus in female (0.3 cm - 11.6 cm) is smaller than the male (0.4 cm - 11.8 cm) in all age groups which is similar to the findings of N. Ranganathan, A.K. Datta and Gerda L. Van Rijk - Z. Wikker M.D Table No.2.

COMMISSURES

Henry Gray (1858) stated that there are 2 commissures in mitral valve namely Antero lateral and Posteromedial commissures.

Harken (1948) reported two commissures namely anterolateral and posteromedial commissures.

Rusted I.E. et al (1952), Hollinshed (1957), N.Ranganathan et al. (1970), A.K. Datta (1986), Solomn Victor, Vijaya Nayak (1994), Sy H.O. (2002), Skandlaki (2004) all reported of 2 commissures in mitial valve namely Anterolateral and Posteromedial commissures.

In present study (2006) all the 45 hearts show two commissures namely Anterolateral and posteromedial commissures and this study coincides with the study of Henry Gray, Harken, Rusted I.E., Hollinshed, N. Ranganathan, A.K. Datta, Solomon Victor, Sy H.O. and Skandalaki.

Rusted I.E. et al. (1952) emphasized the difference between the normal commissures, or areas of fusion at the bases of valves and the pathological commissure produced by further fusion of the edges of the valves. In their material the normal commissures averaged about 0.7 to 0.8 cm in length.

In present study (2006) the length of commissures are measured and it was 0.2 to 0.9 cm. Length of commissures increases in advancing age, which was not referred by any of the scientists.

MITRAL VALVE LEAFLETS

Anterior leaflet

Henry Gray (1858) stated that there are two leaflets in mitral valve namely anterior and posterior.

Quain's elements of anatomy (1929) reported that there are two mitral valve leaflet namely anterior and posterior.

Harken (1948) reported that 26 of 35 hearts had two additional or commissural leaflets. The same was reported by Rusted I.E. et al. (1952), Hollinshed (1957), N. Ranganathan et al. (1970), A.K. Datta (1986), Solomon Victor, Vijaya Nayak (1994), Sy H.O. (2002) and they all said that they are not actually commissural leaflets but they are scallops just behind the commissural line. Skandalaki (2004) also reported that there are two mitral valve leaflets namely anterior and posterior.

Yacoub M. (1976) considered the commissural scallops and separate leaflets and states that mitral valve has four leaflets and is a quadricuspid valve.

In present study (2006) all the 45 hearts show two mitral valve leaflets namely anterior and posterior. which coincides with the study of Henry Gray, Quain, Rusted I.E., Hollinshed, N. Ranganathan, A.K. Datta, Solomon Victor, Sy H.O., Skandalaki and disagree from Harken and Yocoub M.

Henry Gray (1858) reported that the anterior leaflet is triangular.

Quain's elements of anatomy (1929) stated that the anterior leaflet is triangular.

Rusted I.E. et al (1952), Hollinshed (1957), N. Ranganathan et al. (1970), A.K. Datta et al. (1984), Solomon Victor, Vijaya Nayak (1994), Gerda L. Van Rijik - Zwikker MD et al., (1994), Sy HO (2002), Skandalaki (2004) reported that the anterior leaflet is triangular.

In present study (2006) the shape of the anterior leaflet is triangular in all the 45 hearts and so my study coincides with the study of Henry Grey, Quain's elements of anatomy, Rusted J.E., Hollinshed, N. Ranganathan, A.K. Datta, Solomon Victor, Gerda-L, Van Rijik-Zwikker MD, Sy H.O, Skandalaki.

Ariela Pomerance (1967) studied ageing in 805 human hearts and observed the following changes in the mitral valve:

In anterior leaflet - Nodular thickening at the free edge, which when marked is generally referred to as senile sclerosis and lipoid deposition nearer the attached part. Atheromatosis of the anterior cusp of the mitral valve is also considered to be related to age and results in this study confirm this view.

In my present study (2006) same age related changes observed above 50 years age group in anterior leaflet in 10 specimens in the form of nodular thickening and lipoid deposition of anterior leaflet near the attached part.

Henry Gray (1858) reported that the anterior leaflet has no marginal indentations. N. Ranganathan et al. (1970) said that anterior leaflet does not have slit. A.K. Datta (1986) stated that the free margin of the anterior leaflet presents no significant notches.

Gerdal L. Van Rijizwikker M.D. et al. (1994) said that the edge of the anterior leaflet is smooth and there is no slit or cleft seen.

Solomon Victor, Vijaya M. Nayak (1994) said that the anterior or aortic leaflet does not have slits or clefts.

In the present study (2006) the edge of the anterior leaflet is smooth and there is no slit or cleft seen in anterior leaflet in all the 45 specimens, which coincides with the work of the above scientists.

Henry Gray (1858) said that the anterior leaflet has a deep crescentic rough zone receiving various types of chordae tendineae and N. Ranganathan et al. (1970) states that there are rough zone and clear zone present in both anterior and posterior leaflets.

A.K. Datta et al. (1984) said that the rough zone is visualised towards the apex of the leaflet as a crescentic area, which is thicker on palpation and presents attachments of chordae tendineae on the ventricular surface.

Gerda L Van Rijk-Z-wikker M.D. et al. (1994) said that the site of insertion of chords on the ventricular surface of anterior leaflet is called rough zone.

Sy H.O. (2002) said that near the free edge of the anterior leaflet, the atrial surface is irregular with nodular thickenings. This is also the thickest part, corresponding with the line of closure and the free margin. Tendinous cords attach to the underside of this area described as the leaflets rough zone.

In present study (2006) the rough zone was observed towards the apex of the leaflet as a crescentic area where the chordae tendineae are attached on its ventricular surface and is similar to the work of Henry Gray, N. Ranganathan et al., A.K. Datta, Gerdal Van Rijk-Z-Wikker MD, and Sy H.O.

Henry Gray (1858) stated that from the rough zone to the valvar annulus is a clear zone, devoid of chordal attachments.

N. Ranganathan et al. (1970) state that clear zone is present in both anterior and posterior leaflets.

A.K. Datta et al. (1984) identified the clear zone of the anterior leaflet towards the mitral annular side as a smooth and membranous area without any chordal attachment.

Sy H.O. (2002) said that there is a clear zone which is devoid of chordal attachments in anterior leaflet.

In the present study (2006), clear zone which is devoid of chordal attachments was observed in all the 45 specimens in the anterior leaflet which is coinciding with Henry Gray, N. Ranganathan, A.K. Datta, and Sy H.O.

A.K. Datta et al. (1984) measured the central height of the clear zone and found it to be larger than rough zone in the anterior leaflet. They also said that the Central height of the clear zone in anterior leaflet was larger than in the posterior leaflet.

In the present study (2006) central height of the clear zone in anterior leaflet is larger than the rough zone which is similar to the findings of A.K.Datta et al. Further the mean value of rough zone and clear zone of the anterior leaflet suggests gradual increase with the progress of age which was noted by AK Datta et al also Table No.3.

A.K. Datta et al. (1984) studied and measured the height and width of the anterior leaflet. They say that mean value of the width of anterior leaflet shows a sharp increase with the advancement of age and mean height of the anterior leaflet suggest a slow increase with the increment in age.

In my present study (2006) the measurements are taken which coincides with the above author. The width of anteior leaflet in the present study (2006) in the age group of 0-1 year is 0.3-0.8 cm, 1-20 years is 1.7-3.2 cm, 20-40 years is 2.5-3.6 cm above 40 years 2.9-3.8 cm and there is a slow increase of the width of anterior leaflet with advancing age.

The height of anterior leaflet in the present study (2006) in the age group of 0-1 years is 0.5-0.9 cm, 1-20 years is 1.8-2.3 cm, 20-40 years is 1.9-2.6 cm and above 40 years 2.3-3.4 cm which shows a sharp increase as age advances Table No.4,5.

As per A.K. Datta et al. (1984) in all age groups basal measurements of the anterior leaflet are distinctly shorter than the posterior leaflet.

In present study (2006) in all the age groups the basal measurements of the anterior leaflet are shorter than the posterior leaflet which is coinciding with the study of the above author.

Posterior leaflet

Gerd L. Van Rijk-Z-Wikker MD et al. (1994) and A.K. Datta et al. (1984) said that the posterior leaflet is rectangular in shape.

In present study (2006) the shape of posterior leaflet is observed to be rectangular in all the 45 specimens.

Ariela Pemerance (1967) observed in posterior leaflet the following changes in all 805 human hearts.

(i) The mitral ring calcification, (ii) Small puckered scars were seen (iii) Particularly in the female diffuse opacity of the cusp, (iv) The cusp became thickened, opaque and volumious resembling a parachute.

In my present study (2006) in posterior leaflet the cusps are thickened and opaque and there was calcification of mitral annulus observed above 50 years age group.

N. Ranganathan et al. (1970) states that posterior leaflet divided into 3 scallops by two clefts. He found the triscalloped leaflet in 46 hearts among the 50 hearts he studied. In 42 hearts a large middle scallop was present.

A.K. Datta et al. (1984) said that the free margin of the posterior leaflet of mitral valve exhibits in all age groups, two clefts which are identified by the fan shaped attachment of the chordae tendineae and these clefts divide the posterior leaflet into 3 scallops, the middle scallop being the largest. He also said that the rough and clear zones of the posterior leaflet are identified by a ridge in the 3 scallops.

Solomon Victor (1994) studied 100 hearts and found 98 hearts had slits in posterior leaflet and stated that the number of slits in the posterior leaflet varied from one to five but was commonly two.

Carpential A. et al. (1971) state that the free edge of the posterior leaflet is often divided into 3 or more scallops.

Gerda L. Van Rijik MD et al. (1994) said that the posterior leaflet often has multiple indentation or clefts bridged by fan like chords. In the present study (2006) all the specimens showed slits in the posterior leaflet. In 43 specimens - 2 slits and 3 scallops are seen. In 2 specimens - 5 scallops and 4 slits are seen. So the present study (2006) coincides with Soloman Victor, N.Ranganathan, A.Carpentier A, et al., and A.K. Datta's findings.

A.K. Datta et al. (1984) said that each scallop of the posterior leaflet presents the rough, clear and basal zones and the rough and clear zones identified by a ridge in the 3 scallops.

Sy H.O. (2002) said that posterior leaflet had rough zone, clear zone and basal zone and the basal zone was found only in the posterior leaflet which is the proximal area that has insertions of basal cords to its ventricular surface.

In present study (2006) I observed all 3 zones namely rough, clear and basal zones in posterior leaflet in 43 hearts. In 2 hearts in the age group of 1-20 the basal chordae was absent and so there was no basal zone which was not observed by any of the above authors.

Similar to the study of A.K. Datta et al., the rough and clear zone of the posterior leaflet are identified clearly by a ridge in the 3 scallops in 10 specimens in the present study (2006) which was noted only in the specimens of the age group above 40 years.

According to AK Datta et al (1984) in the middle scallop of the posterior leaflets the height of the rough zone is slightly longer than the clear zone and the mean value of both zones increase with age.

In the present study (2006) the central height of clear zone is smaller compared to rough zone and the mean value of both rough and clear zones show an increase with increase of age which coincides with the study of A.K. Datta et al as shown in Table No.6.

A.K. Datta et al. (1984) studied and measured height and width of the posterior leaflet and conclude that the mean value of the basal width of posterior leaflet shows sharp increase as age advances and the mean height of the posterior leaflet suggests a slow increase with the increment in age.

The present study (2006) also confirms that the mean value of the basal width of the posterior leaflet shows a sharp increase with increasing age and as age advances there is slow increase of the mean height of the posterior leaflet. This is shown in Table No.7,8.

CHORDAE TENDINEAE

Tandler J. (1913) classified chordae tendineae into 3 orders.

Ist order - chordae tendineae inserted into the leaflet's edge.

IInd order - chordae tendineae inserted 6 to 8 mm beyond the free margin.

IIIrd order - chordae tendineae inserted into the basal portion of the ventricular aspect of the posterior leaflet.

Quain's elements of Anatomy (1929) distinguishes three orders of chordae tendineae according to the site of attachment to the leaflets.

Ist order chordae are those inserted on the free edge. They are numerous, delicate and often form network near the edge.

The IInd order chordae are inserted on the ventricular surface of the leaflets beyond the free edge, forming the rough zone. These are thicker than the first order chordae.

IIIrd order chordae are attached only to the mural leaflet and they arise directly from the ventricular wall or from small trabeculations. They insert to the basal portion of the leaflet and run only a short distance towards the free margin.

Lam JHC et al. (1970) did a study on chordae tendineae from 50 normal mitral valves and distinguished four main types by their mode of insertion as follows :

1. Commissural chordae which are inserted into the commissures between anterior and posterior leaflets.

2. Rough zone chordae are inserted into the ventricular aspect of the distal rough portion of the anterior and posterior leaflets. In this rough zone chordae two of the anterior leaflets rough zone chordae are thicker than the others and are called strut chordae.

3. Cleft chordae are inserted into the clefts between the scallops of the posterior leaflet.

4. Basal chordae are single strands that arise from the posterior ventricular wall and inserted into the basal zone of the posterior leaflet.

In my present study (2006) based on 45 specimens, this four main types are observed in 43 specimens. In 2 specimens basal chordae are absent. The commissural chordae, rough zone chordae and cleft chordae are observed in all the 45 hearts studied.

So my present study (2006) coincides with the study of Lam J.H.C. et al. whereas Tandler J. (1913) and Quains identified rough zone chordae and basal chordae only.

Solomn Victor, Vijaya M. Nayak (1995) studied the number of chordae at origin in 100 hearts. 1 to 3 chordae originate from anterolateral group of papillary muscle is not observed and it is observed in 1% in posteromedial group 4 to 6 chordae originate from anterolateral group of papillary muscle in 21% and posteromedial group of papillary muscle in 31%.

7 to 9 chordae arose from anterolateral group of papillary muscle in 59% and from posteromedial group of papillary muscle in 34%.

10 to 12 chordae took their origin from anterolateral group of papillary muscle in 20% and from posteromedial group of papillary muscle in 22%.

13 to 16 chordae arose from anterolateral group of papillary muscle in 6% and posteromedial group of papillary muscle in 10%

17 to 20 chordae arose from anterolateral group of papillary muscle in 1% and posteromedial group of papillary muscle in 2%. 21 to 23 chordae originate from anterolateral group of papillary muscle in 1%.

In the present study (2006) the number of chordae at origin is observed. 1 to 3 chordae originate from anterolateral group of papillary muscle in 4% and this is not observed in posteromedial group. 4 to 6 chordae originate from anterolateral group of papillary muscle in 24% and posteromedial group of papillary muscle in 22%. 7 to 9 chordae arose from anterolateral group of papillary muscle in 29% and from posteromedial group of papillary muscle in 29%.

10 to 12 chordae took their origin from anterolateral group of papillary muscle in 22% and posteromedial group of papillary muscle in 29%. 13 to 16 chordae arose from anterolateral group of papillary muscle in 11% and posteriomedial group of papillary muscle in 16%. 17 to 20 chordae originate from anterolateral group of papillary muscle in 4% and posteromedial group of papillary muscle in 4%. 21 to 23 chordae originate from anterolateral group of papillary muscle in 4% shown in Table No.9.

Solomon Victor, Vijay M.Nayak (1995) studied the number of chordae at insertion. His results compared with present study (2006) is shown in Table No.10.

PAPILLARY MUSCLES

Patterns of Papillary Muscles

Rusted I.E. (1951) did an elaborate study of papillary muscles in 200 hearts found that the antero lateral muscle was single, though most frequently grooved lengthwise, in 76.5%, double in 12 percent, triple in 9.5 percent and more than triple in 4 percent. The posterior (posteromedial) papillary muscle was found to be single in 30%, double in 26.5%, triple in 37% and there were more than 3 in 6%.

Solomon Victor, M. Vijaya Nayak (1995) studied and found that antero lateral papillary muscle had 1 belly in 67 hearts, 2 in 27, 3 in 4, 4 in 1 and 5 in 1 heart.

In posteromedial papillary muscle they observed single belly in 50 hearts, 2 in 36, 3 in 11 and 4 in 3 hearts.

In my present study (2006) in 45 hearts it was found that the antero lateral paillary muscle was single in 62.2%, double in 31%, triple in 2.2% more than triple in 4% Table No.11.

The postero medial papillary muscle was found to be single in 48.8%, double in 42.2%, triple in 2.2% and more than three in 2.2%. My study is similar to the study of S.Victor, where (single and double) bellies are common whereas single and triple belly is most common in the study of Rusted I.E.

Site of origin of papillary muscle

Brock R.C. (1952) says that the papillary muscles normally arise from the apical and middle thirds of the left ventricular wall.

Solomon Victor, Vijaya M. Nayak (1995) studied the site of origin of papillary muscle and states that the antero lateral group of 19% of papillary muscle bellies arise from the upper third of the ventricle, 79.5% from middle third and 1.5% from lower third. The Posteromedial group of 6% of papillary muscle bellies arise from the upper third of the ventricle, 92.5% from middle third and 1.5% from lower third Table No.12.

In present study (2006) the antero lateral group of 40.0% of papillary muscle bellies arose from the upper third of the ventricle, 53.3% from middle third and 6.6% from lower third. In the postero medial group of 26.6% of papillary muscle bellies arose from the upper third of the ventricle, 66.6% from middle third and 6.6% from lower third.

So in accordance to the study of Solomon Victor papillary muscles arose from the middle third of the left ventricular wall frequently.

Extent of protrusion of papillary muscle

Ranganathan M.D. and G.E. Burch MD (1969) studied the gross morphological characteristics of the antero lateral and posteromedial papillary muscles of the left ventricles in the ten hearts and classified the papillary muscles into 3 broad categories.

1. Completely tethered papillary muscle ie. papillary muscle fully adherent to the subjacent ventricular myocardium and protruding very little into the ventricular cavity with a few trabecular attachments (Intra luminal).

2. Finger like papillary muscle (equally sessile and intraluminal) (ie) papillary muscle with one third or more of the body protruding freely into the ventricular cavity with a very few or no trabecular attachments.

3. Mixed type papillary muscle (Intra luminal and tip anchored sessile) (ie) a papillary muscle with part of the body protruding freely into the ventricular cavity, but also with considerable trabecular attachments and tethering.

Solomon Victor, M. Vijaya Nayak (1995) studied and found that in the Anterolateral & Posteromedial group, the papillary muscle bellies were mostly intraluminal in 14% and 11%, mostly intraluminal with the tip anchored in 19% and 28%, equally sessile and intraluminal in 54.5% and 41.5%, mostly sessile in 12.5% and 19.5% respectively.

In present study (2006) the antero lateral and postero medial group of papillary muscle bellies were mostly intraluminal in 22.2% and 20.0%, mostly intraluminal with the tip anchored in 22.2% and 28.8%, equally sessile and intraluminal in 48.8% and 44.4%, mostly sessile in 4.4% and 6.6% respectively.

So in Anterolateral and Posteromedial papillary muscle mostly intraluminal with tip anchored and equally sessile and interluminal types the occurrence percentage is similar to the study of Solomon Victor, M.Vijaya Nayak Table No.13.

II. CLINICAL STUDY

For clinical study, five clinical cases (4 male + 1 female) were selected from cardiology department, Government General Hospital, Chennai - 3 between the group of 45 to 60 years with the history of chest pain, dyspnoea, orthopnoea for the past 1 year. They were diagnosed as mitral stenosis, mitral regurgitation and mitral value prolapse.

1.	Ramanathan	48 years	Mitral stenosis
2.	Govindan	55 years	Mitral regurgitation
3.	Parvathy	45 years	Mitral Valve prolapse
4.	Ganeshan	58 years	Mitral regurgitation
5.	Kumar	60 years	Mitral valve prolapse

For the above cases as an investigative procedure Echocardiography is taken.

Imaging of the mitral valve complex are studied. In the above 5 cases Medical Management was followed by Surgical Management

CONCLUSION

In my present study (which included adult and foetal cadaveric study and clinical study) the morphology and morphometric analysis of mitral valve complex were studied and then compared and analysed with the works of many eminent scientists in this field.

The present study to understand the anatomy of the constituent parts of the mitral valve complex not only helps examination of these parts in cross sectional interrogation but also enhances appreciation of valvar anomalies.

The present study to analyse the detailed knowledge of the anatomy of slits and scallops of the mitral valve provides improved understanding of mitral valve function, which aids the surgeon in understanding valve pathophysiology and in designing reconstructive procedures.

Detailed knowledge of normal papillary muscle formation is important to understand when and how various papillary muscle malformations develop and it is also of relevance in the early detection of these anomalies.

In essence, the reparative procedure adopted for mitral incompetence should restore the chordal fan on either side. With this aim it is necessary to judge the type of repair required and to assess the length and number of chordal substitutes and location of site for reimplantation of ruptured chordae and papillary muscles.

In mitral valve prolapse syndrome the left ventricle assumes various configurations which is possibly dependent on the architecture and location of papillary muscles, subject to pull by the prolapsing leaflet.

In mitral valve replacement, retention of chordo papillary support is being favoured to preserve optimum function of left ventricle. However, if the native valve has too many chordae and papillary muscle bellies, these may interfere with the function of the disc or ball, especially if they were mostly intraluminal.

Replacement of mitral valve with mitral homograft has been tried and is reemerging as a surgical alternative. Obviously, it is preferable to use homograft mitral valves with single anterolateral and posteromedial papillary muscle rather than multiple papillary muscles, which will be cumbersome to fix.

The present study will be useful for cardiologists and cardiac surgeons in echocardiography, invasive cardiology and surgical reconstructive of mitral valves.

The morphometric analysis is useful for cardiacsurgeons for determining the size of the prosthetic valve replacement, commissurotomy, commissuroplasty, valvuloplasty and artificial chordae tendineae replacement.

BIBLIOGRAPHY

1. Akitzman D.W. Edwards M.D. Age related changes in the anatomy of the normal human heart. J. Gerontol 1990 Mar; 45(2): M 33-9.

2. Anderson R.H. Becker A.E. The morphologically left ventricle. In: Cardiac anatomy. An integrated text and colour atlas. London : Gower Medical Publishers, 1980; 4.2 - 4.19.

3. Angelini A, Hosy, Anderson R.H. A histological study of the atrioventricular fraction in hearts with normal and prolapsed leaflets of the mitral valve. Br Heart J 1988; 59: 712-6.

4. Ariela Pomeraance. Ageing changes in human heart valves. Brit. Heart J. 1967; 29.

5. Becker A.E. Dewit A.P.M. The mitral valve apparatus: a spectrum of normality relevant to mitral valve prolapse. Br Heart J 1980; 42: 680-9.

6. Berdaj's D, Lajos P, Turin-Ml. A new classification of the mitral papillary muscle. Med Sci Monit. 2005. Jan; 11(1): BR 18-21.

7. Breadley M. Patten. Human Embryology, Second edition.

8. Brock R.C. The surgical and pathological anatomy of the mitral valve. Br Heart J 1952; 14: 489-513.

9. Bulkley B.H. Roberts W.C. Dilatation of the mitral annulus: a rare cause of mitral regurgitation. Am J Med 1975; 59: 457-63.

10. Carpentier A, Deloch A, Davptain J. A new reconstructive operation for correction of mitral and tricuspid insufficiency. J Thorac cardiovasc surg 1971; 61: 1-13.

11. Cheng TO, Xie M-X, Wang X-F, Evaluation of mitral valve prolapse by

four dimensional echocardiography. Am Heart J 1997; 133: 120-9.

12. Datta A.K. (5th edition). Essentials of Human anatomy 1986.

13. Datta A.K. M.M. Mukherjee and S. Ghosh. Morphology and Morphometry of the mitral valve in normal human heart. Indian Heart Journal. Vol. 36, No.6, 1984.

14. Davila J.C. Palmer T.E. The mitral valve: anatomy and pathology for the surgeon. Arch Surg 1962; 84: 174-98.

15. Duplessis L.A. Merchand P. The anatomy of the mitral valve and its associated structures. Thorax 1964. 19: 221-7.

16. Gerda L. Van Rijk - Zwikker MD, Ben J. Delemarre, M.D., and Hars A. Huysmans M.D. J Card Surg 1994; 9: 255-261.

17. Harken D.E., Ellis, L.B. Ware, P.F. and Norman, L.R. The surgical treatment of mitrla stenosis, valvuloplasty, New England J Med 238: 801, 1948.

18. Henry Gray (38th edition) Gray's Anatomy (1858).

19. Hollinshed. Second edition, Anatomy for surgeons (1957).

20. Hutchins G.M. Moore G.W. Skoog D.K. The association of floppy mitral valve with disfunction of the mitral annulus fibrosus. N Engl J Med 1986; 314: 535-40.

21. Inderbirshoh, GP. Pal. Human Embryology. Seventh edition (1976) p.230.

22. Kitzman D.W., Edwards M.D. Age related changes in the anatomy of the normal human heart. J Gerantol 1990 Mar; 45(2): No.33-9.

23. Lam JHC, Ranganathan N. Wigle E. Morphology of the human mitral valve. I. Chordae tendineae: a new classification. Circulation 1970; 41: 449-58.

24. Langman's medical embroyology, 6th edition.

25. Mahendrakar M. Cardiac Anatomy - viewed through the eyes of clinicians. J Anat Soc India 53(2) 44-48 (2004).

26. MC Alpine W.A. Heart and coronary arteries. An anatomical atlas for clinical diagnosis, radiological investigation and surgical treatment. New York. Springer-Verlag, 1965: 39-56.

27. Michele A. Chiechi, M.D. William M. Lees, M.D., and Robert Thompson M.D., Chicago, ILL, J Thoracic surg. 1956.

28. Ormiston J.A., Shah P.M. Tei C., et al. Size and motion of the mitral valve annulus in man: 1. A bio-dimensional echocardiographic method and findings in normal subjects. Circulation 1981; 64: 113.

29. Perloff, J.K. Roberts W.C. The mitral valve apparatus. Functional anatomy of mitral regurgitation. Circulation 1972; 46: 227-39.

30. Petra W. Oosthoek, Ph.D. Arnold C.G. Wenisk, M.D., Lambertus J. Wisse, Adriane C. Gitten berger-de Groot, Ph.D. Development of the papillary muscles of the mitral valve : Morphogenetic background of parachute like asymmetric mitral valves and other mitral valve anomalies. J Thorac cardiovas surg 1998; 116: 36-46.

31. Police C. Piton M. Filly K. et al. Mitral and aortic valve orifice area in normal subjects and in patients with congestive cardiomyopathy, determination by two-dimensional echocardiography. Am J Cardiol 1982; 49: 1191.

32. Ranganathan N, Lam JHC, Wigle E.D., Morphology of the human mitral valve II. The valve leaflets circulation 1970; 41: 459-67.

33. Ranganathan, N. M.D. G.E. Burch, M.D. New orleans, La Gross morphology and arterial supply of the papillary muscles of the left ventricle of man. American heart journal 1969; Vol. 77, No.4, p.506-516.

34. Roberts W.C. Perloff J.K. Mitral valvular disease: a clinicopathologic surgery of the conditions causing the mitral valve to function abnormally. Am Intern Med 1972, 77: 939.

35. Rusted I.E., Scheifley C.H, Edwards J.E. Guides to the commissures in operations the mitral valve. Proc staff meet Mayo Clin 1951; 26: 297-305.

36. Rusted I.E., Schiefley C.H., Edwards J.H., Studies of the mitral valve 1. Anatomic features of the normal mitral valve and associated structures. Circulation 1952; 6: 825-31.

37. Silverman M.E. Hurst J.W : The mitral complex : interaction of the anatomy, physiology and pathology of the mitral annulus, mitral valve leaflets. Chordae tendineae and papillary muscles. Am Heart J 1968; 76: 399.

38. Skandalaki's surgical anatomy. Vol.I, 2004 edition.

39. Solomon Victor, Vijaya M. Nayak. Definition and function of commissures, slits and scallops of the mitral valve: Analysis in 100 hearts. Asia Pacific J Thorac. Cardiovasc surg 1994; 3(1) : 10-16.

40. Sakiris T. A.G. Strum R.E. Wood E.H. Experimental studies on the mechanisms of closure of cardiac valves with use of roentgen. Videodensitometry. Am J Cardiol 1973; 32: 136.

41. Sakiris T. A.G. Von Bernuth G. Rastalli G.C. Size and motion of the mitral valve annulus in anerthetized infact dogs. J Appl Physiol 1971; 30: 611.

42. Tandler J. Anatomie des besch des Anatomie des menschen. Jena : Bandelben Gusto-V Fischer Verlagsbuch and lung, 1913: Vol.3, Abt i, 84.

43. Tetsuro Sakai M.D. Yutaka Okmit M.D. Ph.D. Xvichi Usda, M.D. Ph.D. Takafumi Tahata M.D. Hitoshi Ogino, M/D. Ph.D. Ketsuhiko Matsyuama, M.D. Ph.D. Shigehitomiki M/.D. Distance between mitral annulus and papillary muscles: Anatomic study in normal human hearts. J. Thorac Cardiovasc surg 1999; 118: 636-41.

44. Tirone E, David M.D. Papillary muscle - Annular continuity: Is it important? J Card surg 1994; 9: 252-254.

45. Van Rijk-Zwikker G.L. Mart F, Schipperheyn J.J. et al. comparison of rigid and flexible rings for annuloplasty of the porcine mitral valve. Circulation 1990; 82 (suppl. V) V-58.

46. Vander Bel-Kehn J. Becker A.E. The surgical pathology of rheumatic and floppy mitral valves: distinctive morphologic features upon gross examination. Am J Surg Pathol 1986; 10: 282-92.

47. Wilcox B.R, Anderson R.H. Surgical anatomy of the heart. 2nd edition. London> Gower Medical Publishing, 1992: 3.4-3.7.

48. Walmsley T. The heart In : Sharpey Schafer E, Symington J, Bryce T.H., eds Qumin's elements of anatomy; 11th edition, Vol.4, p. 3, London. Longman Green and CO 1929: 42.

49. Yoav Turgeman M.D. Shavl Atar, M.D. and Tiberio Rosenfeld, M.D. The subvalvular apparatus in rheumatic mitral stenosis. Chart 2003; 124: 1929-1936.

50. Zimmerman J. The functional and surgical anatomy of the heart. Anm R Coll surg Engl 1966; 39: 348-66.

Table – 1

Age wise comparative study of the circumference of mitral valve annulus.

Age Group	A.K.Datta et al. (1984)	Present Study (2006)
1-20 years	8.5 cm	8.1 cm
20-40 years	10.2 cm	9.8 cm
Above 40 years	11.2 cm	11.5 cm

Fig. 1: Age wise comparative study of the circumference of mitral valve annulus.

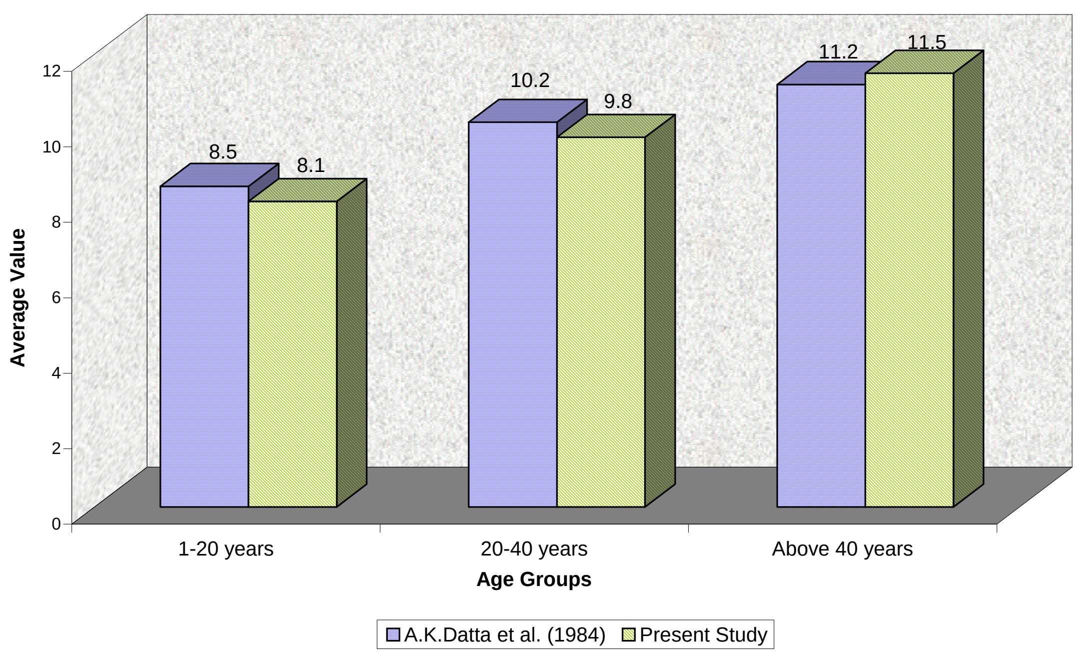


Table - 2

Genderwise comparative study of the circumference of mitral valve annulus

Scientist	Male (Average value)	Female (Average Value)
N.Ranganathan (1970)	9.0 cm	7.2 cm
A.K.Datta et al (1984)	10.3 cm	9.7 cm
Gerdal Rijik (1994)	10 cm	9. cm
Present study	8.9 cm	8.3 cm

Fig.2: Genderwise comparative study of the circumference of mitral valve

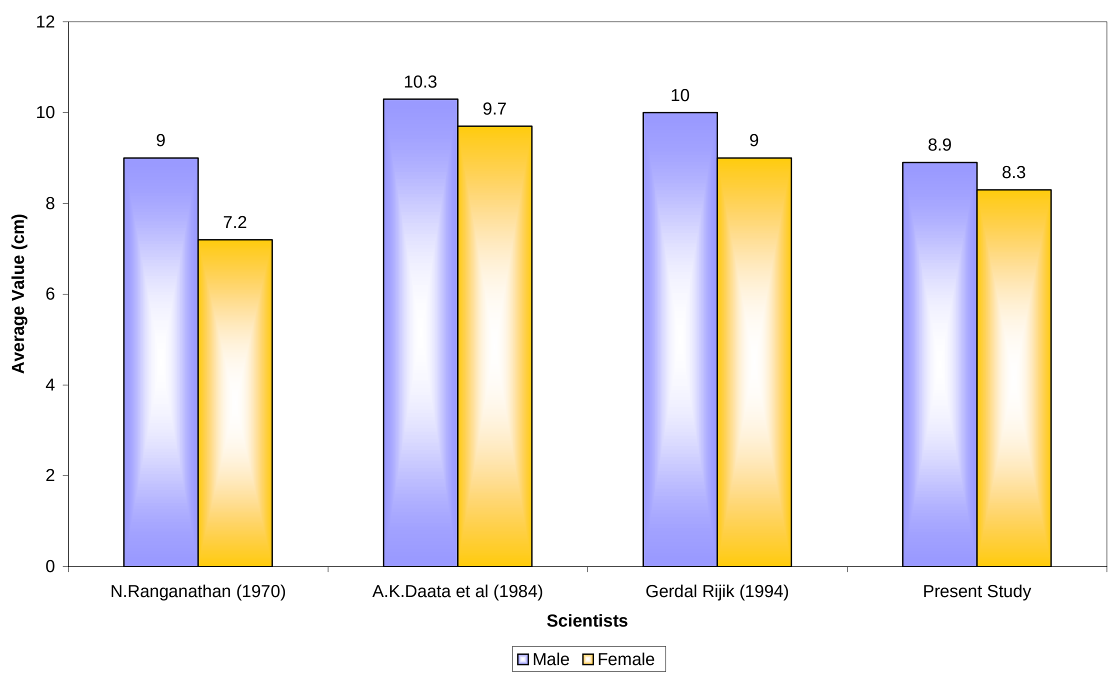


Table 3

Mean value of the central height of the rough zone and clear zone in anterior leaflet comparison of previous study with present study

Age Group	A.K.Datta et al. (1984)		Present Study (2006)	
	Rough Zone (in cm)	Clear Zone (in cm)	Rough Zone (in cm)	Clear Zone (in cm)
1-20 years	0.5	1.6	0.5	1.5
20-40 years	0.6	1.8	0.6	1.7
Above 40 years	0.9	1.9	0.7	1.9

Fig.3 : Mean value of the central height of the rough zone in anterior leaflet comparison of previous study with present study

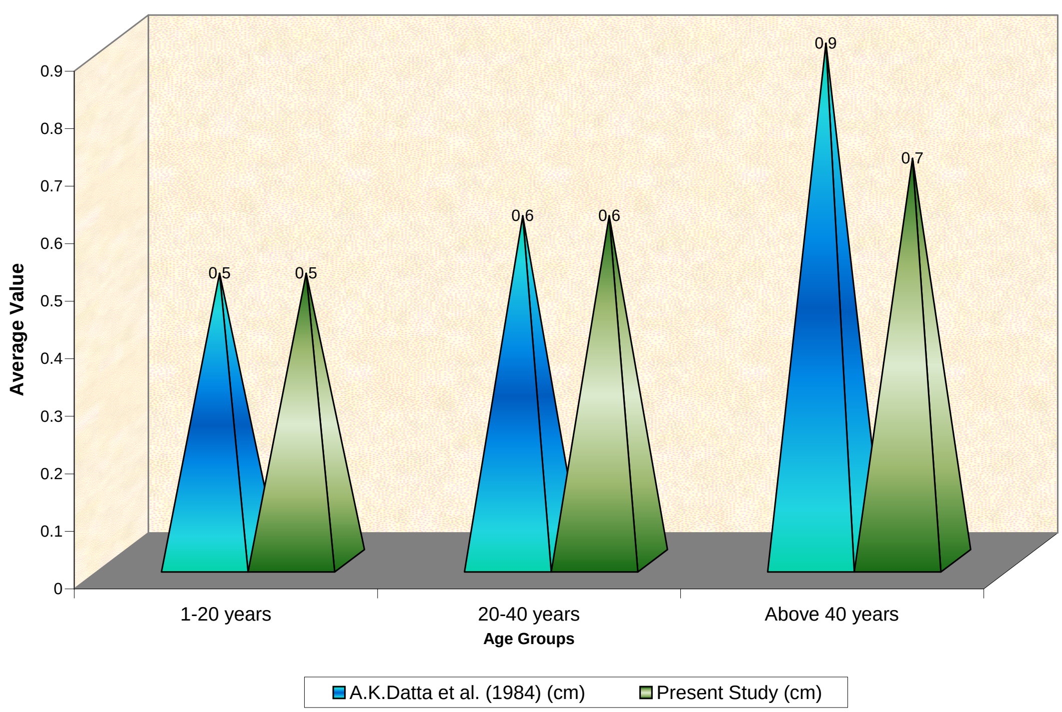


Fig. 3a : Mean value of the central height of the clear zone in anterior leaflet comparison of previous study with present study

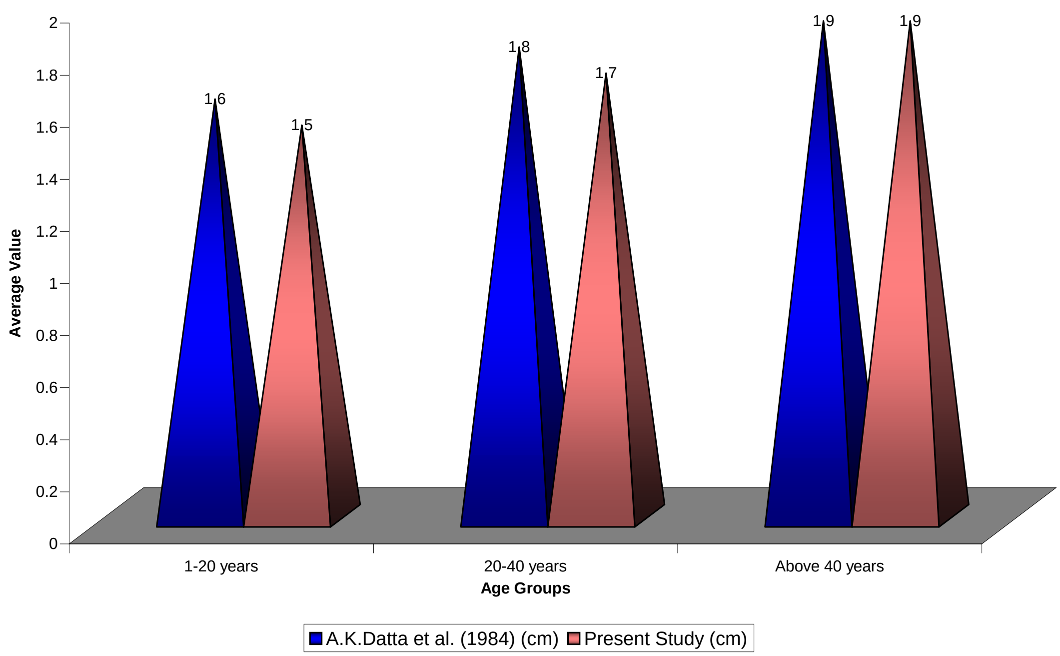


Table 4

Width of anterior leaflet. A comparison of mean values of previous study with present study

Age Group	A.K.Datta et al. (1984) (in cm)	Present Study (2006) (in cm)
1-20 years	2.7	2.6
20-40 years	2.9	3.1
Above 40 years	3.7	3.3

Fig.4: Width of anterior leaflet. A comparison of mean values of previous study with present study

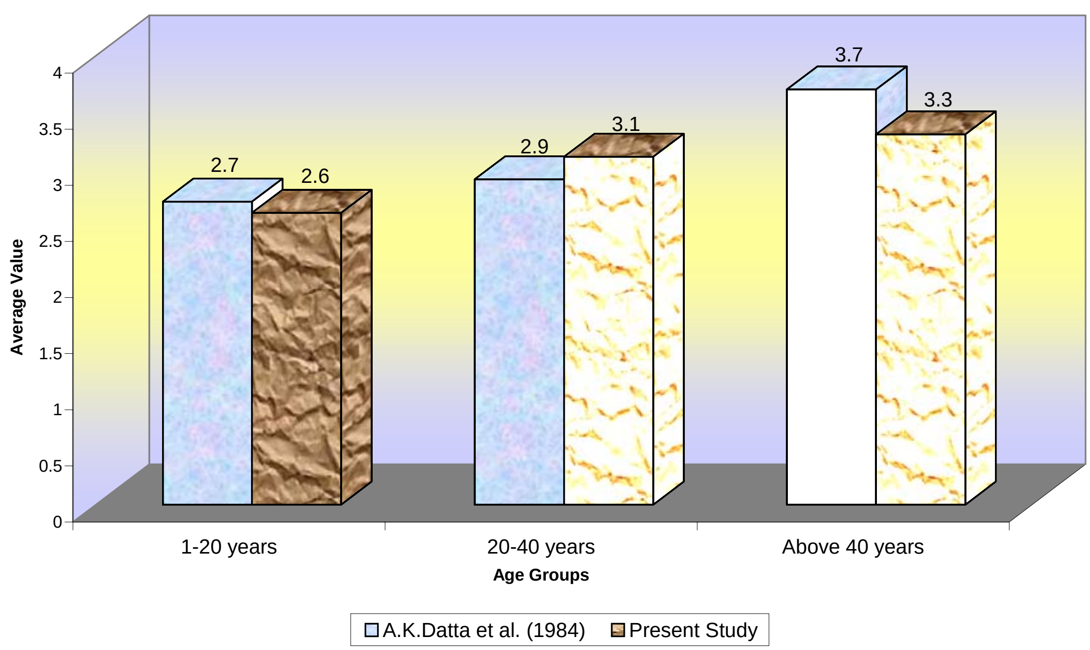


Table 5

Height of anterior leaflet. A comparison of mean values of previous study with present study

Age Group	A.K.Datta et al. (1984)	Present Study
1-20 years	2.2 cm	2.0 cm
20-40 years	2.4 cm	2.4 cm
Above 40 years	2.8 cm	2.7 cm

Fig.5: Height of anterior leaflet. A comparison of mean values of previous study with present study

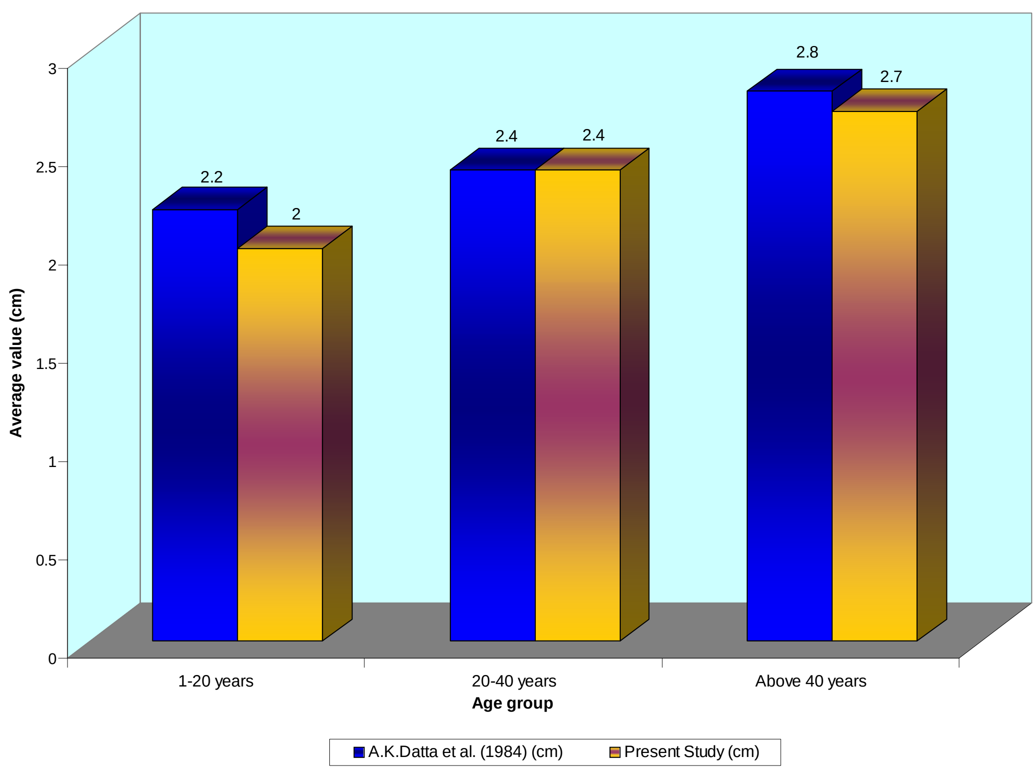


Table – 6

Mean value of the central height of the Rough zone and clear zone in posterior leaflet comparison of previous study with present study

Age Group	A.K.Datta et al. (1984)		Present Study (2006)	
	Rough Zone (in cm)	Clear Zone (in cm)	Rough Zone (in cm)	Clear Zone (in cm)
1-20 years	0.4	0.4	0.5	0.3
20-40 years	0.7	0.4	0.6	0.4
Above 40 years	0.7	0.5	0.6	0.5

Fig.6: Mean value of the central height of the Rough zone and clear zone in posterior leaflet comparison of previous study with present study

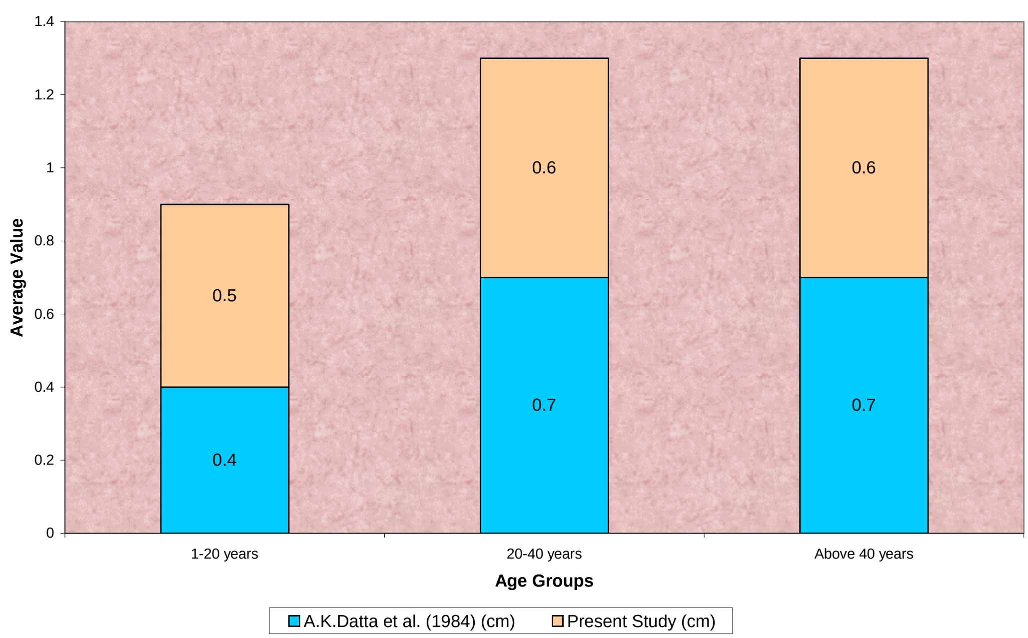


Fig.6: Mean value of the central height of the Rough zone and clear zone in posterior leaflet comparison of previous study with present study

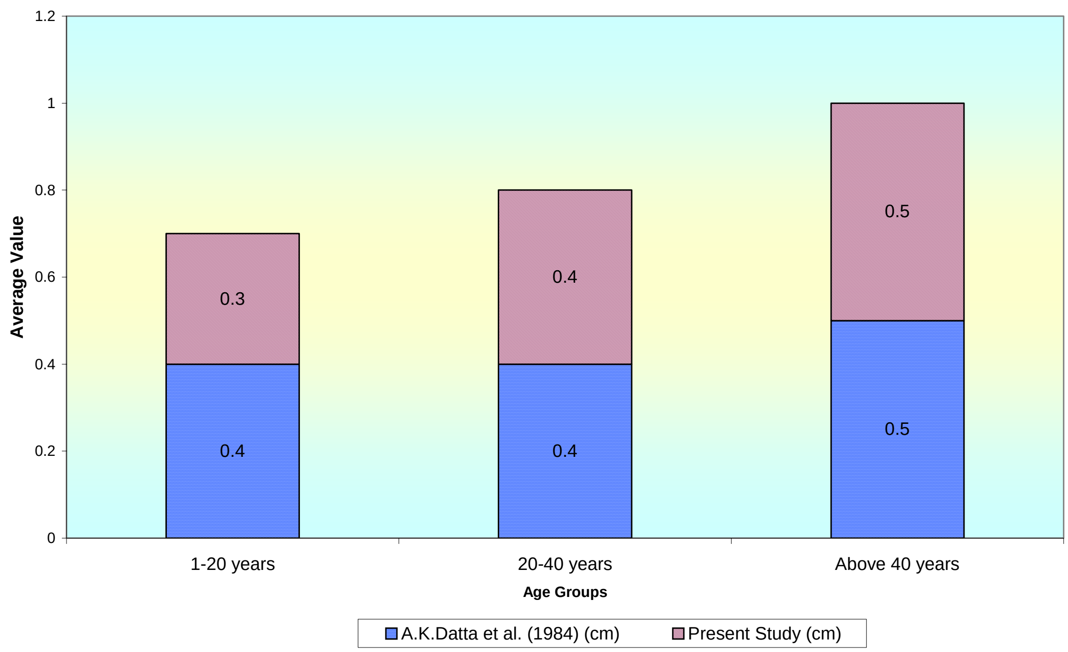


Table – 7

Width of posterior leaflet. A comparison of mean values of previous study with present study

Age Group	A.K.Datta et al. (1984)	Present Study (2006)
1-20 years	6.2 cm	6.0 cm
20-40 years	7.0 cm	6.9 cm
Above 40 years	7.5 cm	7.4 cm

Fig.7: Width of posterior leaflet. A comparison of mean values of previous study with present study

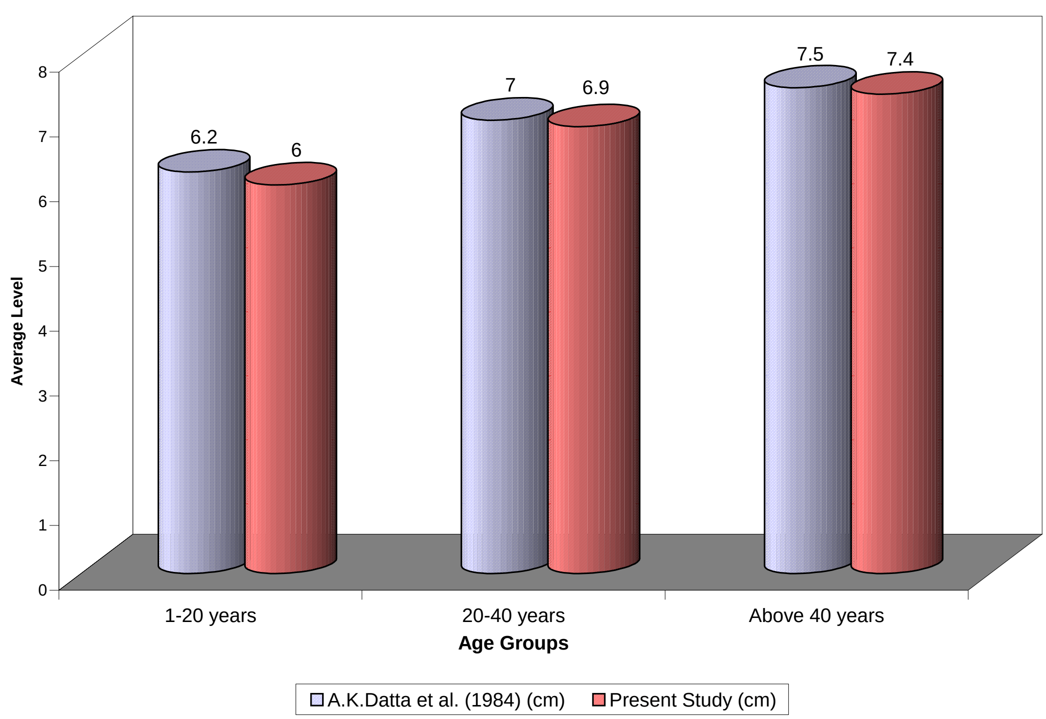


Table – 8

Height of posterior leaflet. A comparison of mean values of previous study with present study

Age Group	A.K.Datta et al. (1984) (in cm)	Present Study (2006) (in cm)
1-20 years	1.1	0.9
20-40 years	1.3	1.3
Above 40 years	1.5	1.3

Fig.8 : Mean value of the height of posterior leaflet comparison of previous study result with present study

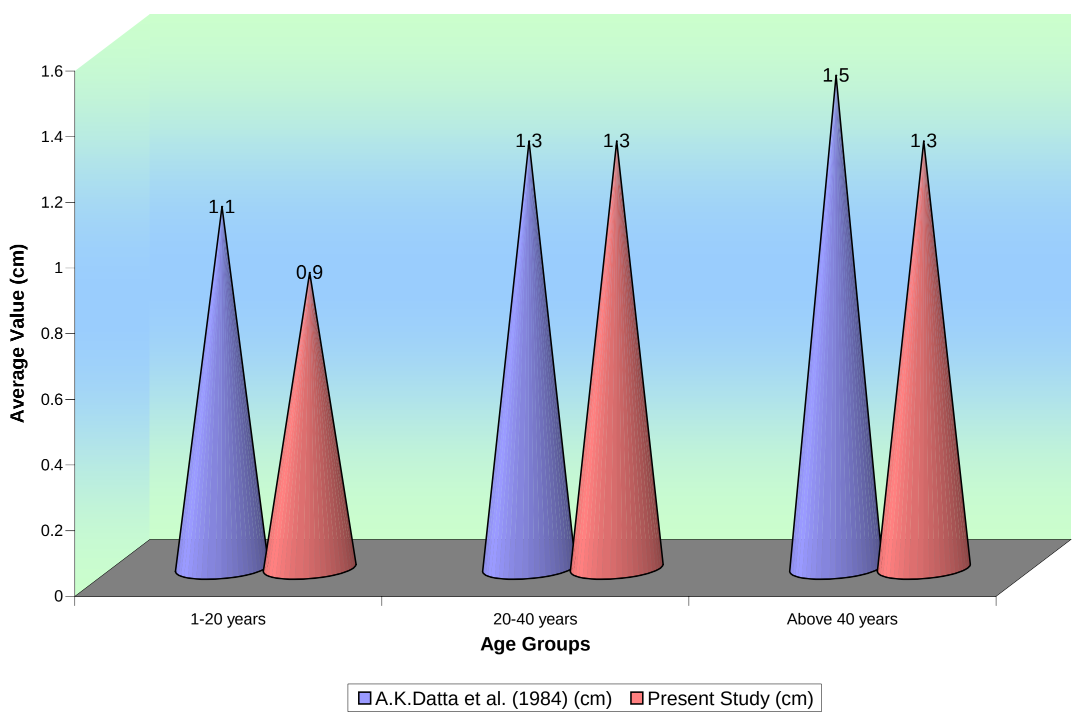


Table – 9

Number of chordae at origin – A comparative study

No. of Chordae	S. Victor Study (1995)		Present Study (2006)	
	Anterolateral	Posteromedial	Anterolateral	Posteromedial
1-3	-	1%	2 (4%)	-
4-6	21%	31%	11 (24%)	10 (22%)
7-9	51%	34%	13 (29%)	13 (29%)
10-12	20%	22%	10 (22%)	13 (29%
13-16	6%	10%	5 (11%)	7 (16%)
17-20	1%	2%	2 (4%)	2 (4%)
21-23	1%	-	2 (4%)	-

Fig. 9 : Number of chordae at origin – A comparative study

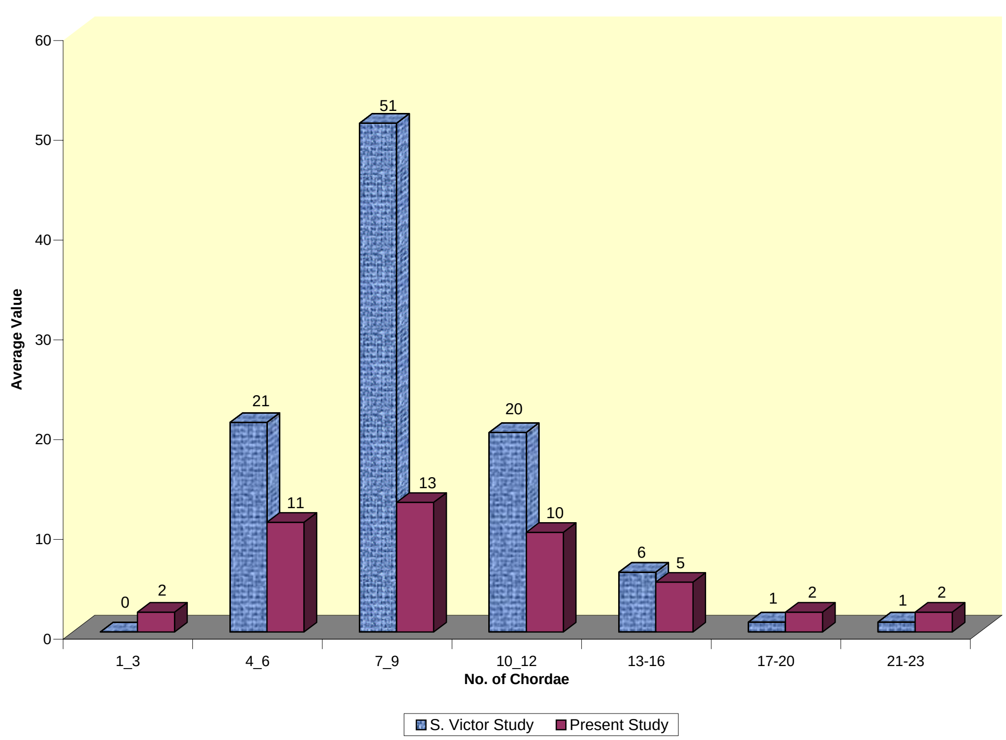


Fig. 9a : Number of chordae at origin – A comparative study

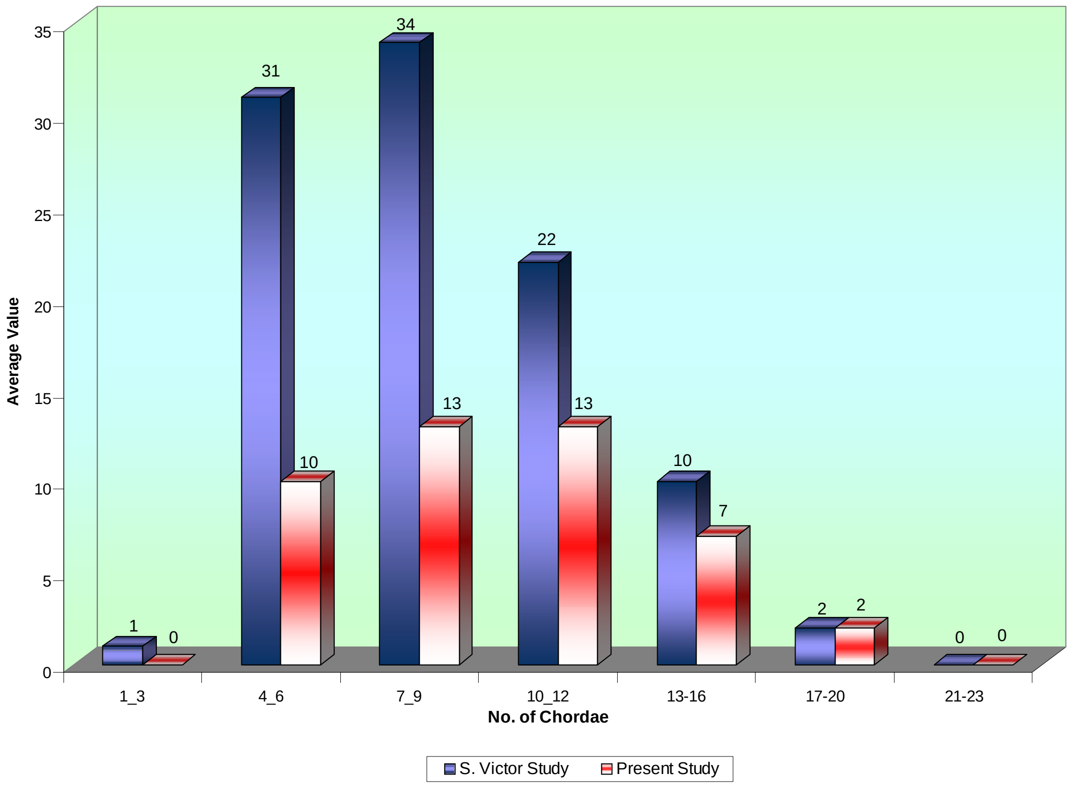


Fig. 9b : Number of chordae at origin – A comparative study

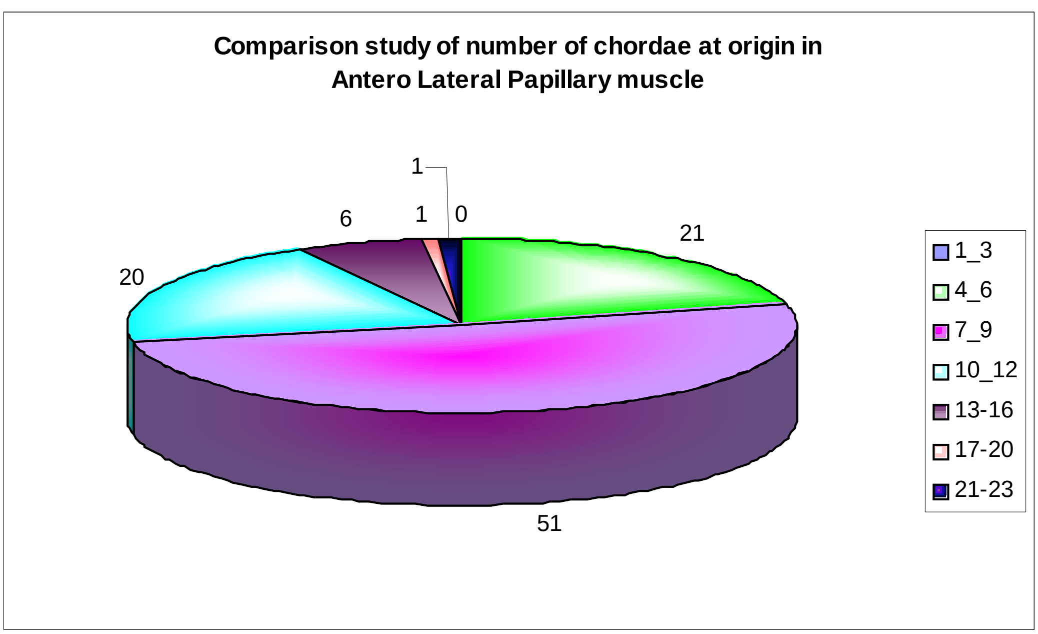


Fig. 9c : Number of chordae at origin – A comparative study

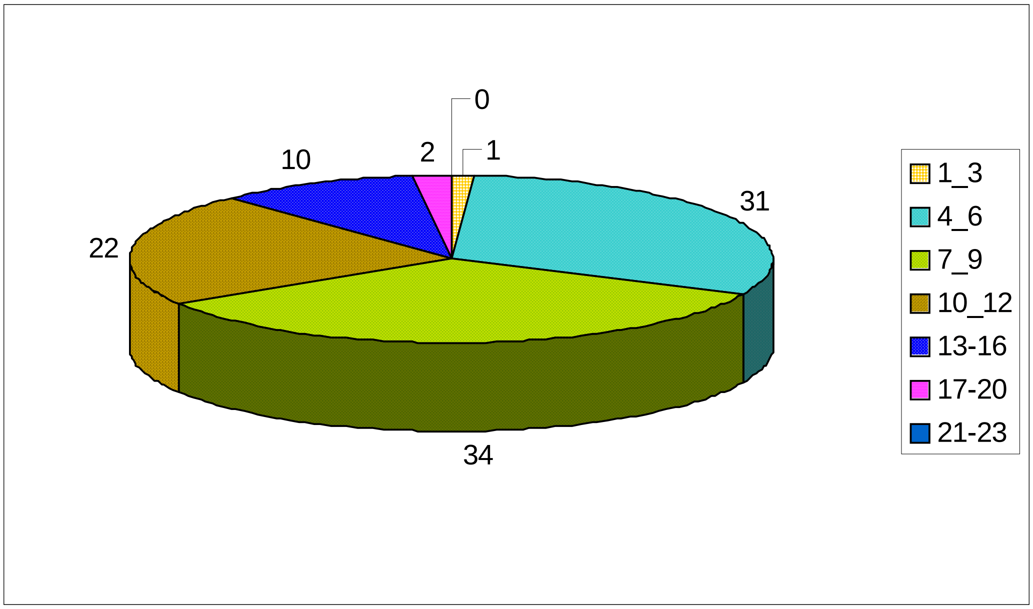


Table – 10

Number of Chordae at insertion – A comparative study

No. of Bellies	S. Victor Study (1995)		Present Study (2006)	
	Anterolateral	Posteromedial	Anterolateral	Posteromedial
10-20	4%	9%	3 (7%)	5 (11%)
21-30	40%	31%	13 (29%)	11 (24%)
31-40	31%	45%	10 (22%)	12 (27%)
41-50	17%	9%	12 (27%)	10 (22%)
51-60	5%	4%	3 (7%)	3 (7%)
61-70	2%	1%	2 (4%)	2 (4%)
71-80	1%	1%	2 (4%)	2 (4%)

Fig. 10 : Number of Chordae at insertion – A comparative study

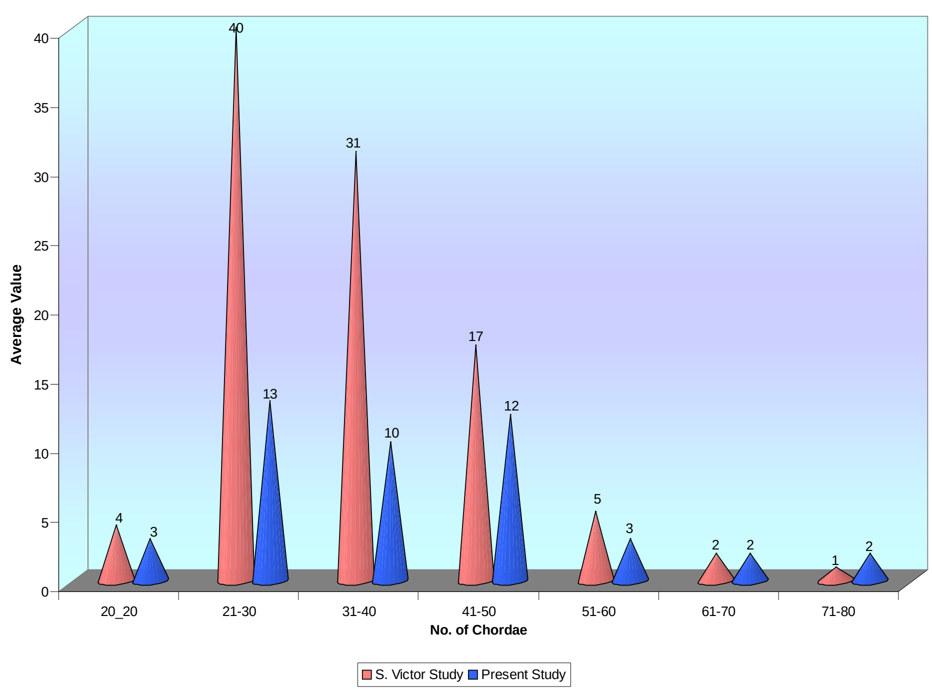


Fig. 10a : Number of Chordae at insertion – A comparative study

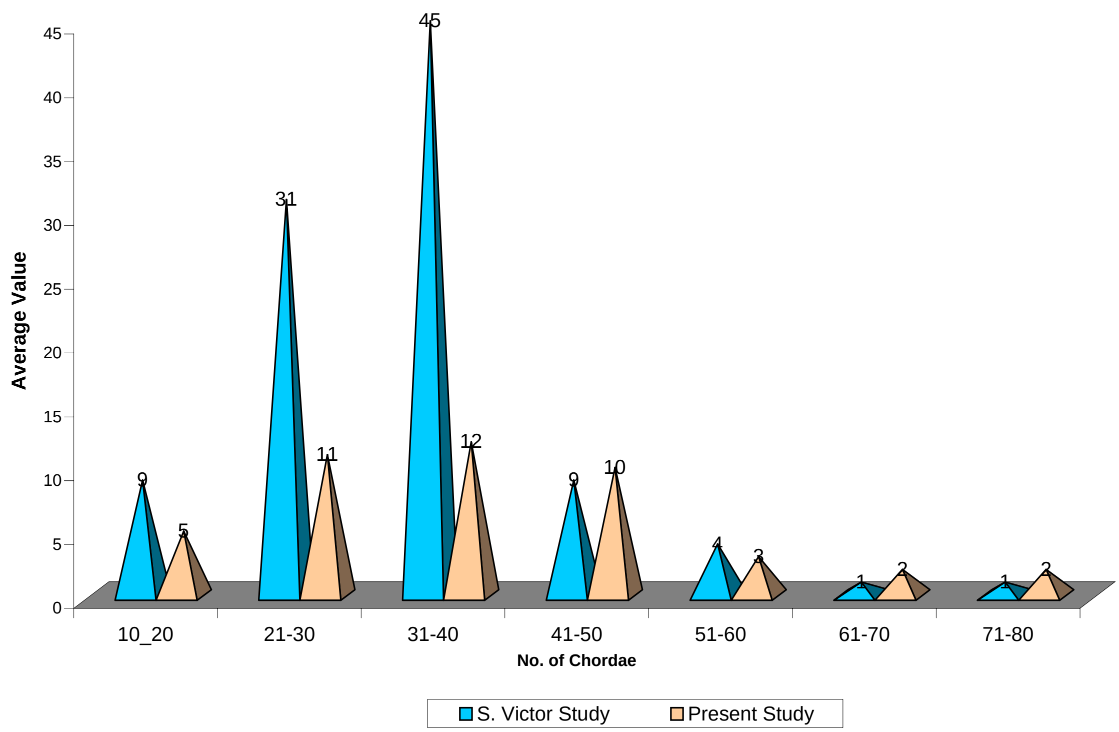


Table – 11

Patterns of Papillary Muscles. A comparison of previous study with present study

No. of Bellies	Pattern	S. Victor Study (1995)		Present Study (2006)	
		AL	PM	AL	PM
Single	Conical	32%	12%	14 (31%)	9 (20%)
	Mamillated	14%	12%	5 (11%)	8 (18%)
	Flat topped	9%	8%	5 (11%)	3 (7%)
	Grooved	10%	6%	4 (9%)	2 (4%)
	Stepped	2%	5%	-	-
	Wavy	-	3%	-	-
	Arched	-	2%	-	-
	Sloped	-	1%	-	-
	Saucerized	-	1%	-	-
Two	Two tired	11%	9%	6 (13%)	7 (16%)
	Interlinked	4%	10%	2 (4%)	4 (9%)
	Parallel	7%	6%	2 (4%)	2 (4%)
	Arched	1%	5%	-	2 (4%)
	V	1%	4%	1 (2%)	2 (4%)
	Y	1%	1%	1 (2%)	1(2%)
	H	2%	2%	1 (2%)	1(2%)
Three	Parallel	2%	3%	1 (2%)	1(2%)
	Interlinked	-	5%	-	-
	Two interlinked + 1 Separate	2%	-	-	-
	Arched	-	1%	-	-
	Two tiered + 1 separate	-	1%	-	-
Four	Parallel	-	2%	1 (2%)	1(2%)
	Interlinked	1%	-	1 (2%)	-
Five	Scattered	1%	-	1 (2%)	1(2%)
Six	Parallel	-	-	0	1 (2%)

Table – 12

Origin of papillary muscle. A comparison of previous study

Site	S. Victor Study (1995)		Present Study (2006)	
	Anterolateral Papillary Muslce	Posteromedial Papillary Muslce	Anterolateral Papillary Muslce	Posteromedial Papillary Muslce
Upper third	19%	6%	40.0%	26.6%
Middle third	79.5%	92.5%	53.3%	66.6%
Lower third	1.5%	1.5%	6.6%	6.6%

Fig.12 : Origin of papillary muscle. A comparison of previous study

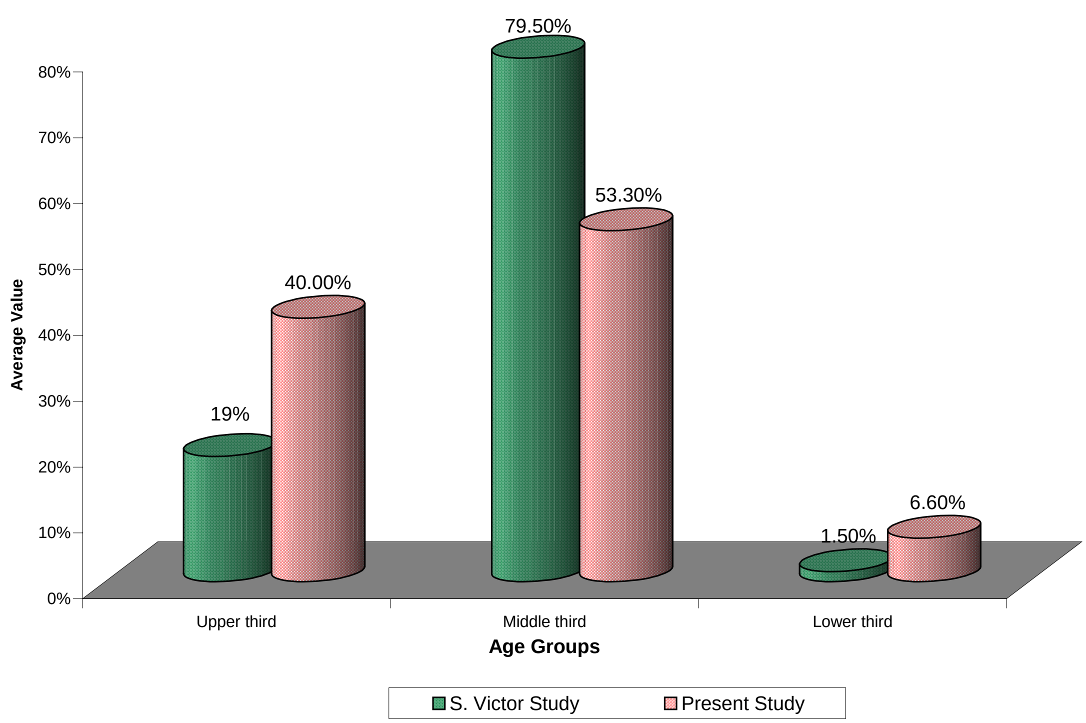


Fig. 12 : Origin of papillary muscle. A comparison of previous study

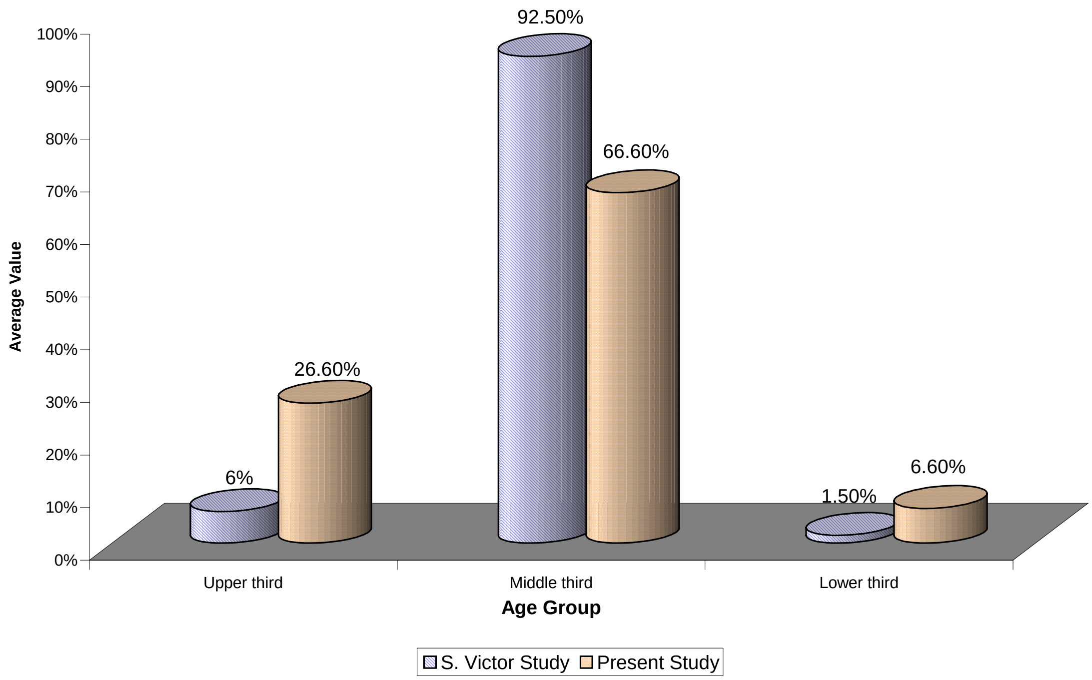


Table - 13

Extent of protrusion of papillery muscles. A comparison of previous study with present study

Extent of protrusion of papillary muscles	S. Victor Study (1995)		Present Study (2006)	
	Anterlateral Papillary Muscle	Posteromedial Papillary Muscle	Anterlateral Papillary Muscle	Postermedial Papillary Muscle
Mostly intra luminal	14%	11%	22.2%	20.0%
Mostly intra luminal with tip enclosed	19%	28%	22.2%	28.8%
Equally sessile and intraluminal	54.5%	41.5%	48.5%	44.4%
Mostly sessile	12.5%	19.5%	4.4%	6.6%

Fig. 13: Extent of protrusion of papillery muscles. A comparison of previous study with present study

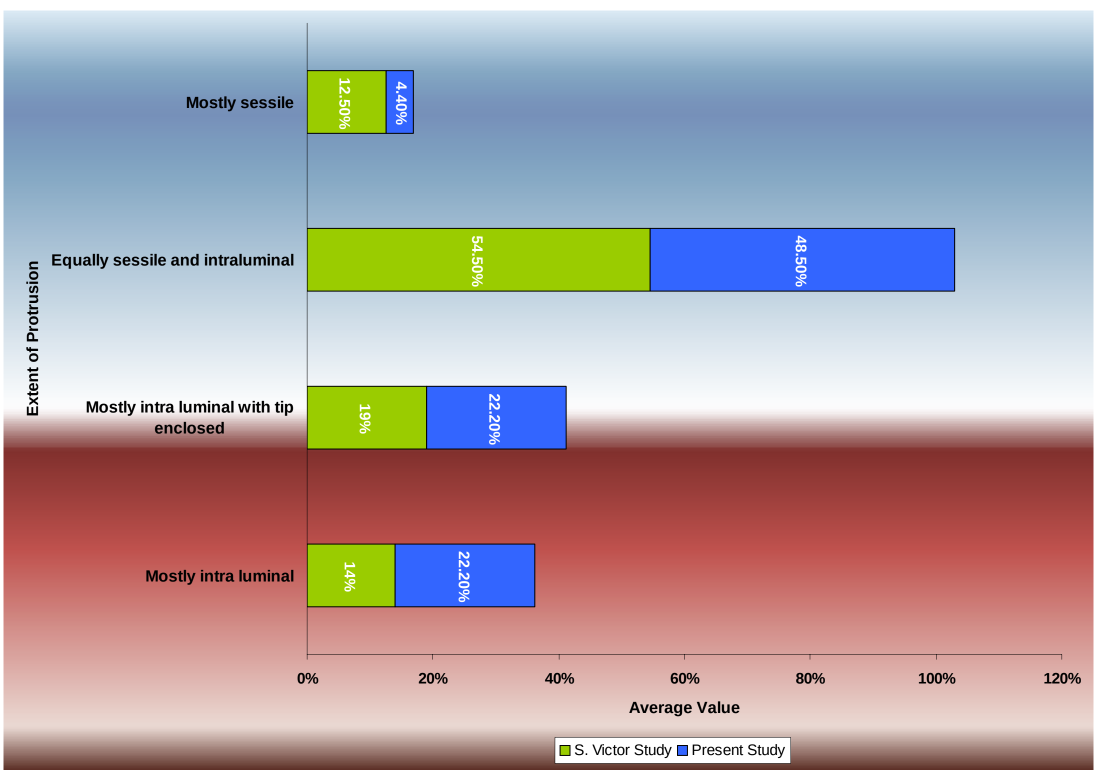


Fig.13a : Extent of protrusion of papillery muscles. A comparison of previous study with present study

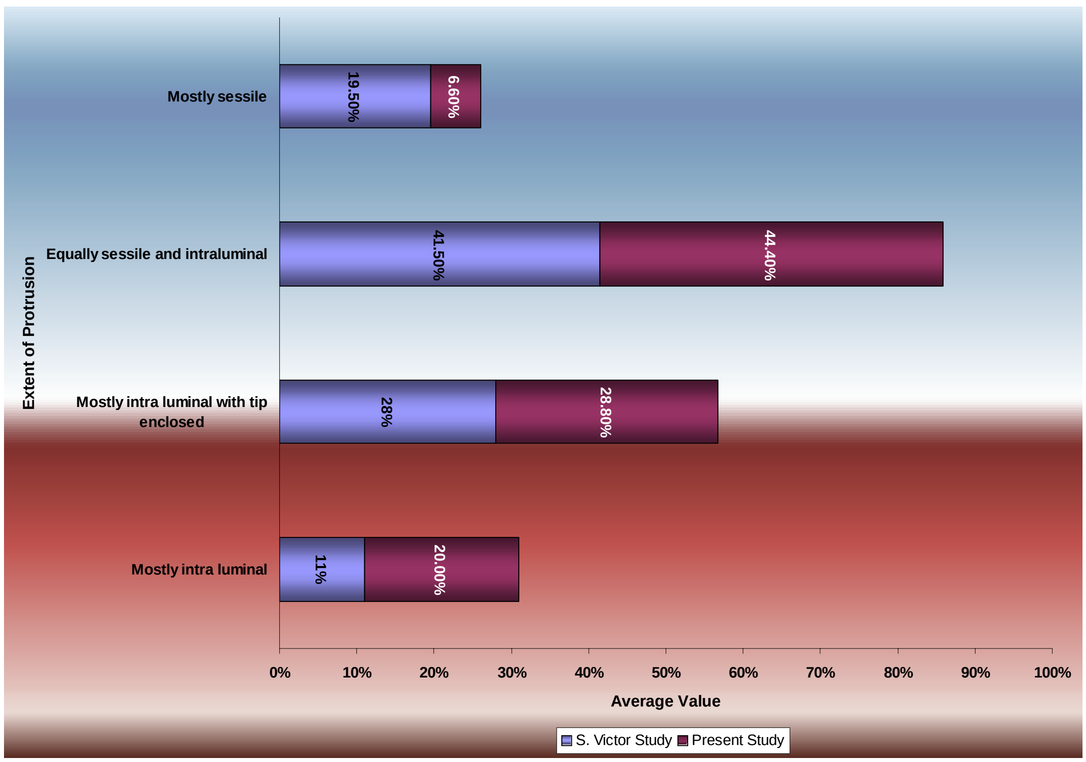


Table - 1

Circumference of Mitral Annulus in 4 age Groups

Specimen number	Age in years with sex	Circumference (cm)
0 – 1 yrs.		
1	6 months – (M)	0.4
2	8 months – (M)	0.5
3	4 months – (M)	0.4
4	6 months – (F)	0.3
5	7 months – (F)	0.4
1 – 20 yrs.		
1	5 – (F)	6.5
2	8 – (F)	6.8
3	10 – (F)	7.0
4	11 – (M)	7.1
5	12 – (M)	7.4
6	16 – (M)	8.9
7	17 – (M)	9.1
8	18 – (M)	9.4
9	17 – (F)	9.6
10	14 – (F)	9.3
21 – 40 yrs.		
1	28 – (M)	9.6
2	26 – (M)	9.5
3	29 – (F)	9.7
4	22 – (M)	9.6
5	27 – (F)	9.7
6	33 – (M)	9.9
7	36 – (F)	9.8

Specimen number	Age in years with sex	Circumference (cm)
8	38 – (M)	9.9
9	37 – (F)	10.1
10	37 – (M)	10.8
11	36 – (M)	10.5
12	35 – (M)	9.7
13	26 – (M)	9.4
14	28 – (M)	9.5
15	29 – (F)	9.1
Above 40 yrs.		
1	50 – (M)	11.1
2	46 – (M)	10.8
3	48 – (F)	10.7
4	47 – (M)	10.5
5	52 – (M)	10.4
6	51 – (F)	10.2
7	58 – (M)	10.9
8	65 – (M)	11.2
9	70 – (M)	11.7
10	80 – (F)	11.6
11	47 – (M)	10.4
12	49 – (M)	10.5
13	53 – (M)	10.5
14	56 – (F)	10.3
15	59 – (F)	10.6

Table – 1(a)

Statistical analysis of the mitral annulus

Age group in years	**Age difference in Circumference of mitral annulus (in cm)**		
	Range	**Mean**	**S.D.**
0 – 1 yrs.	0.3 - 0.5	0.32	0.07
1 – 20 yrs.	6.5 – 9.6	8.11	1.25
21 – 40 yrs.	9.1 – 10.8	9.79	0.43
Above 40 yrs.	10.2 – 11.8	10.76	0.46

Table - 1(b)

Age group in years	**Sex difference in Circumference of Mitral annulus**					
	Male			**Female**		
	Range	**Mean**	**SD**	**Range**	**Mean**	**SD**
0 – 1 yrs	0.4 – 0.5	0.43	0.06	0.3 – 0.4	0.35	0.07
1 – 20 yrs	7.1 – 9.4	8.38	1.05	6.5 – 9.3	7.84	1.48
21 – 40 yrs	9.4 – 10.8	9.84	0.46	9.1 – 10.1	9.68	0.36
Above 40 yrs	10.4 – 11.8	10.8	0.43	10.2 – 11.6	10.68	0.55

Table – 2

Commissures length in the 4 age groups

Sp. No.	Age in years with Sex	Anterior Commisure Length (cm)	Posterior Commisure Length (cm)
0-1 yrs.			
1	6m - (M)	0.3	0.2
2	8m - (M)	0.5	0.3
3	4m - (M)	0.3	0.1
4	6m - (F)	0.6	0.4
5	7m - (F)	0.5	0.4
1-20 yrs.			
1	5 - (F)	5	4.4
2	8 - (F)	5	4
3	10 - (F)	6.5	6
4	11 - (M)	4.5	3
5	12 - (M)	5	4
6	16 - (M)	7	5
7	17 - (M)	6	5.2
8	18 - (M)	5	4.1
9	17 - (F)	5	4.3
10	14 - (F)	6	5.1
21 – 40 years			
1	28 - (M)	7	6
2	26 - (M)	7	5.5
3	29 - (F)	5	4.5
4	22 - (M)	8	6.5
5	27 - (F)	7.5	6.5
6	33 - (M)	7.1	6.6

Sp. No.	Age in years with Sex	Anterior Commisure Length (cm)	Posterior Commisure Length (cm)
7	36 - (F)	8.1	6.5
8	38 - (M)	9.2	7.5
9	37 - (F)	8.3	5.8
10	37 - (M)	9.3	8
11	36 - (M)	8.5	8.1
12	35 - (M)	8	7.5
13	26 - (M)	7.5	7.2
14	28 - (M)	7.6	6.5
15	29 - (F)	8.4	7.5
Above 40 years			
1	50 - (M)	9.8	8.9
2	46 - (M)	8	7.5
3	48 - (F)	9.7	8.8
4	47 - (M)	9.8	8.7
5	52 - (M)	9.7	9.2
6	51 - (F)	9.5	8.8
7	58 - (M)	9.4	8.9
8	65 - (M)	9.2	8.7
9	70 - (M)	8.5	8.2
10	80 - (F)	9.1	8.8
11	47 - (M)	8.8	8.5
12	49 - (M)	9.7	8.9
13	53 - (M)	9.6	8.8
14	56 - (F)	9.8	8.7
15	59 - (F)	9.7	8.8

Table - 2(a)

Statistical Analysis of the Commissures

Age group in yrs	Anterior commissure length (cm)			Posterior commissure length (cm)		
	Range	Mean	SD	Range	Mean	SD
0 – 1 yrs	0.2 – 0.3	0.44	0.13	0.2 – 0.4	0.28	0.13
1 – 20 yrs	0.4 – 0.6	5.5	0.82	0.5 – 0.6	4.5	0.8
21 – 40 yrs	0.5 – 0.7	7.77	1.05	0.6 – 0.8	6.7	1.0
Above 40 yrs	0.6 – 0.8	9.35	0.54	0.7 – 0.9	8.7	0.4

Table - 2(b)

Commissures Range

Age Group	A.C.	P.C.
0 - 1 years	0.2 - 0.3 cm	0.2 - 0.4 cm
1 - 20 years	0.4 - 0.6 cm	0.5 - 0.6 cm
20 - 40 years	0.5 - 0.7 cm	0.6 - 0.8 cm
Above 40 years	0.5 - 0.8 cm	0.7 - 0.9 cm

Table - 3

Width (basal measurement) and height of Anterior and Posterior Leaflets in four age groups

Sp. No.	Age in years with Sex	Width of Leaflet in cm		Height of Leaflet in cm	
		Anterior	Posterior	Anterior	Posterior
0-1 yrs.					
1	6m - (M)	0.2	0.5	0.4	0.2
2	8m - (M)	0.5	0.8	0.6	0.3
3	4m - (M)	0.2	0.4	0.3	0.2
4	6m - (F)	0.3	0.6	0.5	0.3
5	7m - (F)	0.4	0.7	0.5	0.2
1-20 yrs.					
1	5 - (F)	1.7	5.1	1.8	0.7
2	8 - (F)	1.9	5.0	2	0.9
3	10 - (F)	2.0	5.2	2.2	1.0
4	11 - (M)	2.4	6.0	2.1	1.1
5	12 - (M)	2.9	6.2	2.2	1.2
6	16 - (M)	2.8	6.6	2.1	1.0
7	17 - (M)	3.0	6.4	1.8	1.1
8	18 - (M)	2.7	6.8	1.9	1.0
9	17 - (F)	3.0	6.4	2.2	0.8
10	14 - (F)	3.2	6.5	2.3	1.1
21 – 40 years					
1	28 - (M)	3.0	6.7	2.2	1.0
2	26 - (M)	3.1	6.4	2.4	1.2
3	29 - (F)	3.0	6.5	2.3	1.1
4	22 - (M)	2.5	7.0	2.6	1.4
5	27 - (F)	3.1	6.9	1.9	1.5

Sp. No.	Age in years with Sex	Width of Leaflet in cm		Height of Leaflet in cm	
		Anterior	Posterior	Anterior	Posterior
6	33 - (M)	3.3	6.5	2.2	1.2
7	36 - (F)	3.2	7.0	1.9	1.1
8	38 - (M)	3.6	7.1	2.6	1.3
9	37 - (F)	3.3	7.4	2.6	1.3
10	37 - (M)	3.0	7.5	2.4	1.1
11	36 - (M)	3.6	7.0	2.5	1.3
12	35 - (M)	3.4	6.9	2.6	1.2
13	26 - (M)	2.5	6.8	2.5	1.4
14	28 - (M)	3.4	6.5	2.1	1.3
15	29 - (F)	2.5	6.9	2.5	1.4
Above 40 years					
1	50 - (M)	3.7	7.2	2.5	1.3
2	46 - (M)	3.8	7.2	2.4	1.4
3	48 - (F)	3.7	7.1	2.3	1.5
4	47 - (M)	3.6	7.2	2.8	1.4
5	52 - (M)	3.0	7.5	3.4	1.3
6	51 - (F)	3.4	7.0	2.6	1.5
7	58 - (M)	3.6	7.1	2.4	1.1
8	65 - (M)	3.8	7.7	2.6	1.5
9	70 - (M)	3.7	7.9	2.5	1.0
10	80 - (F)	3.8	8.0	2.6	1.1
11	47 - (M)	3.5	7.1	2.4	1.3
12	49 - (M)	3.7	7.1	2.5	1.5
13	53 - (M)	3.0	7.5	3.3	1.1
14	56 - (F)	2.9	7.6	3.4	1.3
15	59 - (F)	3.6	7.1	3.3	1.2

Table - 3 (a)

Statistical Analysis

Age group in years	Basal Width of Leafet				Height of Leaflet			
	Anterior		Posterior		Anterior		Posterior	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
0-1 years	0.32	0.13	0.60	0.16	0.46	0.11	0.24	0.05
1 – 20 years	2.56	0.53	6.02	0.67	2.06	0.18	0.99	0.15
21 – 40 years	3.10	0.37	6.87	0.32	2.35	0.24	1.25	0.14
Above 40 years	3.52	0.31	7.35	0.32	2.73	0.40	1.30	0.17

Table - 3 (b)

Width and height of Anterior Leaflet

Age Group	Width (Range)	Height (Range)
0-1 yrs	0.3-0.6 cm	0.2 – 0.5 cm
1-20 yrs	1.8 – 2.3 cm	1.7 – 3.2 cm
21-40 yrs	1.9 – 2.6 cm	2.5 – 3.6cm
Above 40 yrs	2.3 – 3.4 cm	2.9 – 3.8 cm

Table - 3 (c)

Width and height of Posterior Leaflet

Age Group	Width (Range)	Height (Range)
0-1 yrs	0.4 - 0.8 cm	0.2 – 0.3 cm
1-20 yrs	5.0 – 6.8 cm	0.7 – 1.2 cm
21-40 yrs	6.4 – 7.5 cm	1.0 – 1.5 cm
Above 40 yrs	7.0 – 8.0 cm	1.0 – 1.5 cm

Table – 4

Measurement in cm of the central height of the rough zone and clear zone of both leaflets in the four age groups

Sp. No.	Age in years with Sex	Anterior leaflet		Posterior Leaflet	
		Rough Zone	Clear Zone	Rough Zone	Clear Zone
0-1 yrs.					
1	6m - (M)	0.2	0.6	0.3	0.2
2	8m - (M)	0.3	0.8	0.5	0.3
3	4m - (M)	0.2	0.5	0.4	0.2
4	6m - (F)	0.4	0.8	0.5	0.2
5	7m - (F)	0.5	0.9	0.6	0.3
1-20 yrs.					
1	5 - (F)	0.4	1.2	0.4	0.3
2	8 - (F)	0.3	1.4	0.4	0.4
3	10 - (F)	0.5	1.6	0.4	0.3
4	11 - (M)	0.6	1.7	0.5	0.4
5	12 - (M)	0.3	2.0	0.5	0.4
6	16 - (M)	0.5	1.5	0.5	0.3
7	17 - (M)	0.4	1.4	0.5	0.4
8	18 - (M)	0.6	1.3	0.5	0.3
9	17 - (F)	0.5	1.6	0.5	0.5
10	14 - (F)	0.6	1.7	0.6	0.3
21-40 yrs.					
1	28 - (M)	0.5	1.7	0.6	0.3
2	26 - (M)	0.5	1.8	0.5	0.5
3	29 - (F)	0.6	1.7	0.6	0.4

Sp. No.	Age in years with Sex	Anterior leaflet		Posterior Leaflet	
		Rough Zone	Clear Zone	Rough Zone	Clear Zone
4	22 - (M)	0.5	2.1	0.7	0.4
5	27 - (F)	0.5	1.4	0.8	0.4
6	33 - (M)	0.6	1.5	0.6	0.4
7	36 - (F)	0.7	1.1	0.6	0.3
8	38 - (M)	0.8	1.8	0.6	0.4
9	37 - (F)	0.6	2.0	0.6	0.5
10	37 - (M)	0.7	1.7	0.6	0.4
11	36 - (M)	0.5	1.6	0.5	0.3
12	35 - (M)	0.6	1.8	0.5	0.5
13	26 - (M)	0.5	1.7	0.6	0.4
14	28 - (M)	0.5	2.0	0.7	0.4
15	29 - (F)	0.5	1.4	0.8	0.5
Above 40 years					
1	50 - (M)	0.7	2.0	0.6	0.6
2	46 - (M)	0.6	1.8	0.8	0.5
3	48 - (F)	0.7	1.6	0.8	0.6
4	47 - (M)	0.8	2.0	0.8	0.5
5	52 - (M)	0.9	2.5	0.6	0.5
6	51 - (F)	0.7	2.0	0.8	0.6
7	58 - (M)	1.0	1.4	0.6	0.5
8	65 - (M)	1.0	1.7	0.8	0.6
9	70 - (M)	0.8	1.6	0.6	0.5
10	80 - (F)	0.9	1.7	0.6	0.4
11	47 - (M)	0.6	1.8	0.8	0.5
12	49 - (M)	0.8	1.6	0.7	0.6
13	53 - (M)	0.7	2.1	0.6	0.5
14	56 - (F)	0.7	2.0	0.5	0.4

Sp. No.	Age in years with Sex	Anterior leaflet		Posterior Leaflet	
		Rough Zone	Clear Zone	Rough Zone	Clear Zone
15	59 - (F)	0.8	2.2	0.6	0.4

Table - 4 (a)

Statistical Analysis

Age group in years	Anterior Leafet				Posterior Leaflet			
	Rough Zone		Clear Zone		Rough Zone		Clear Zone	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
0-1 years	0.32	0.13	0.72	0.16	0.46	0.11	0.24	0.05
1 – 20 years	0.47	0.12	1.54	0.23	0.48	0.06	0.36	0.07
21 – 40 years	0.57	0.10	1.69	0.26	0.62	0.09	0.41	0.07
Above 40 years	0.78	0.13	1.87	0.28	0.68	0.11	0.51	0.07

Table - 4(b)

Range of Central Height of rough zone and clear zone in Anterior Leaflet

Age Group	Anterior leaflet	
	Rough Zone	Clear Zone
0 - 1 year	0.2 - 0.5 cm	0.5 - 0.9 cm
1 - 20 years	0.3 - 0.6 cm	1.2 - 2.0 cm
20 - 40 years	0.5 - 0.8 cm	1.4 - 2.1 cm
Above 40 years	0.6 - 1.0 cm	1.4 - 2.2 cm

Table - 4(c)

Range of Central Height of rough zone and clear zone in Posterior Leaflet

Age Group	Posterior Leaflet (middle scallop)	
	Rough Zone	Clear Zone

0 - 1 year	0.3 – 0.6 cm	0.2 - 0.3 cm
1 - 20 years	0.4 – 0.6 cm	0.3 - 0.5 cm
20 - 40 years	0.5 - 0.8 cm	0.3 - 0.5 cm
Above 40 years	0.5 - 0.8 cm	0.4 - 0.6 cm

Table - 5

Length of chordae tendinae in mitral valve complex

Spec No.	Age in years with Sex	Strut Chordae		Rough Zone Chordae Ave. Lth				Basal Zone Chordae		Commissural Chordae Ave Lth		Cleft Chordae	
		No.	Ave. Lth	No.	AL	No.	PL	No.	Ave. Lth	AL	PL	No.	Ave. Lth
0 – 1 year													
1	6m - (M)	2	1.05	8	0.95	7	0.94	3	1.03	1.10	1.20	2	1.05
2	8m - (M)	2	1.15	6	0.72	7	0.68	3	0.43	1.00	1.10	2	0.75
3	4m - (M)	2	0.85	8	0.63	6	0.40	3	0.43	1.10	1.00	2	0.60
4	6m - (F)	2	1.15	7	1.08	7	0.98	3	1.16	1.50	1.60	2	1.10
5	7m - (F)	2	1.25	9	1.04	8	0.98	3	1.30	1.40	1.50	2	0.85
1 – 20 Years													
1	5 - (F)	2	0.95	8	1.08	8	1.00	4	1.07	1.50	1.60	2	1.00
2	8 - (F)	2	1.00	9	1.00	7	0.94	3	1.30	1.40	1.50	2	0.90
3	10 - (F)	2	1.05	9	1.00	8	0.98	3	1.20	1.60	1.70	2	1.05
4	11 - (M)	2	1.15	8	0.97	7	1.04	3	1.13	1.50	1.70	2	1.00
5	12 - (M)	2	1.05	9	0.98	7	1.11	3	1.16	1.60	1.70	2	0.85
6	16 - (M)	2	1.20	8	0.98	7	1.22	4	0.85	1.50	1.60	2	0.75
7	17 - (M)	2	1.00	9	1.00	7	1.02	3	0.90	1.60	1.80	2	0.85
8	18 - (M)	2	1.15	9	1.00	8	0.98	3	1.10	1.50	1.60	2	1.25
9	17 - (F)	2	1.05	8	0.97	7	1.04	3	1.10	1.60	1.70	2	1.70
10	14 - (F)	2	1.15	9	0.97	7	1.11	3	1.20	1.50	1.70	2	1.90
21 – 40 years													
1	28 - (M)	2	1.05	8	0.98	7	1.22	3	1.13	1.70	1.80	2	1.75
2	26 - (M)	2	1.10	9	1.00	9	1.02	3	1.10	1.60	1.80	2	1.40
3	29 - (F)	2	1.25	9	1.12	7	1.04	3	1.13	1.50	1.70	2	0.85
4	22 - (M)	2	1.25	9	1.14	8	1.13	3	1.10	1.60	1.80	2	0.95
5	27 - (F)	2	1.05	9	1.02	7	1.00	3	1.13	1.50	1.60	2	0.85
6	33 - (M)	2	1.05	9	1.10	8	1.08	3	1.10	1.60	1.80	2	0.85
7	36 - (F)		1.15	9	1.05	7	1.15	3	0.93	1.70	1.80	2	0.95
8	38 - (M)	2	1.15	9	1.07	8	1.13	3	1.00	1.80	1.90	2	1.10

Spec No.	Age in years with Sex	Strut Chordae		Rough Zone Chordae Ave. Lth				Basal Zone Chordae		Commissural Chordae Ave Lth		Cleft Chordae	
		No.	Ave. Lth	No.	AL	No.	PL	No.	Ave. Lth	AL	PL	No.	Ave. Lth
9	37 - (F)	2	1.25	9	1.02	9	1.02	3	0.93	1.50	1.70	2	1.15
10	37 - (M)	2	1.15	9	1.08	8	1.13	3	1.10	1.50	1.60	4	1.07
11	36 - (M)	2	1.25	9	1.06	7	1.04	3	1.20	1.50	1.60	2	0.85
12	35 - (M)	3	1.20	8	0.97	8	1.00	3	1.16	1.70	1.80	2	0.75
13	26 - (M)	2	1.25	9	1.14	8	1.13	3	1.10	1.60	1.70	2	0.95
14	28 - (M)	2	1.05	8	1.01	7	1.04	4	1.10	1.50	1.60	2	0.65
15	29 - (F)	2	1.10	9	0.96	8	0.97	3	1.20	1.60	1.70	2	1.15
Above 40 years													
1	50 - (M)	2	1.25	8	1.05	8	1.07	3	1.10	1.50	1.60	2	1.00
2	46 - (M)	2	1.05	9	1.13	8	1.13	3	1.10	1.50	1.60	2	0.95
3	48 - (F)	2	1.15	8	1.05	7	1.05	3	1.10	1.60	1.70	2	1.00
4	47 - (M)	2	1.10	9	0.83	7	1.01	3	0.90	1.60	1.80	2	0.85
5	52 - (M)	2	1.15	9	1.04	7	1.17	3	1.13	1.60	1.70	2	0.95
6	51 - (F)	2	1.15	9	1.28	8	1.03	3	1.10	1.60	1.80	2	0.90
7	58 - (M)	2	1.25	8	1.20	7	1.10	3	1.16	1.50	1.70	2	0.80
8	65 - (M)	2	1.05	8	0.98	8	1.01	3	1.16	1.80	1.90	2	0.85
9	70 - (M)	2	1.10	7	1.12	8	1.08	3	1.10	1.80	1.90	2	0.75
10	80 - (F)	2	1.05	8	1.08	8	1.15	3	1.06	1.50	1.70	2	0.75
11	47 - (M)	2	0.40	6	0.20	7	0.20	4	0.17	0.20	0.30	2	0.25
12	49 - (M)	2	0.25	5	0.18	6	0.21	3	0.13	0.20	0.30	2	0.30
13	53 - (M)	2	0.15	6	0.21	5	0.18	3	0.30	0.30	0.20	2	0.35
14	56 - (F)	2	0.15	6	0.16	8	0.23	3	0.20	0.20	0.40	2	0.40
15	59 - (F)	2	0.25	6	0.20	5	0.20	3	0.23	0.30	0.40	2	0.30

Table - 6

Number of Chordae at Origin

No. of Chordae	Anterolateral Papillary Muscle	Posteromedial Papillary Muscle
1 - 3	2 (4%)	-
4 – 6	11 (24%)	10 (22%)
7 - 9	13 (29%)	13 (29%)
10 - 12	10 (22%)	13 (29%)
13 - 16	5 (11%)	7 (16%)
17 - 20	2 (4%)	2 (4%)
21 - 23	2 (4%)	-

Table - 6(a)

Number of Chordae at insertion into leaflet

No. of Chordae	Anterior Leaflet	Posterior Leaflet
10 - 20	3 (7%)	5 (11%)
21 - 30	13 (29%)	11 (24%)
31 - 40	10 (22%)	12 (27%)
41 - 50	12 (27%)	10 (22%)
51 - 60	3 (7%)	3 (7%)
61 - 70	2 (4%)	2 (4%)
71 - 80	2 (4%)	2 (4%)

Table - 7

Patterns of Papillary Muscles

No. of Bellies	Pattern	AL group	Pm group
Single	Conical	14 (31%)	9 (20%)
	Mamillated	5 (11%)	8 (18%)
	Flat topped	5 (11%)	3 (7%)
	Grooved	4 (9%)	2 (4%)
Two	Two tired	6 (13%)	7 (16%)
	Interlinked	2 (4%)	4 (9%)
	Parallel	2 (4%)	2 (4%)
	Arched	-	2 (4%)
	V	1 (2%)	2 (4%)
	Y	1 (2%)	1 (2%)
	H	1 (2%)	1 (2%)
Three	Parallel	1 (2%)	1 (2%)
Four	Parallel	1 (2%)	1 (2%)
	Interlinked	1 (2%)	-
Five	Scattered	1 (2%)	1 (2%)
Six	Parallel	0	1 (2%)

Table - 8

Origin of Papillary Muscle

Site	**Anterolateral Papillary Muscle**	**Posteromedial Papillary Muscle**
Upper third	18 (40%)	12 (27%)
Middle third	24 (53%)	30 (67%)
Lower third	3 (7%)	3 (7%)

Table - 9

Extent of Protrusion of Papillary Muscle

	Anterolateral Papillary Muscle	**Posteromedial Papillary Muscle**
Mostly intra luminal	11 (24%)	9 (20%)
Mostly intra luminal with tip enclosed	10 (22%)	13 (29%)
Equally sessile and intraluminal	22 (49%)	20 (44%)
Mosty sessile	2 (4%)	3 (7%)

Fig. 14(a). Dissection of Specimen.

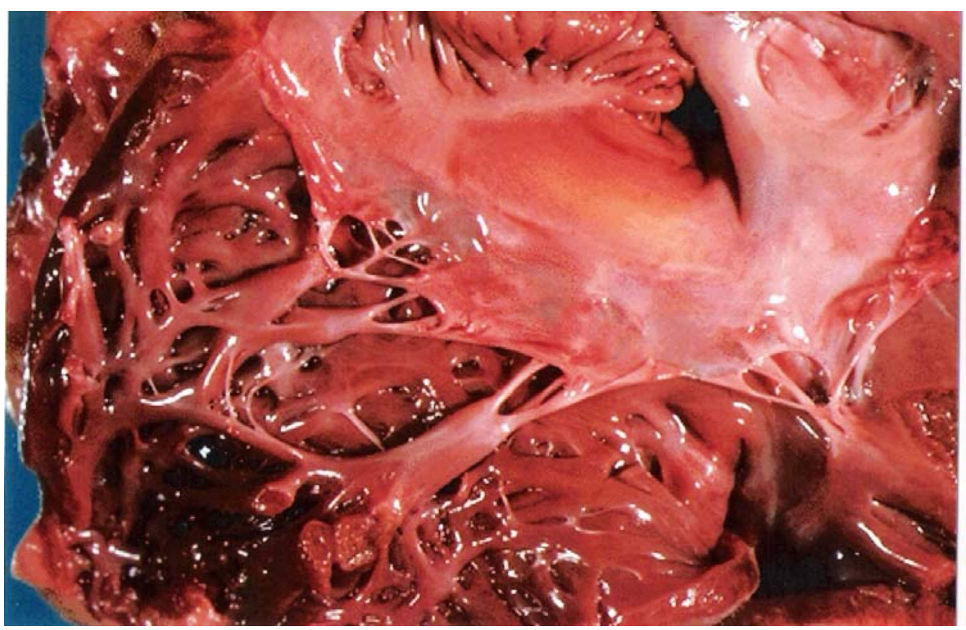


Fig. 14(b). Left ventricle seen after incision.

Fig. 15: Mitral annulus measurement.

Fig. 16: Measurement of Commissural Length.

Fig. 17: Measurement of anterior and posterior leaflet.

Fig.18: Measurement of length of chordae tendineae

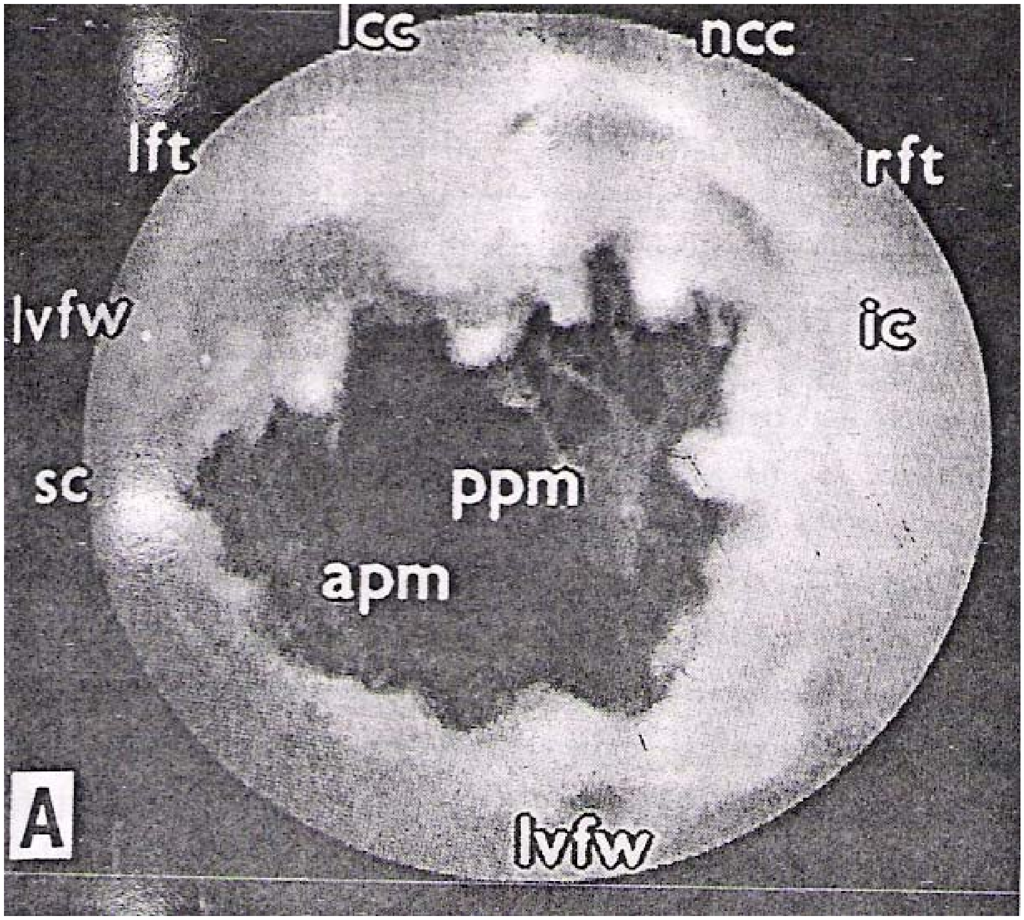


Fig. 1: Left Atrial view of the mitral valve
Apm = anterior papillary muscle; ic = inferior commissure; lcc = left coronary cusp; lft = left fibrous trigone; lvfw = left ventricular free wall; ncc = non coronary cusp; rft = right fibrous trigone; ppm = posterior papillary muscle; sc = superior commisure

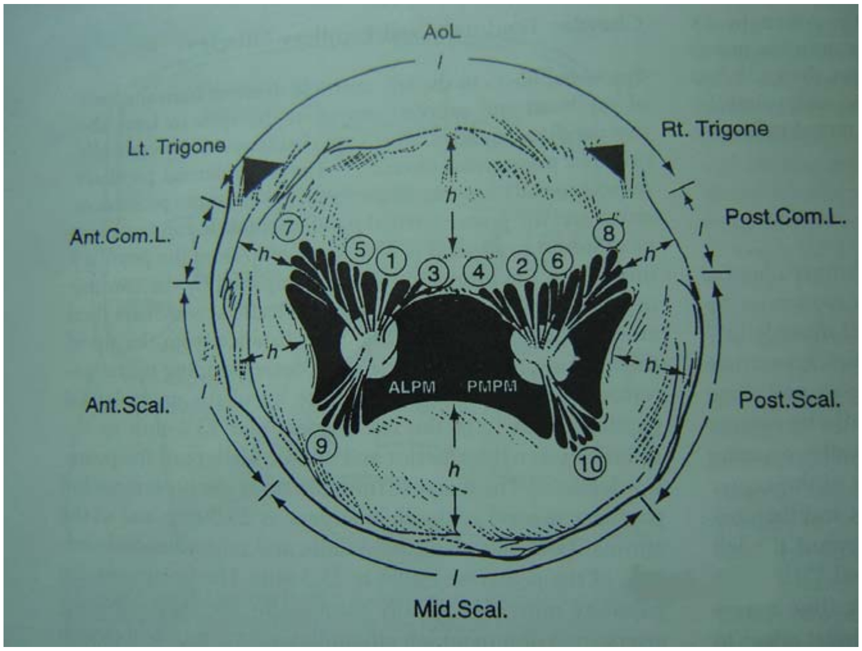


Fig. 2: Mitral apparatus. ALPM, Anterolateral papillary muscle; PMPM, Posteromedial papillary muscle; AoL, Aortic leaflet; Ant.Com.L., Anterior commissural leaflet; Post.Com.L., Posterior commissural leaflet; Ant.Scal., Anterior scallop; Post.Scal., Postterior scallop; Mid.Scal., Middle scallop; h, height of leaflet; l, length of attachment of leaflet; Rt. Trigone, right fibrous trigone; Lt. Trigone, left fibrous trigone; 1, anterior main chordae; 2, posterior main chorda; 3, anterior paramedial chordae; 4, posterior paramedical chordae; 5, anterior paracommissural chordae; 6, posterior paracommissural chordae; 7, anterior commissural chordae; 8, posterior commissural chordae; 9, anterior cleft chordae; 10, posterior cleft chordae.

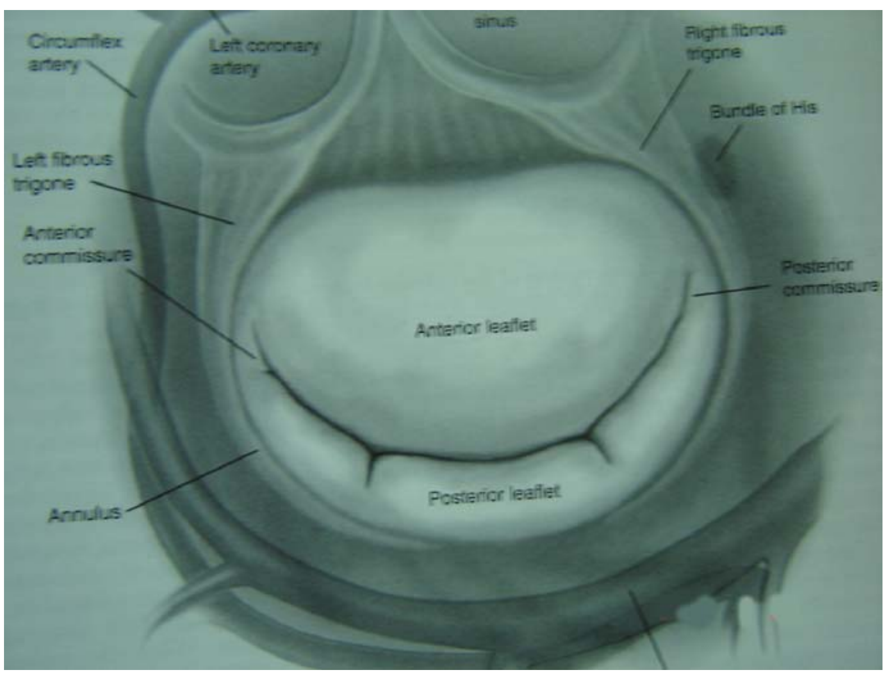


Fig .3: D shaped mitral annulus

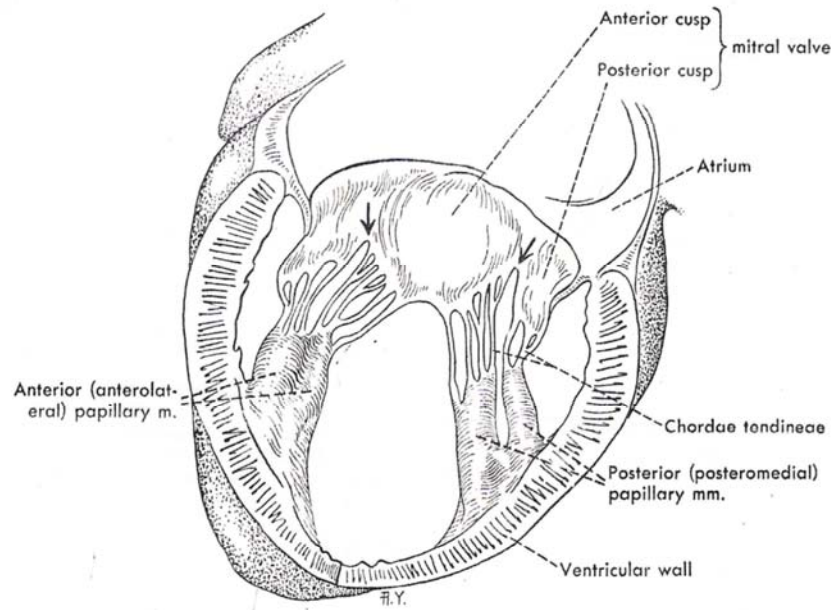


Fig. 4: Schematic of the interior of the left ventricle, opened to show the papillary muscles and the bicuspid valve. The arrows on the valves indicate the commissures, or valvular junctions; note that in this case the groove between the two posterior papillary muscles and the groove at the apex of the anterior papillary muscle point to the commusures

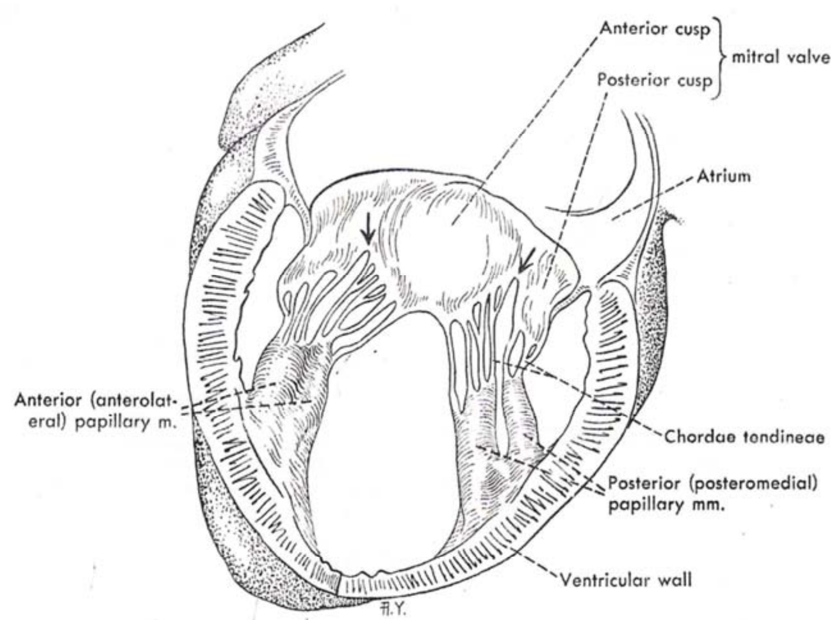


Fig. 4: Schematic of the interior of the left ventricle, opened to show the papillary muscles and the bicuspid valve. The arrows on the valves indicate the commissures, or valvular junctions; note that in this case the groove between the two posterior papillary muscles and the groove at the apex of the anterior papillary muscle point to the commusures

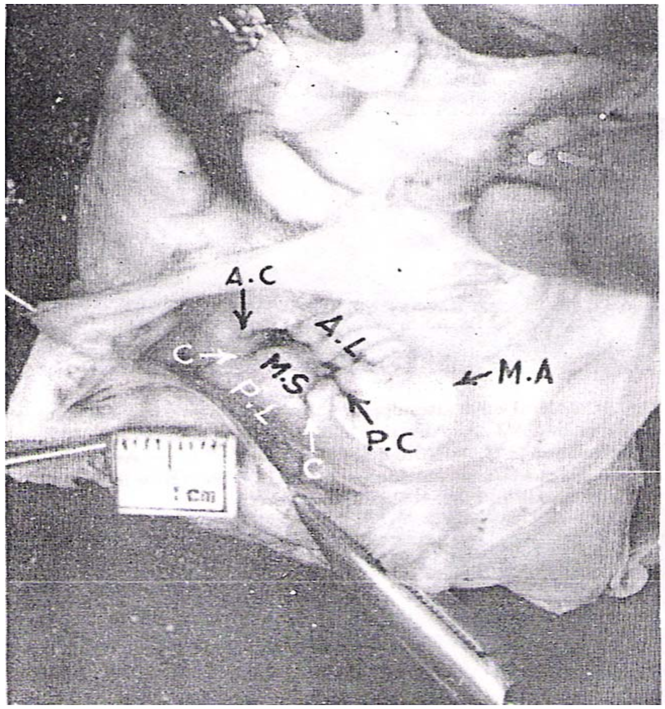


Fig. 5(a): Left atrial view of the mitral valve in the age group of 1 – 20 yrs. A.L = Anterior leaflet; P.L. = Posterior leaflet; A.C = Anterolateral commissure; P.C. = Posteromedial commissure; M.A. = Mitral Annulus.

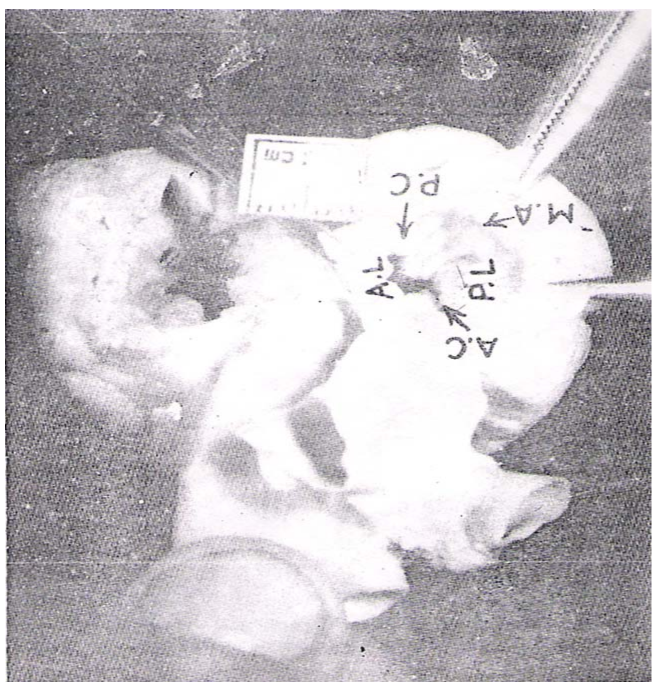


Fig. 5(b): Left atrial view of the mitral valve in the age group of 21 – 40 yrs. A.L = Anterior leaflet; P.L. = Posterior leaflet; A.C = Anterolateral commissure; P.C. = Posteromedial commissure; C = Clefts intervening between three scallops.

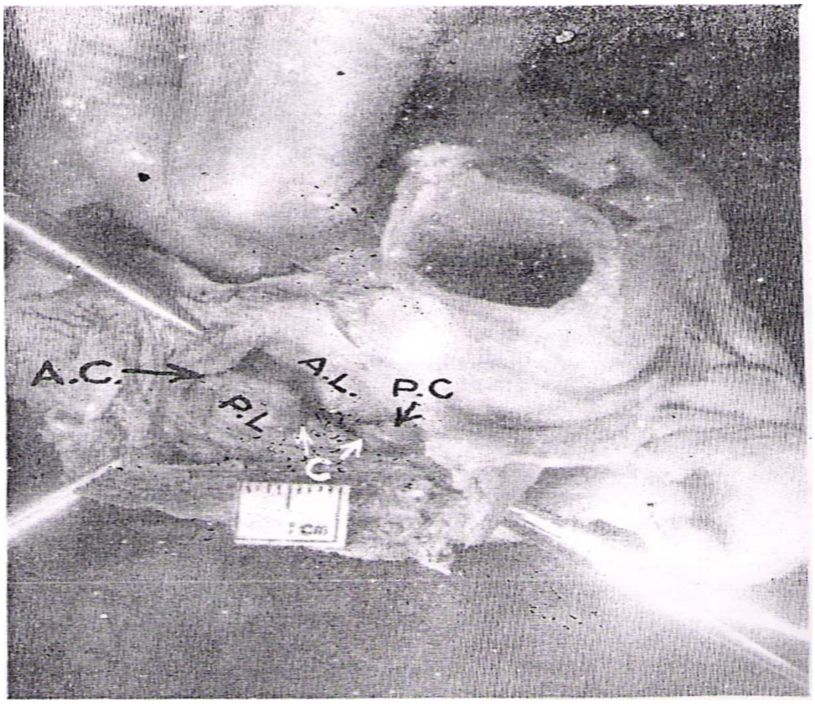


Fig.5(c): Left atrial view of the mitral valve in the age group of above 40 yrs. A.L = Anterior leaflet; P.L. = Posterior leaflet; A.C = Anterolateral commissure; P.C. = Posteromedial commissure; M.S = Middle Scallop; C = Clefts intervening between three scallops.

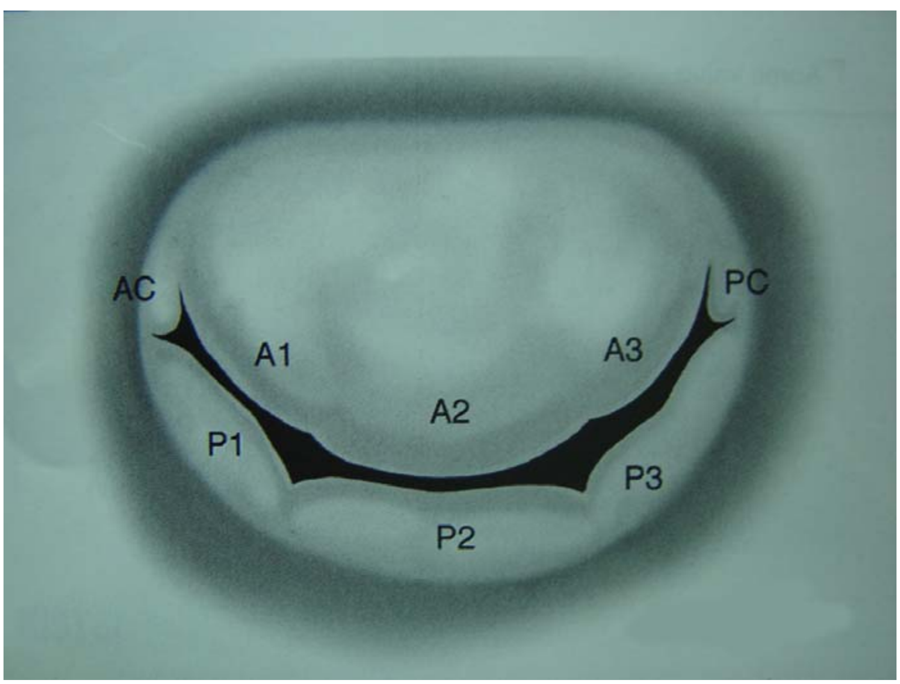


Fig. 6: Segmental description of Carpentier et al.

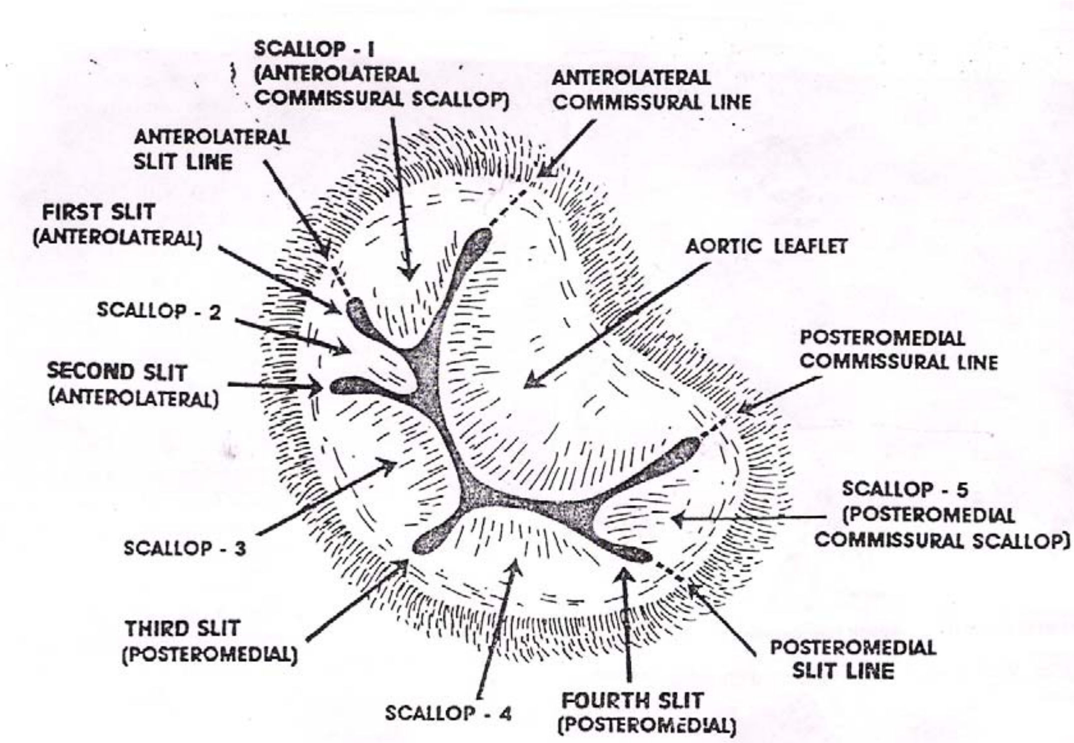


Fig.7(a): Commissural/slit lines and scallops of posterior leaflet.

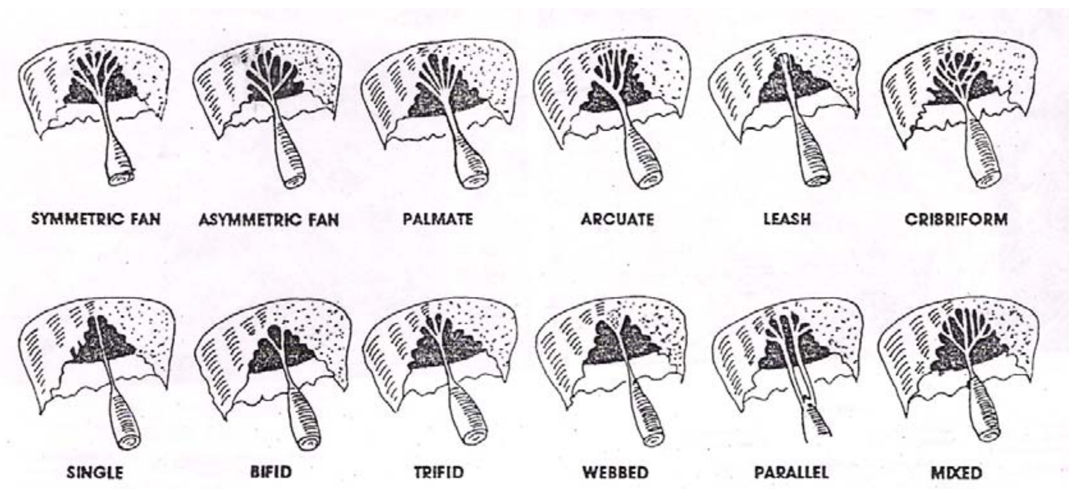


Fig. 7(b): Varied configuration of the commissural chordae.

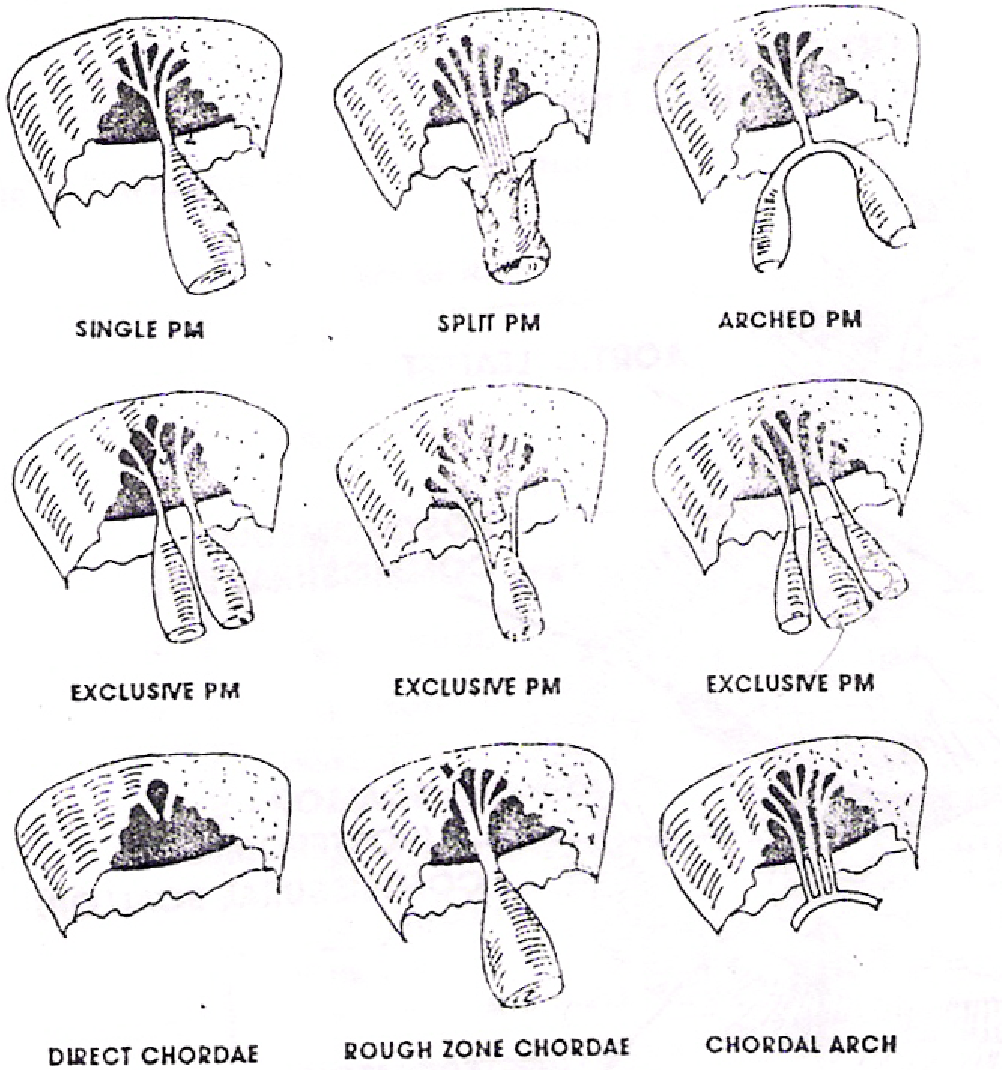


Fig. 7(c): Varied origin of Commissural chordae

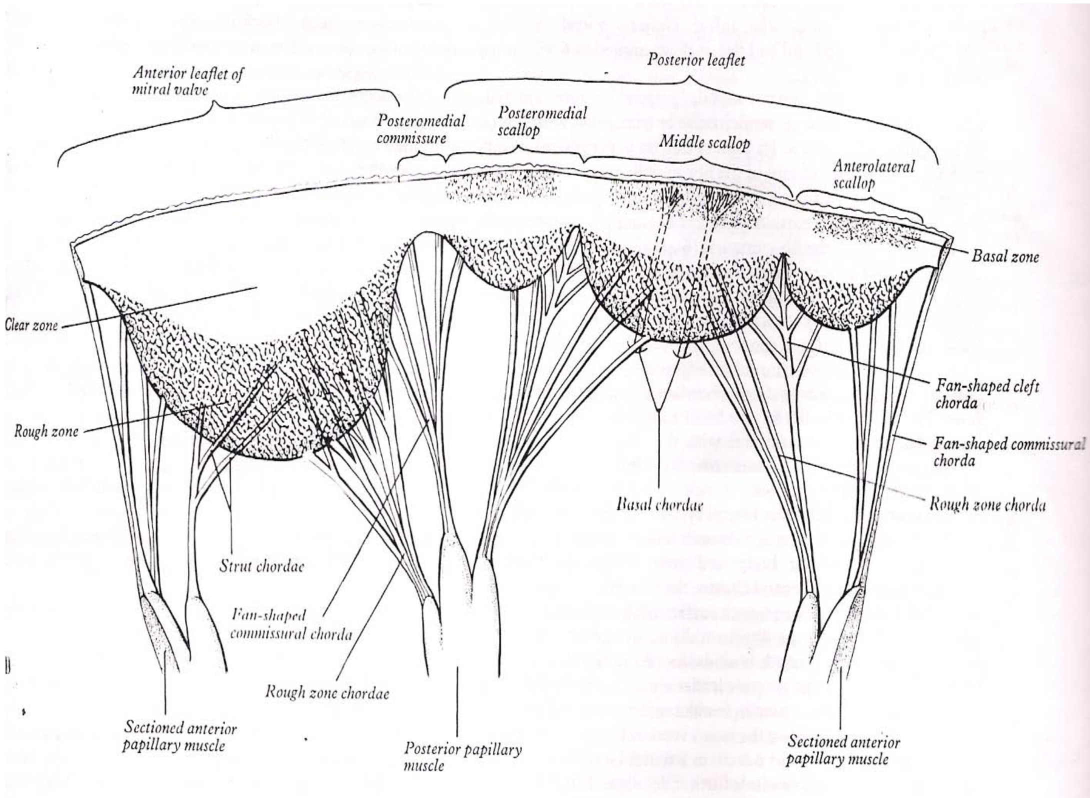


Fig 8(a). Types of chordae tendineae

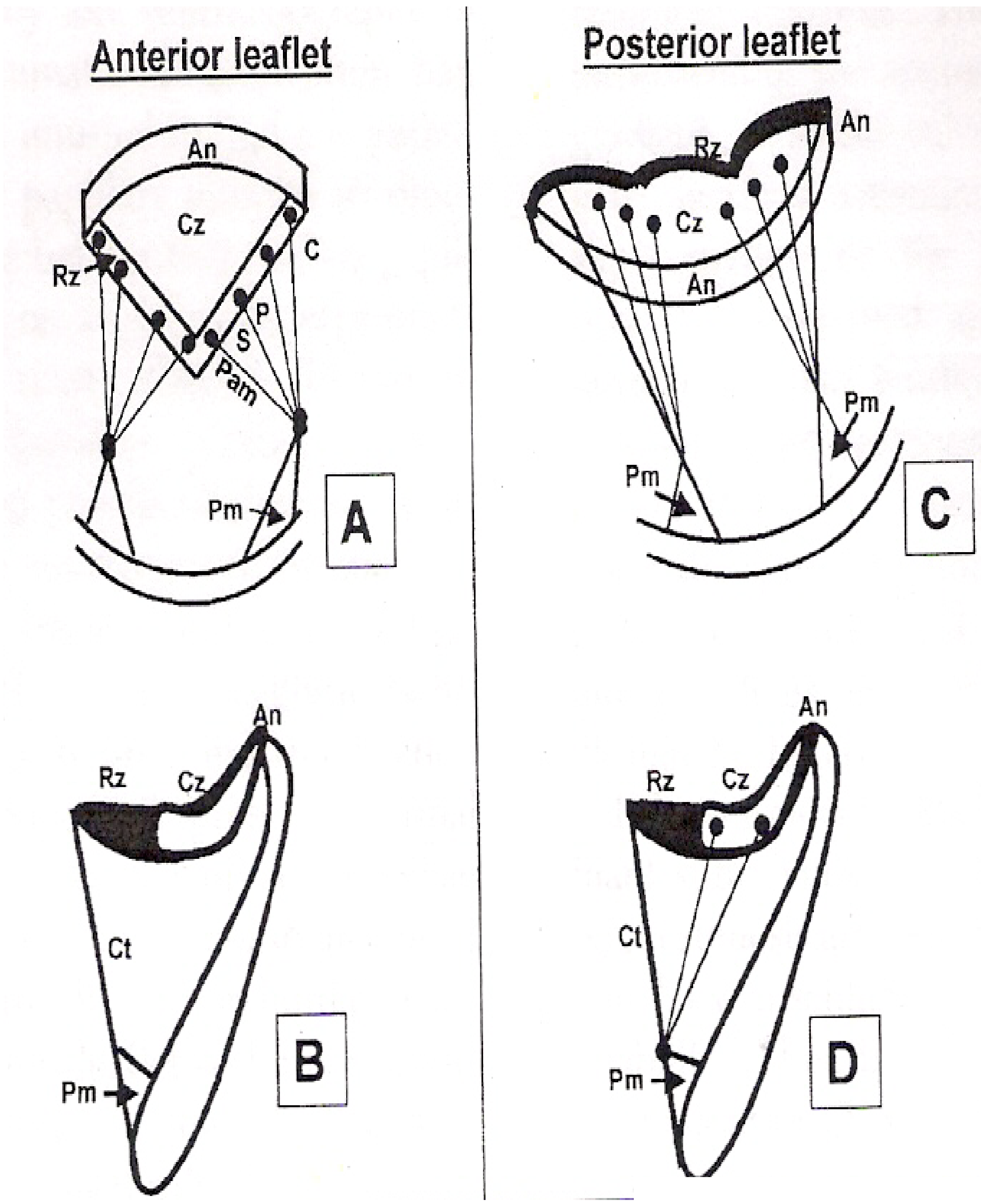


Fig. 9: A schematic of the classification of Lam et al showing course and point of insertion of chordae tendineae directed to the anterior and posterior mitral leaflets. Top left, A and top right, C present ventricular view of the anterior and posterior mitral leaflets, respectively. Bottom left, B and bottom right, D, present a lateral view, respectively. An = annulus; Cz = clear zone; Rz = rough zone; Pm = papillary muscle; Ct = chordae tendineae; C = commissural; P = paracommissural; pam = paramedian; S = strut.

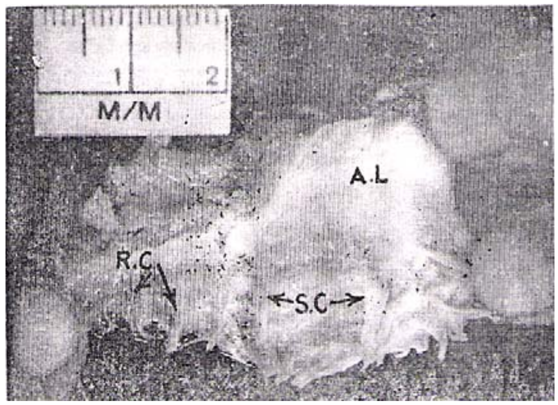


Fig. 10(a). Ventricular view of mitral valve in the age group 1 – 20 yrs. A.L = Anterior leaflet; S.C = Strut chordae; R.C = Rough zone chordae.

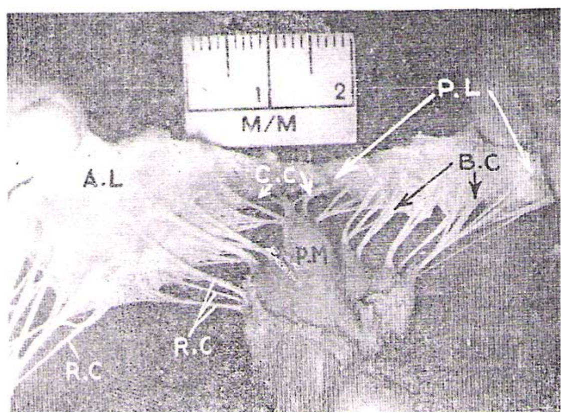


Fig. 10(b): Ventricular view of mitral valve in the age group 21 – 40 yrs. A.L = Anterior leaflet; S.C = Strut chordae; B.C = Basal chordae; C.C = Commissural chordae; R.C = Rough zone chordae; P.M. = Papillary Muscle.

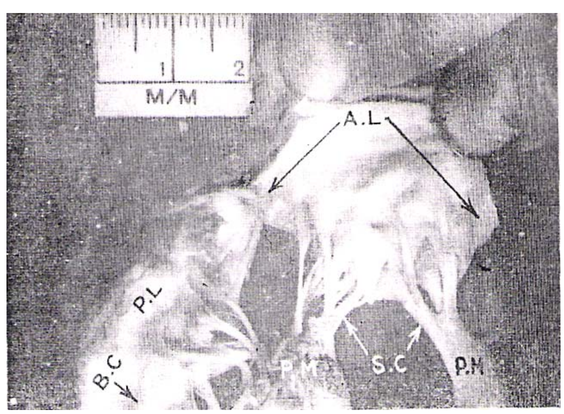
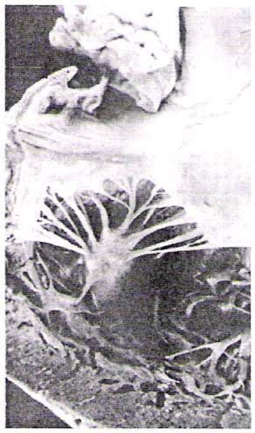
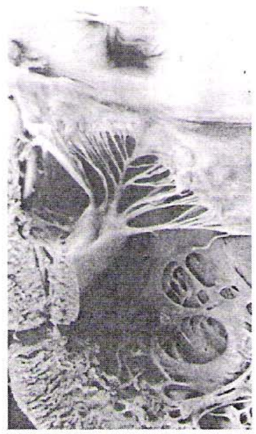
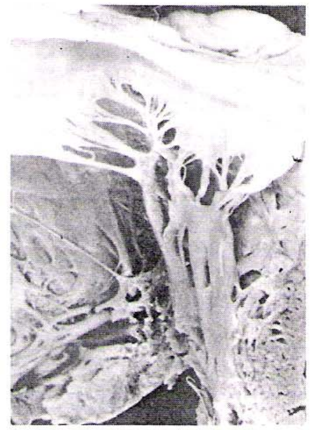


Fig. 10(c): Ventricular view of mitral valve in the age group of above 40 yrs. A.L = Anterior leaflet; S.C = Strut chordae; B.C = Basal chordae; R.C = Rough zone chordae; P.M. = Papillary Muscle.


A

B

S

D

E

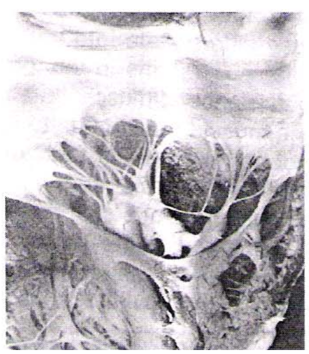
F



Fig. 11: Varied pattern of fanning out of chordae

G H

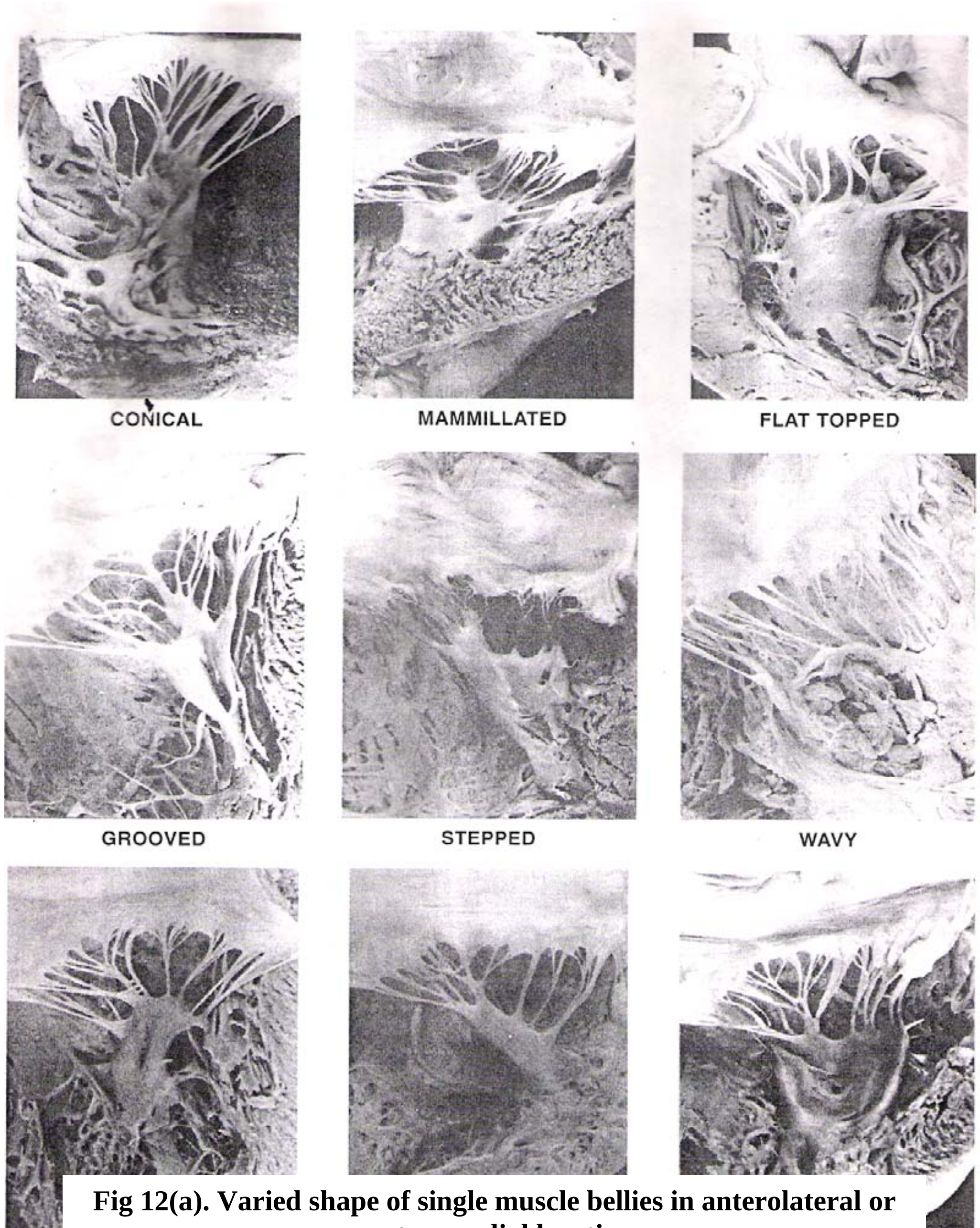


Fig 12(a). Varied shape of single muscle bellies in anterolateral or posteromedial location

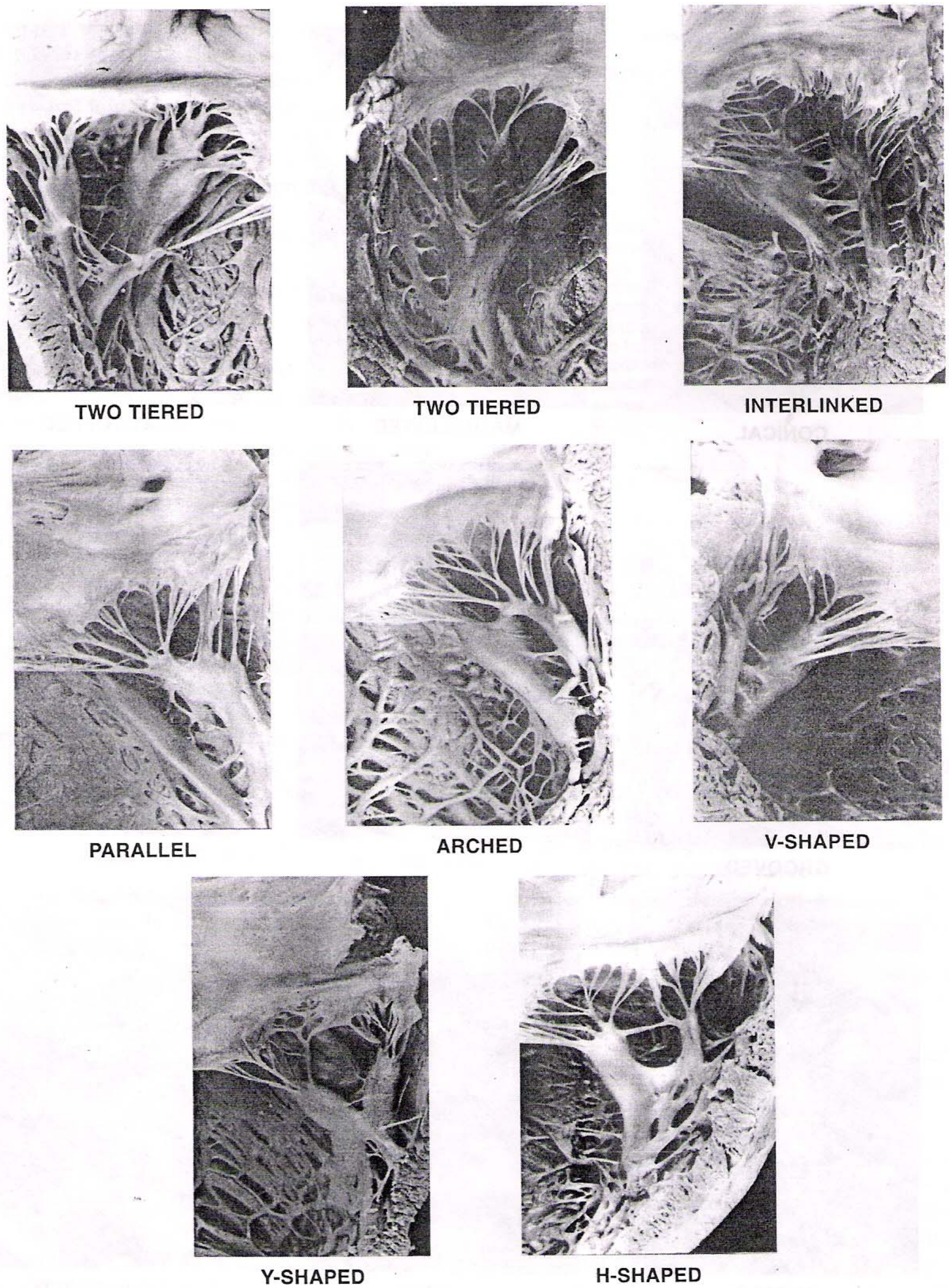


Fig 12(b). Varied Configuration of two muscle bellies in anterolateral or posteromedial location

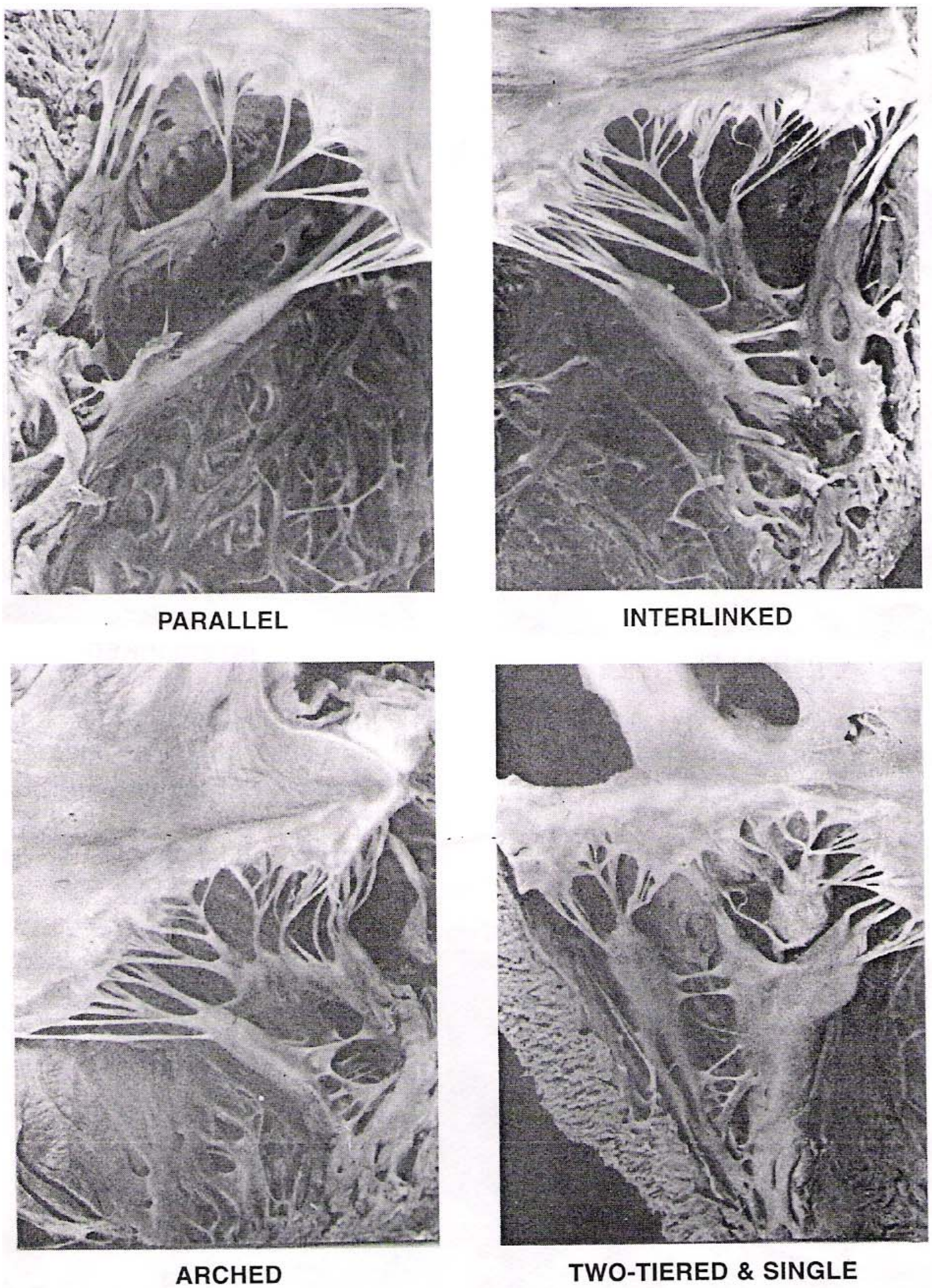


Fig 12(c). Varied Configuration of three muscle bellies in anterolateral or posteromedial location

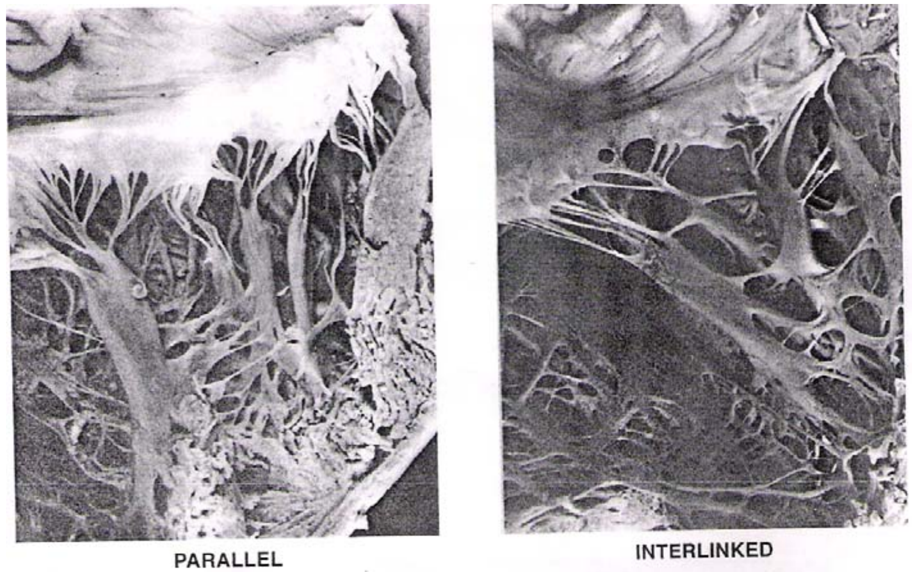


Fig 12(d). Varied Configuration of four muscle bellies in anterolateral or posteromedial location

Fig 12(e). Varied Configuration of five muscle bellies in anterolateral or posteromedial location

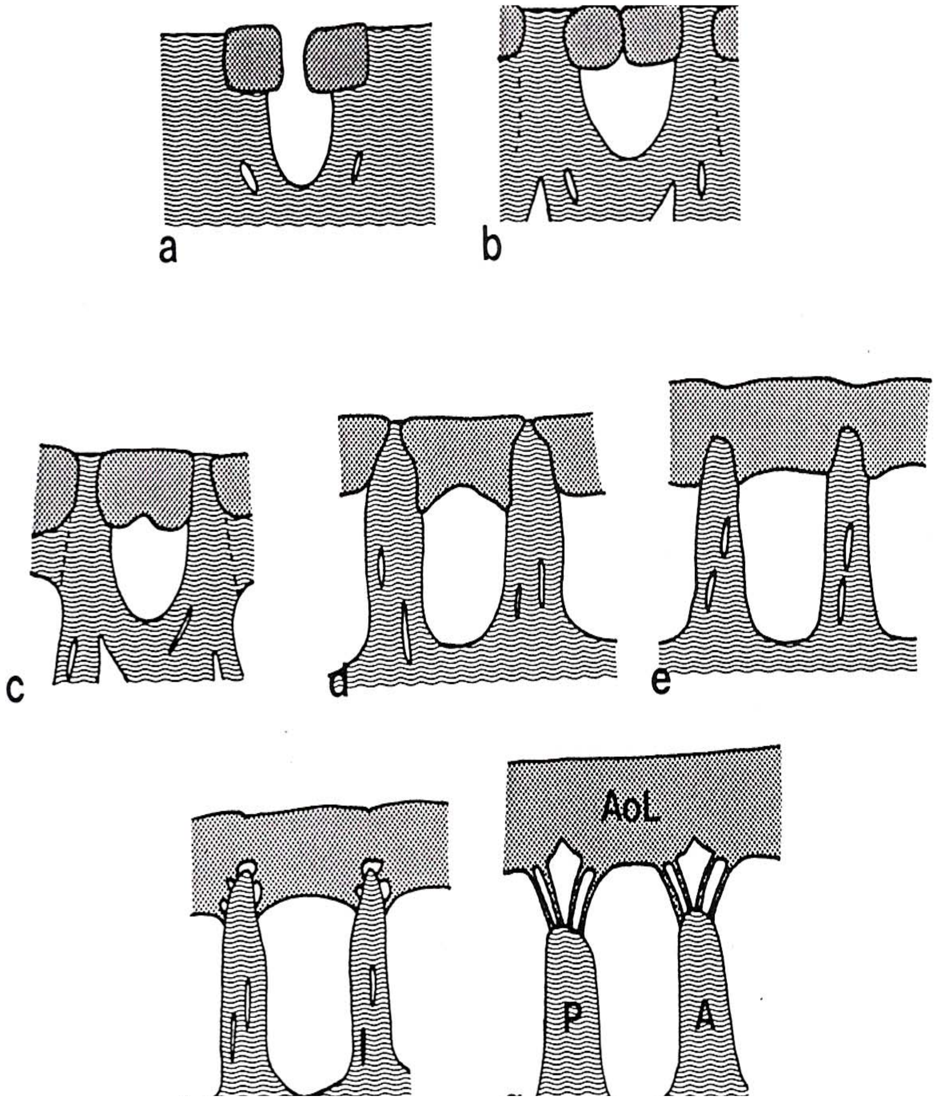


Fig 13. Development of Papillary Muscle

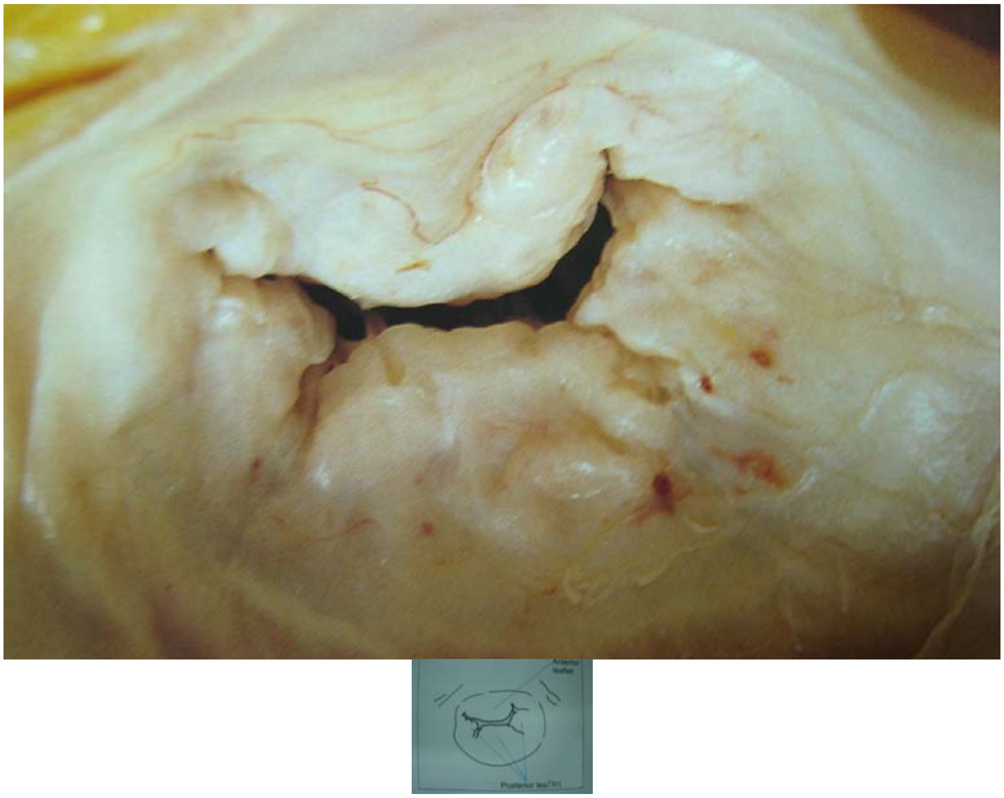


Fig 19(a). Mitral valve annulus of 70 yrs old male viewed from the atrial side.

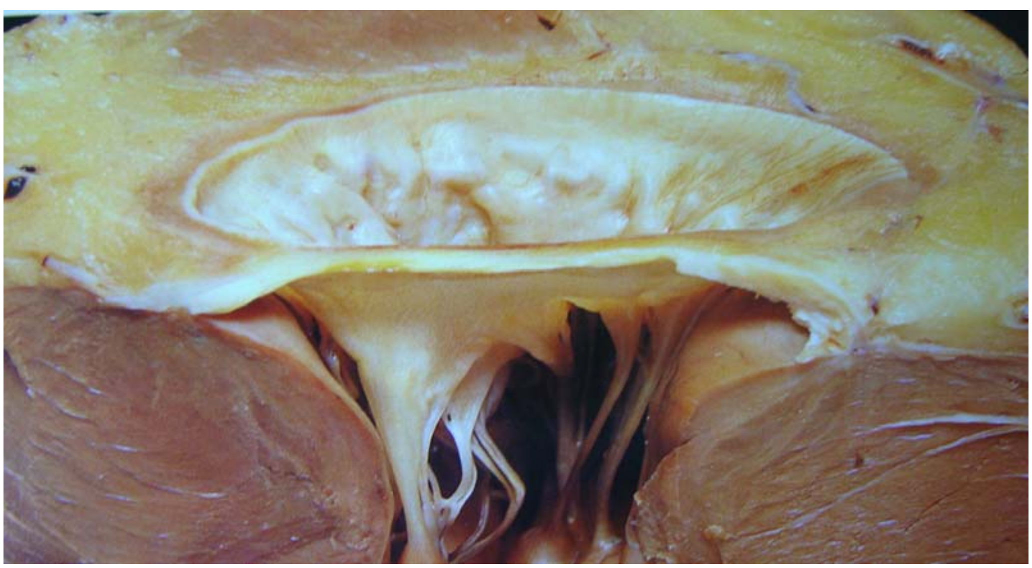


Fig 19(b). Normal Funnel shaped structure of the Mitral valve of a 49 yr old man.

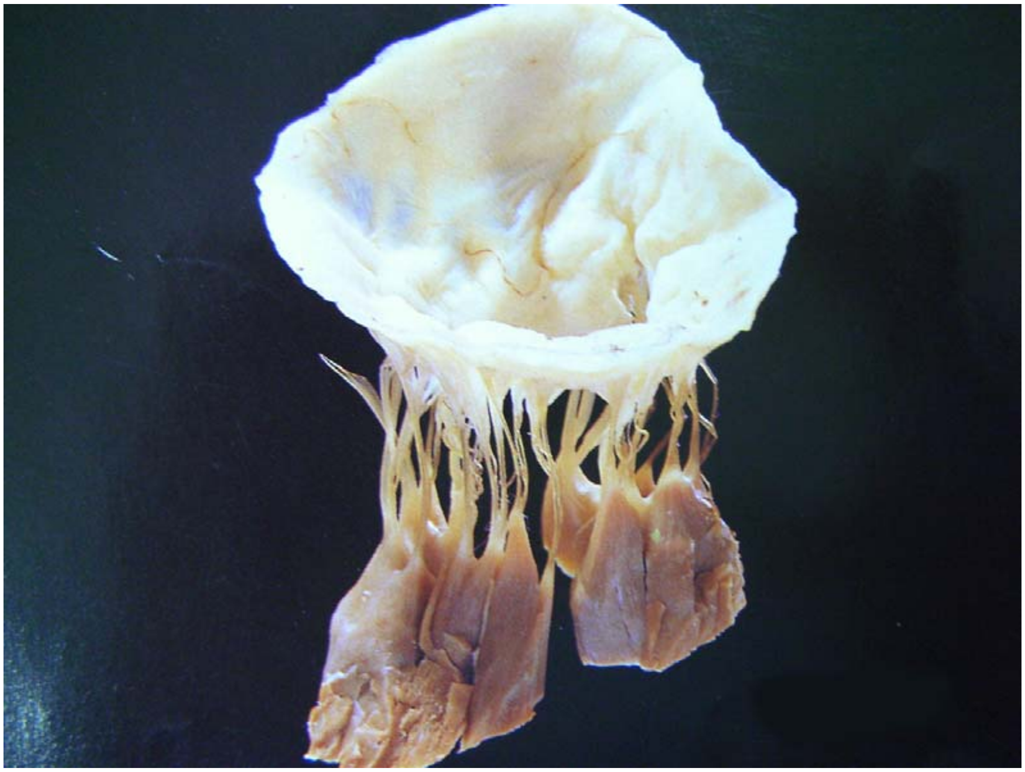


Fig 19(c). Resected Mitral valve from the 70 yrs old man.

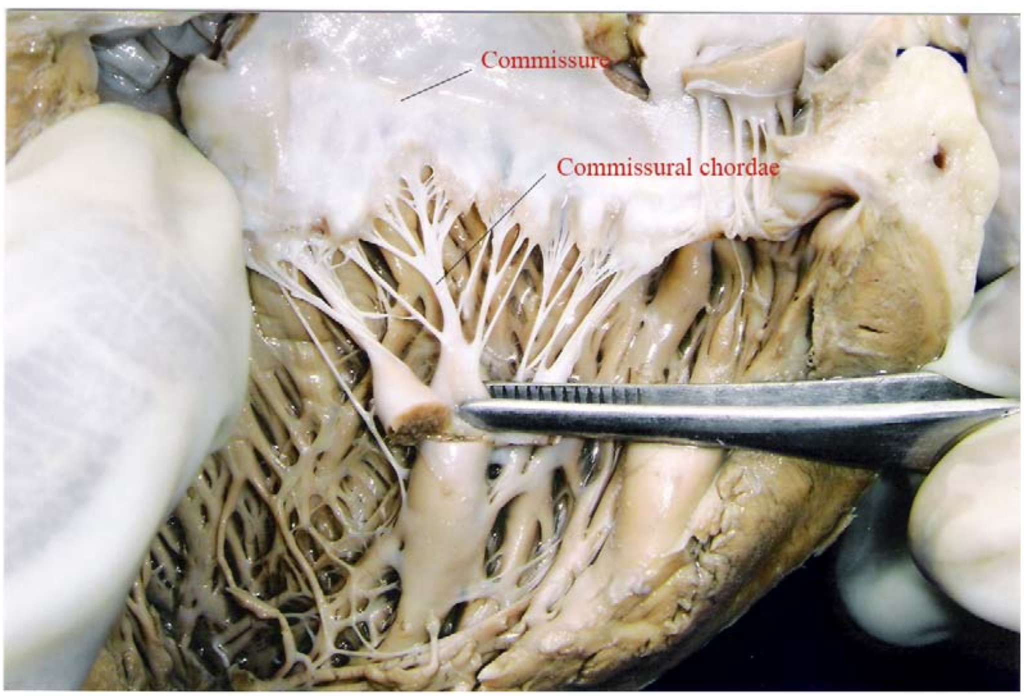


Fig 20. Commissure and Commissural chordae

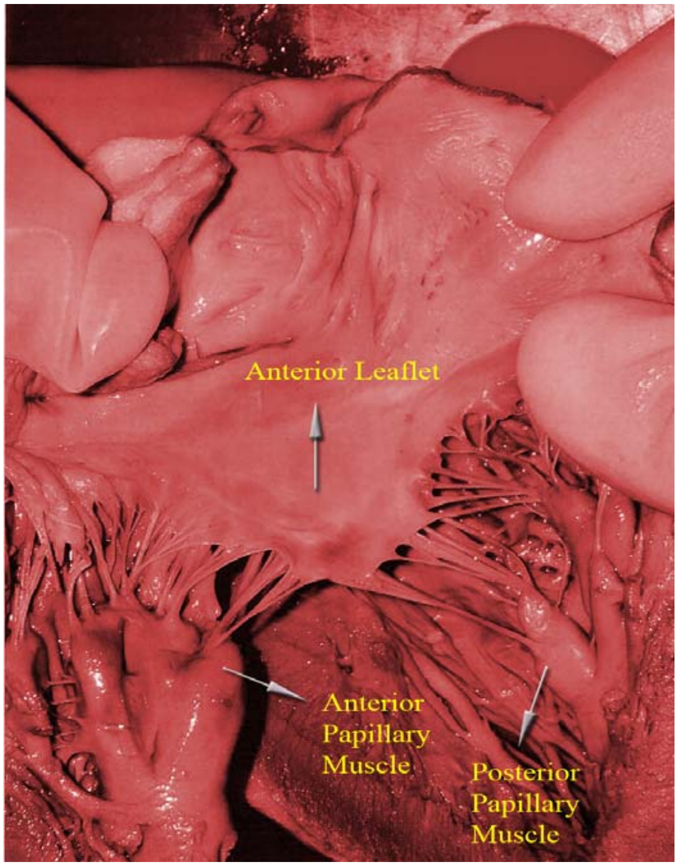


Fig 21. Anterior leaflet receiving chordae tendineae from both papillary muscles.

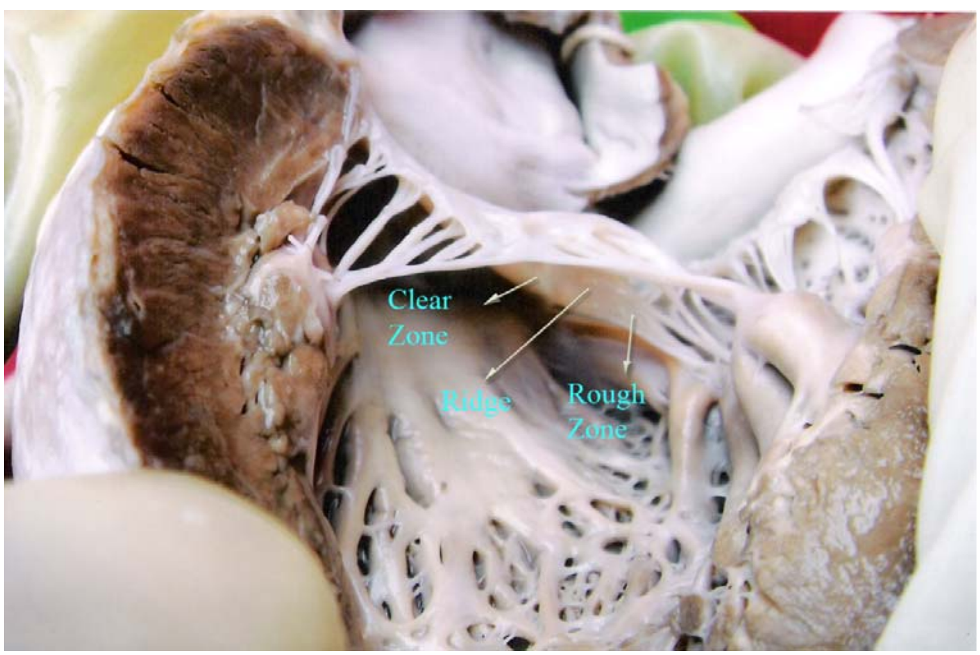


Fig 22. Ridge separating the rough zone and clear zone of anterior leaflet.

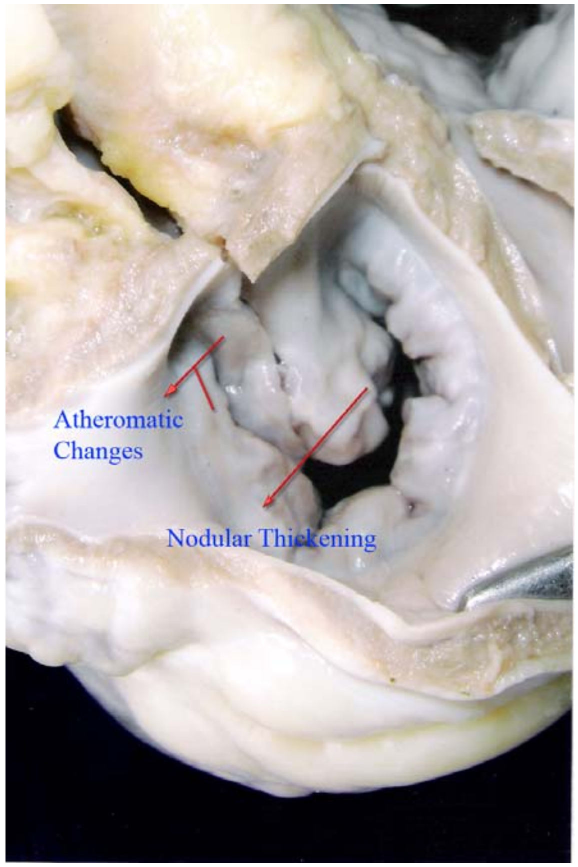


Fig 23. Atheromatic changes and nodular thickening in anterior leaflet

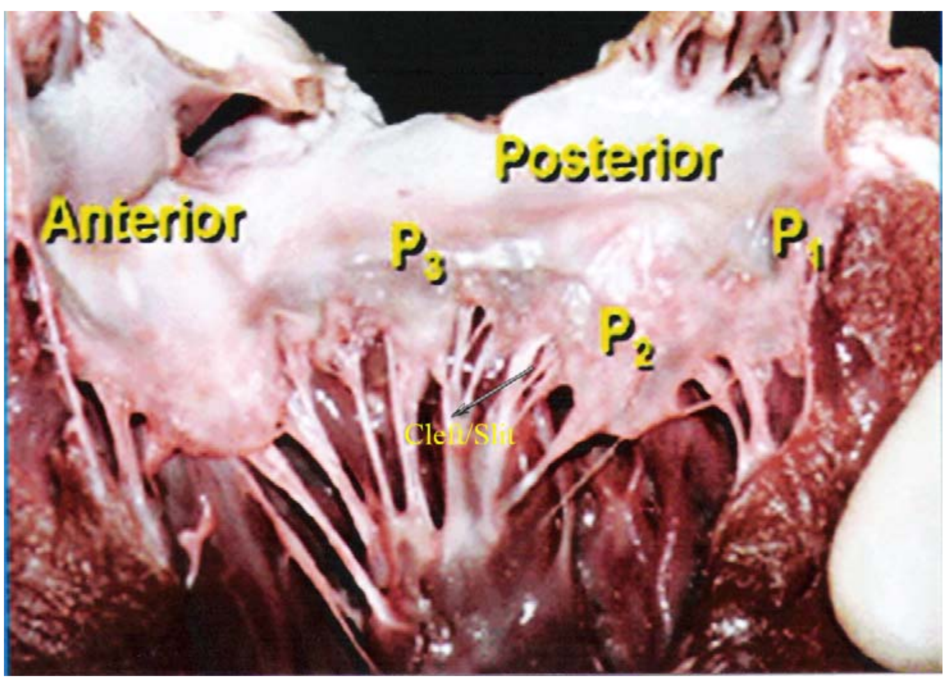


Fig 24. Clefts / Slits dividing the posterior leaflet into three scallops.

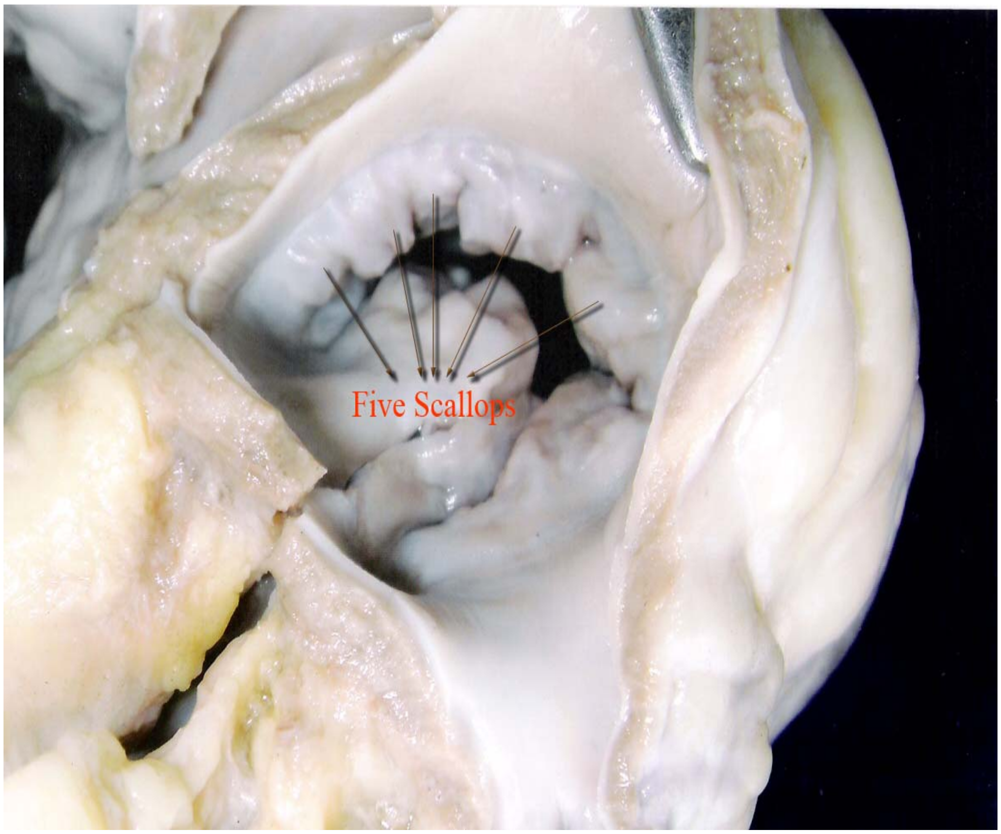


Fig 25. Five scallops and four clefts in posterior leaflet.

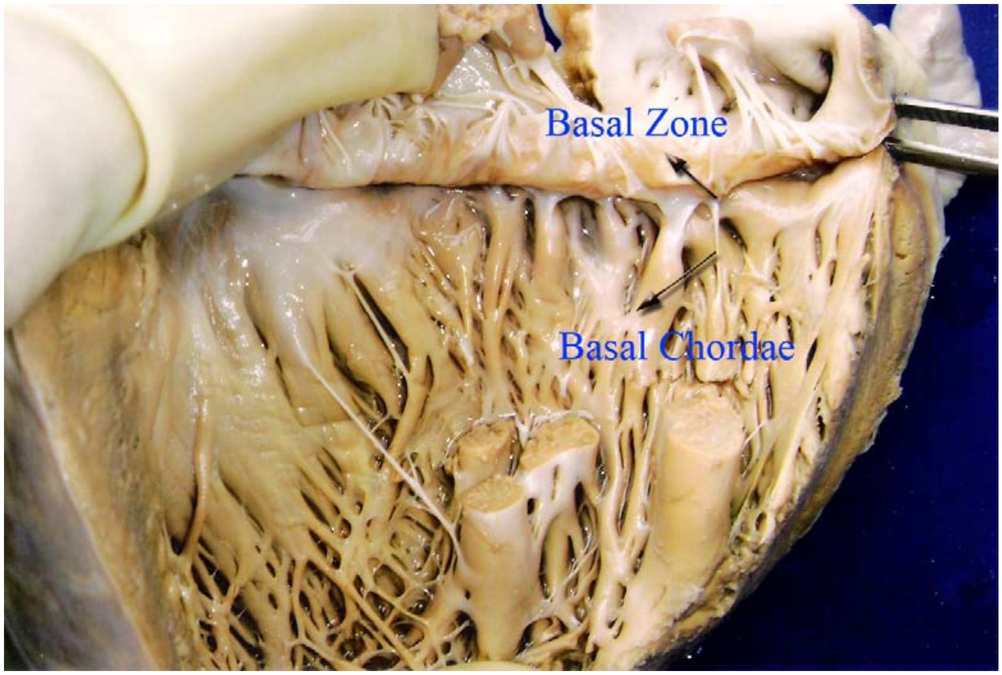


Fig 26. Basal zone and basal chordae in posterior leaflet.

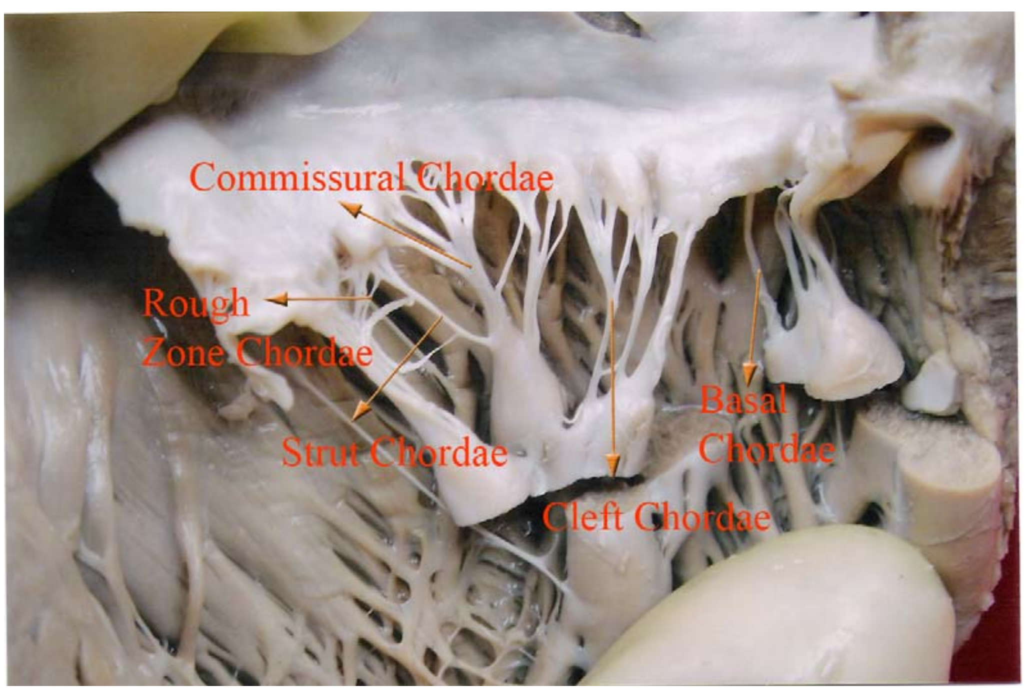


Fig 27. Types of chordae.

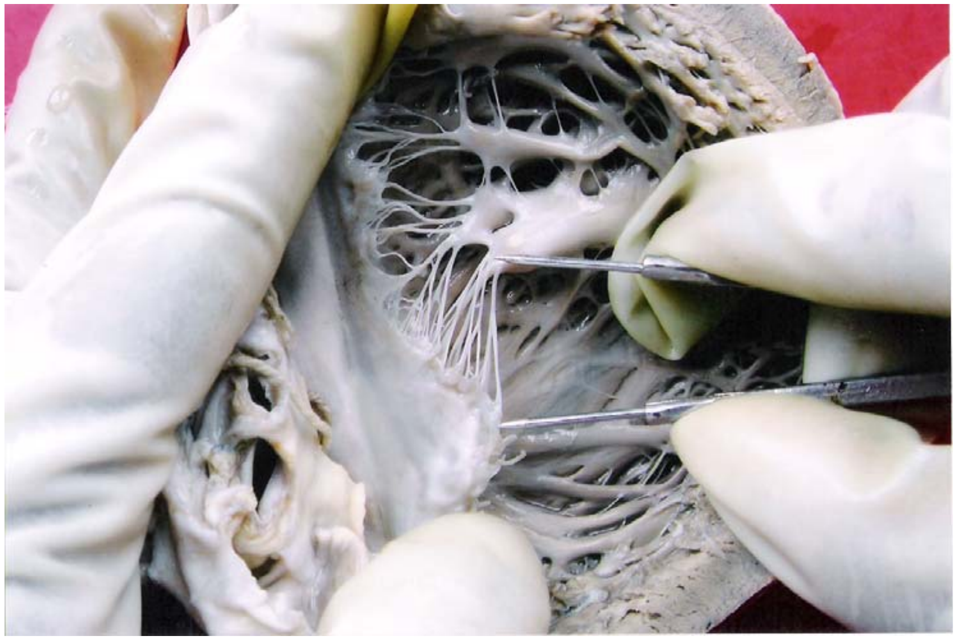


Fig 28. Number of chordae at origin.

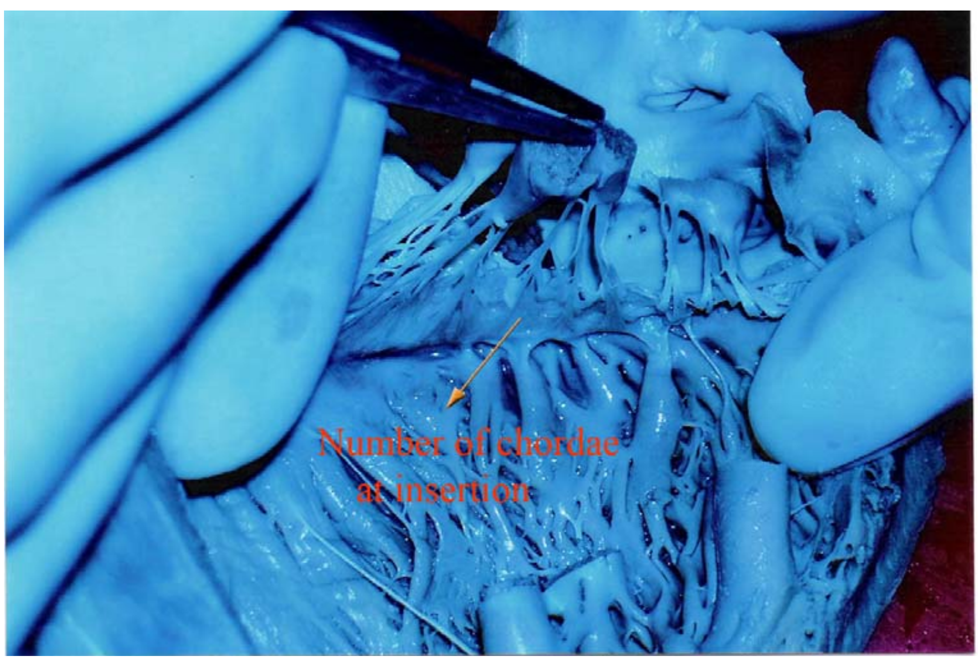
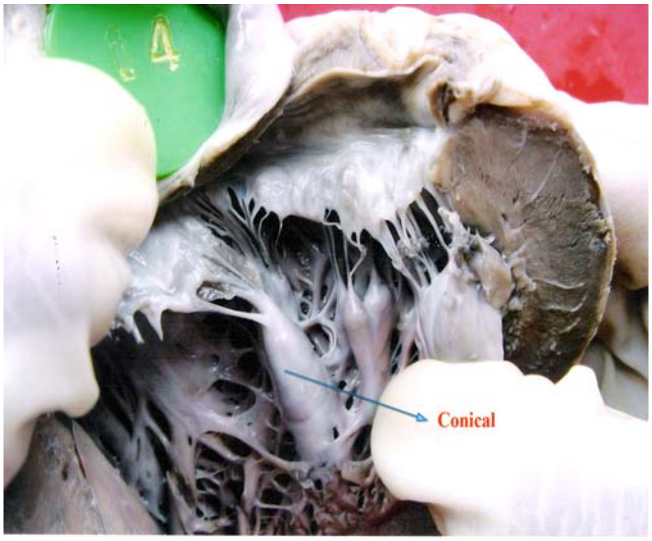
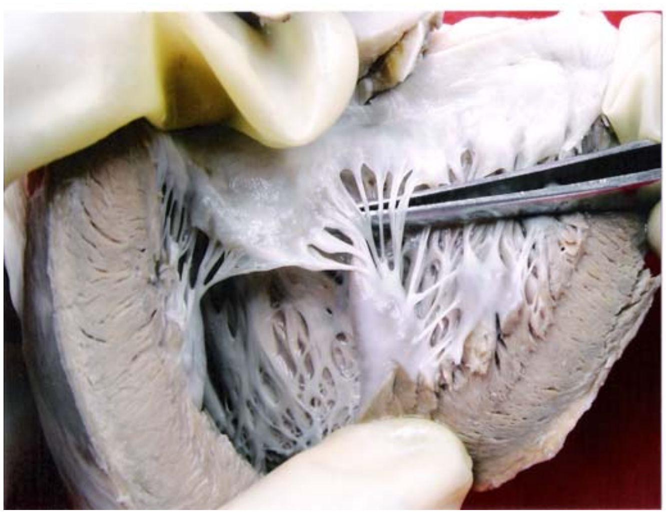


Fig 29. Number of Chordae at insertion.



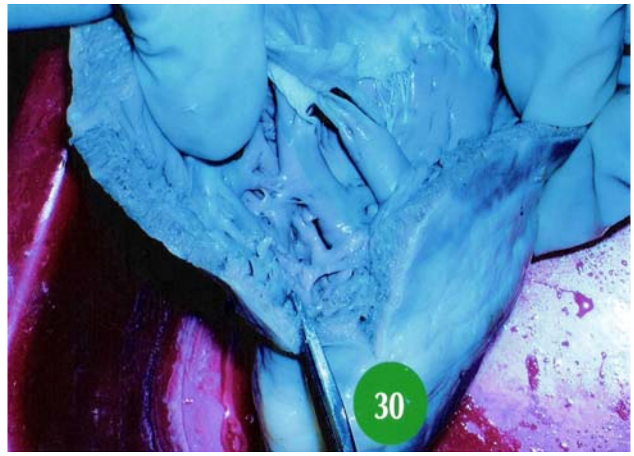
Conical Mamillated

Flat Topped



Grooved Arched

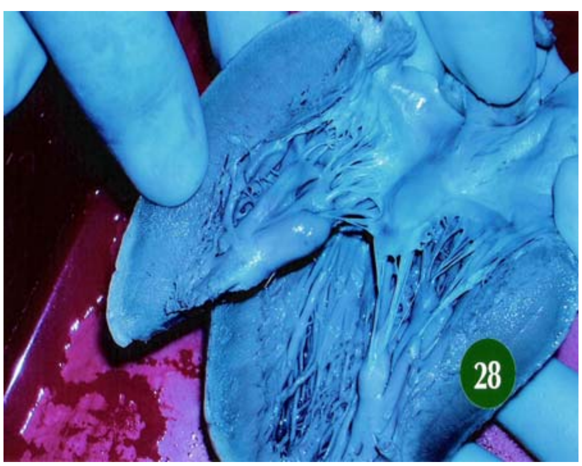
Fig 30(a). Varied shape of single muscle bellies in anterolateral and posteromedial location

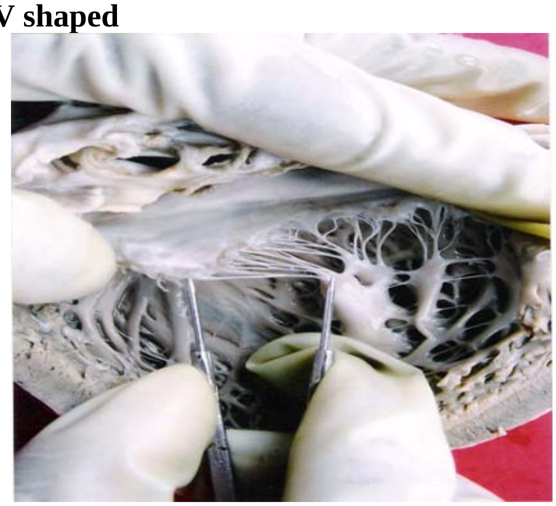


Interlinked

H shaped

V shaped



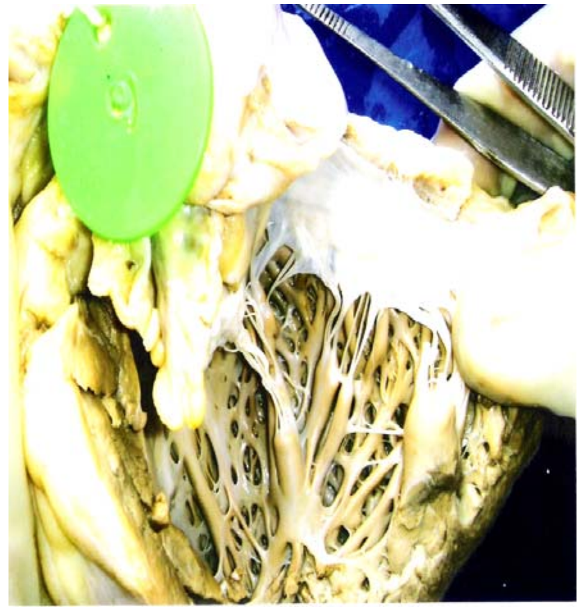


Y Shaped

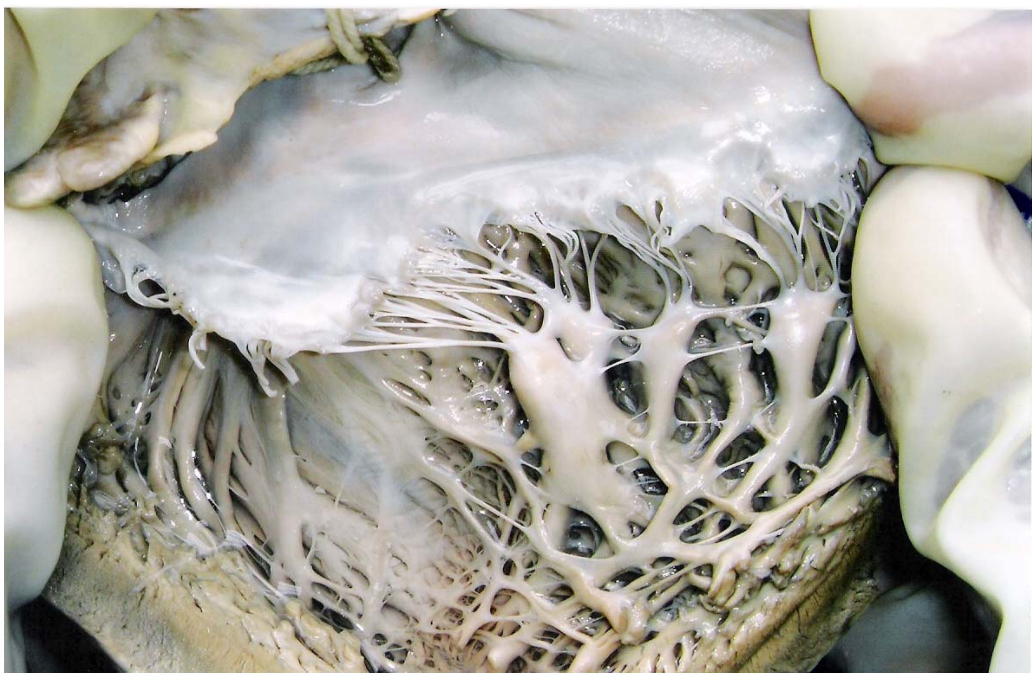
Parallel

Fig 30(b). Varied shape of two muscle bellies in anterolateral and posteromedial location

Interlinked

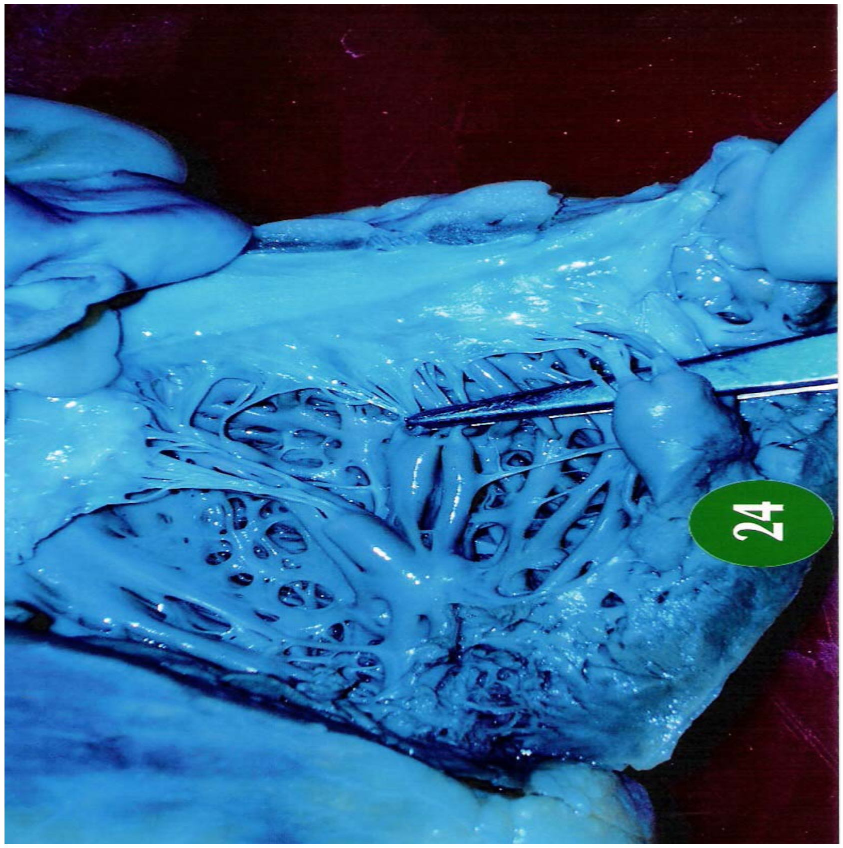


Parallel



Two tiered and single

Fig 30(c). Varied shape of three muscle bellies in anterolateral and posteromedial location



Parallel

Fig 30(d). Configuration of four muscle bellies.

Fig 30(e). Five muscle bellies in posteromedial group.

Fig 31(a). Papillary muscle arising from the middle third of left ventricle

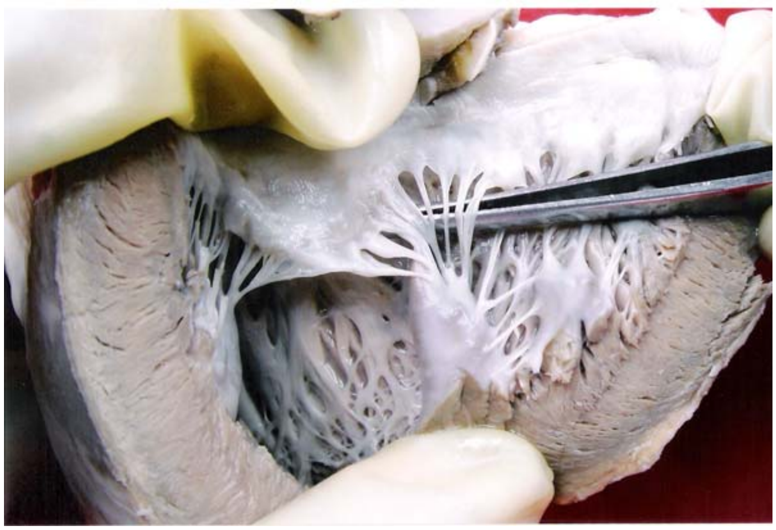


Fig 31(b). Papillary muscle arising from the lower third of left ventricle

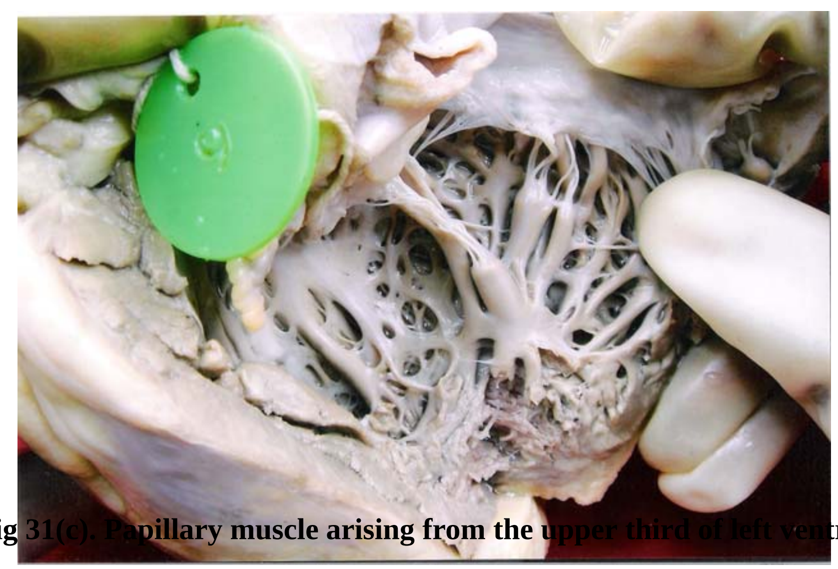


Fig 31(c). Papillary muscle arising from the upper third of left ventricle

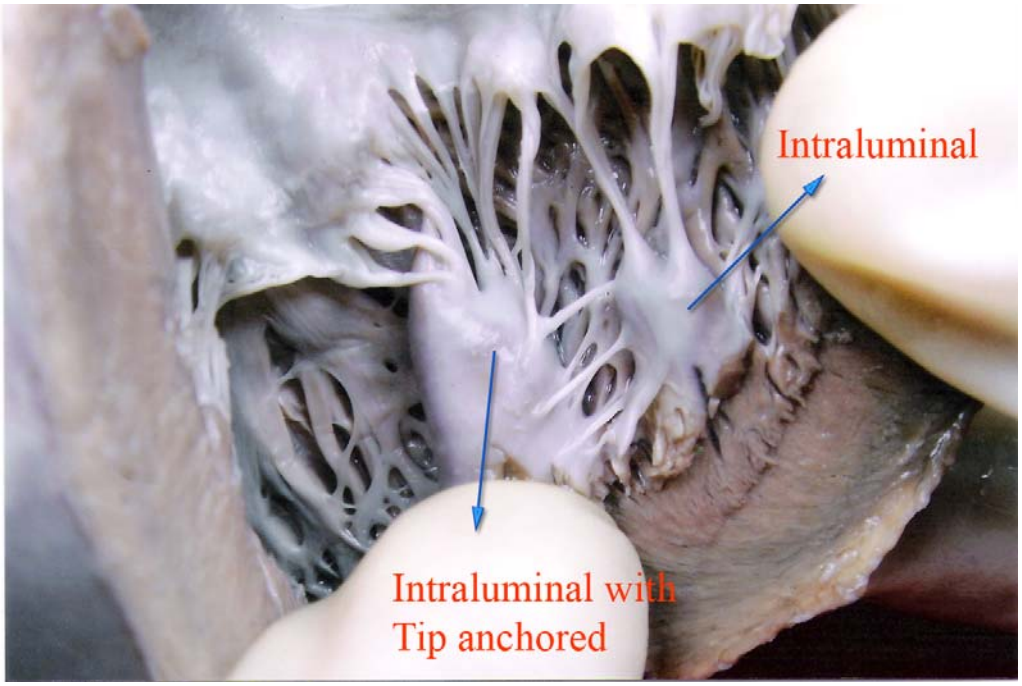


Fig 32(a). Extent of protrusion of papillary muscle

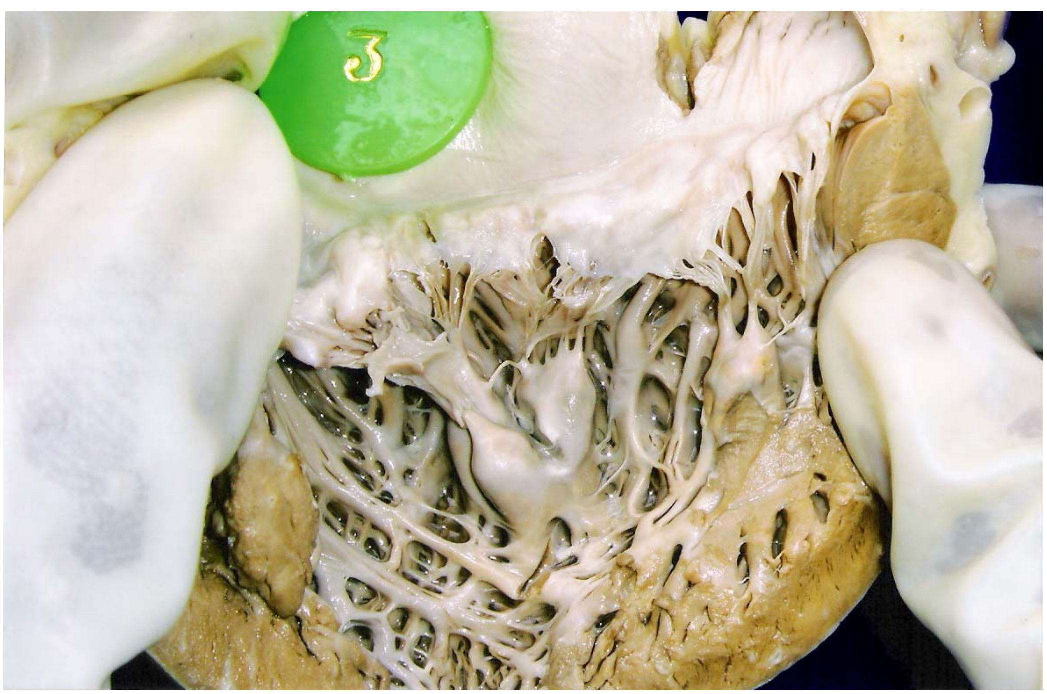


Fig 32(b). Sessile and intraluminal type of papillary muscle.

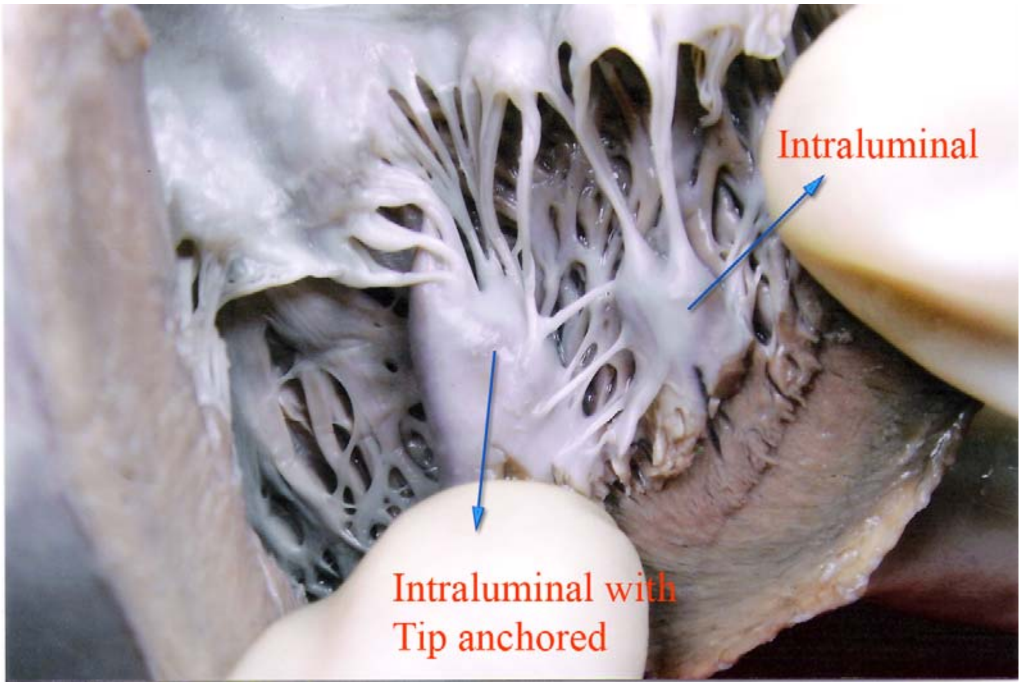


Fig 32(a). Extent of protrusion of papillary muscle

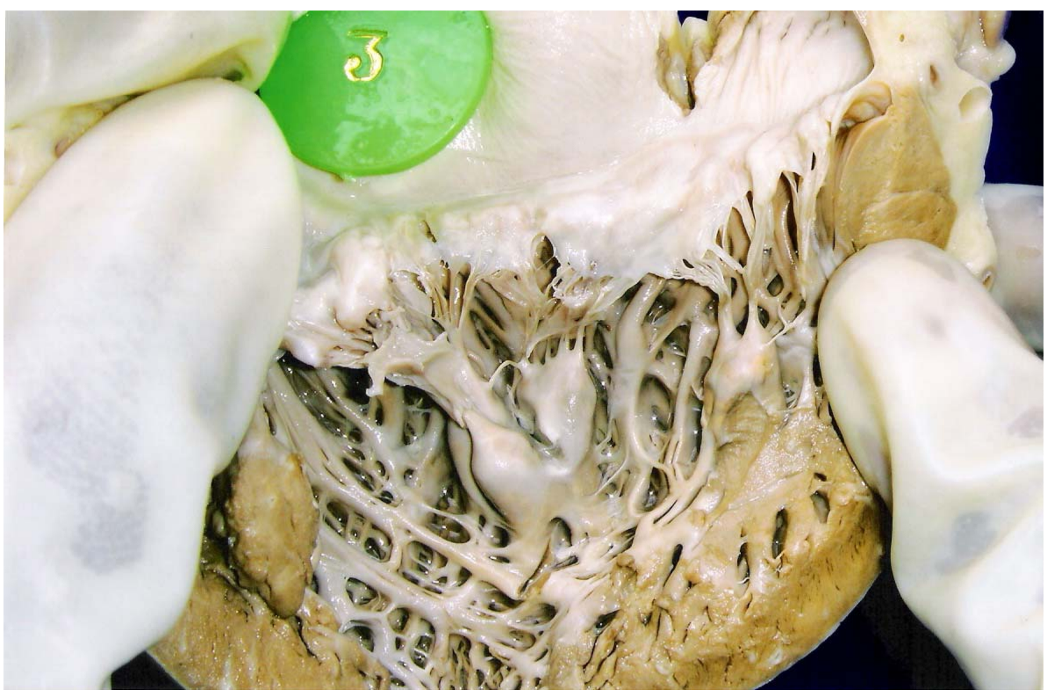


Fig 32(b). Sessile and intraluminal type of papillary muscle.

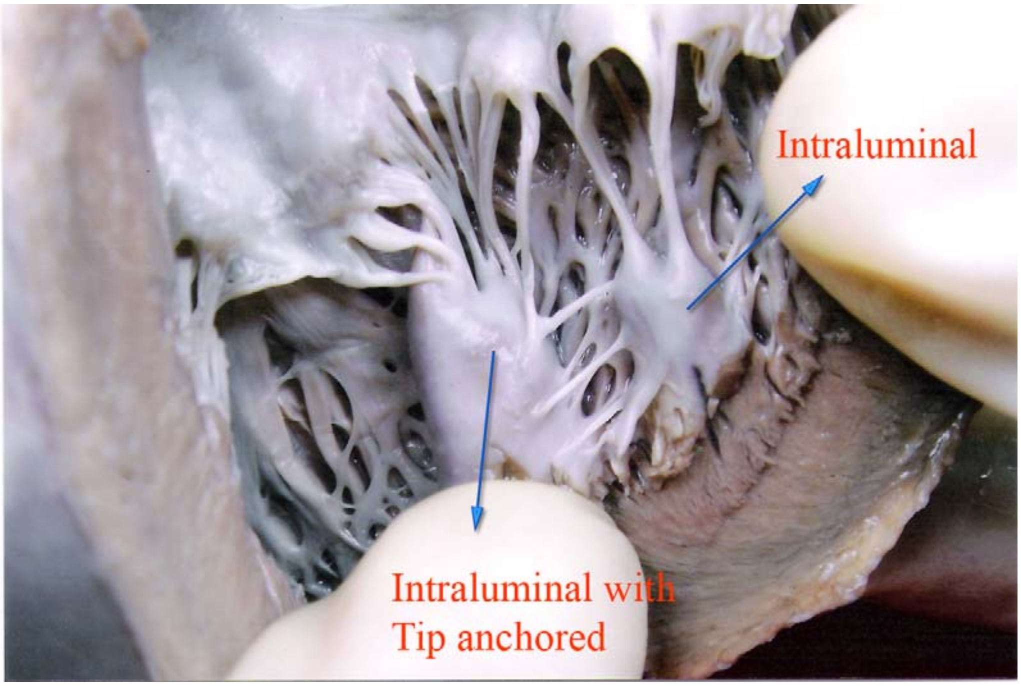


Fig 32(a). Extent of protrusion of papillary muscle

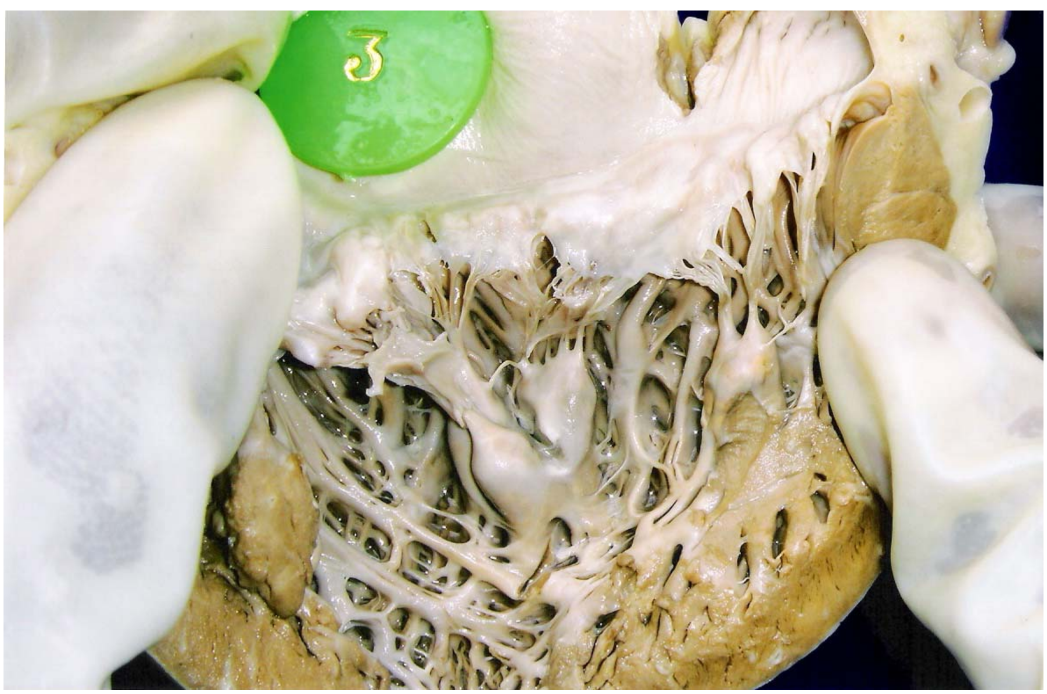


Fig 32(b). Sessile and intraluminal type of papillary muscle.

Fig 33. Foetal Heart

Fig 34. Foetal heart – mitral annulus

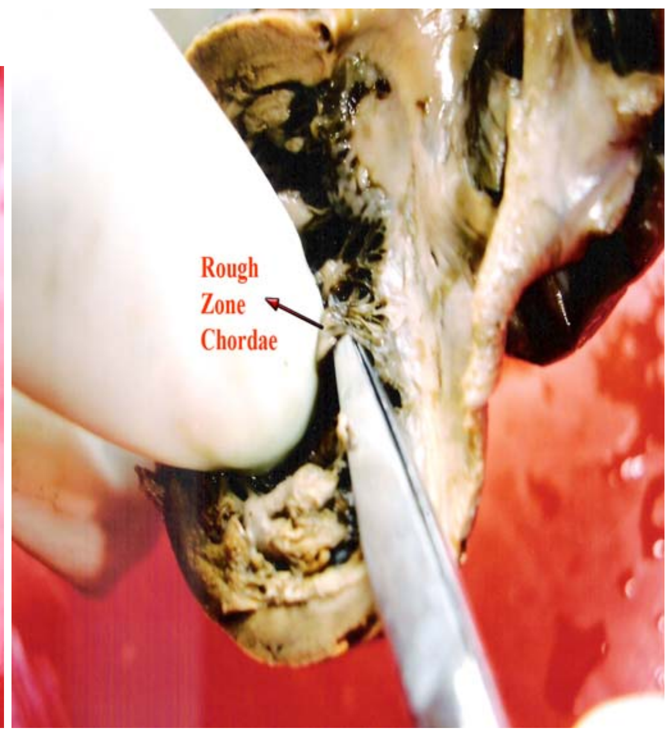
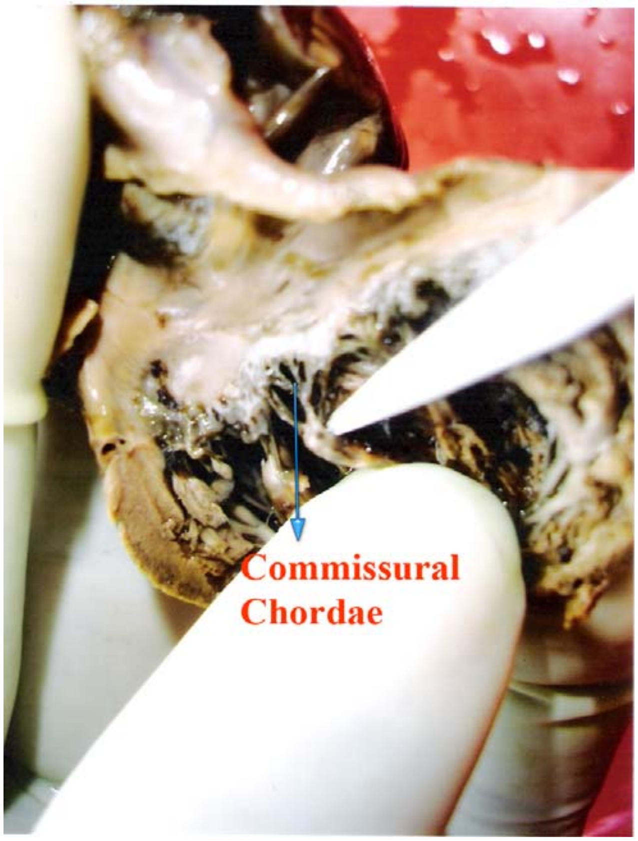


Fig 35. Six papillary Muscles

Fig 36. Foetal Rough Zone Chordae



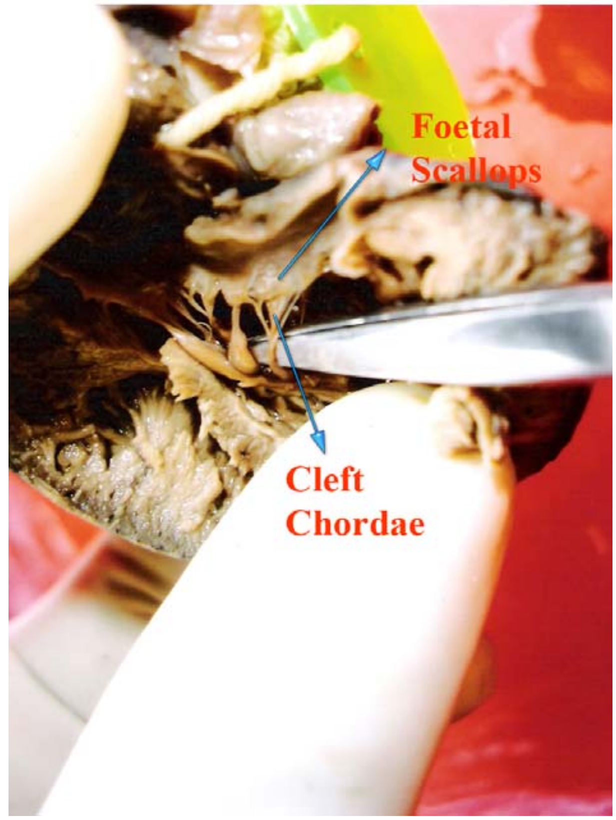


Fig 37. Foetal Commissural Chordae **Fig 38. Foetal cleft chordae and scallops**

Fig 39. Foetal heart incision

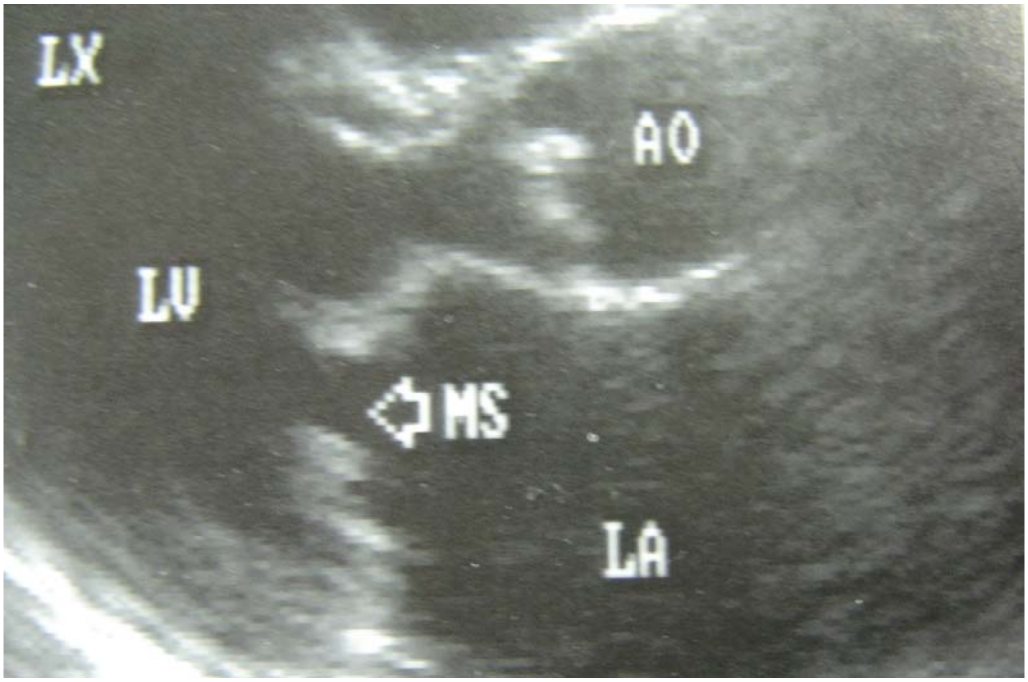


Fig 40. Mitral stenosis – Long axis 2 dimensional echo of a patient with mitral stenosis shows a typical doming of both leaflets with a diminished separation (MS) between the anterior and posterior edge.

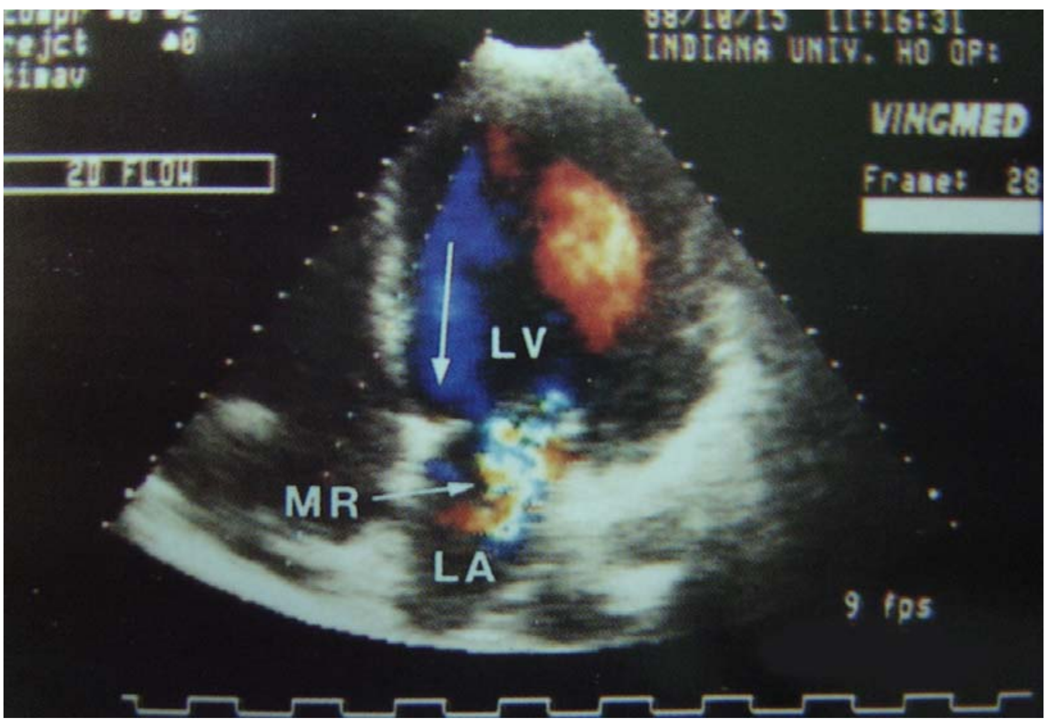


Fig 41. Mitral regurgitation – Colour flow Doppler study of a patient with MR. The multicolored regurgitant jet (MR) can be seen protruding into the left atrium.

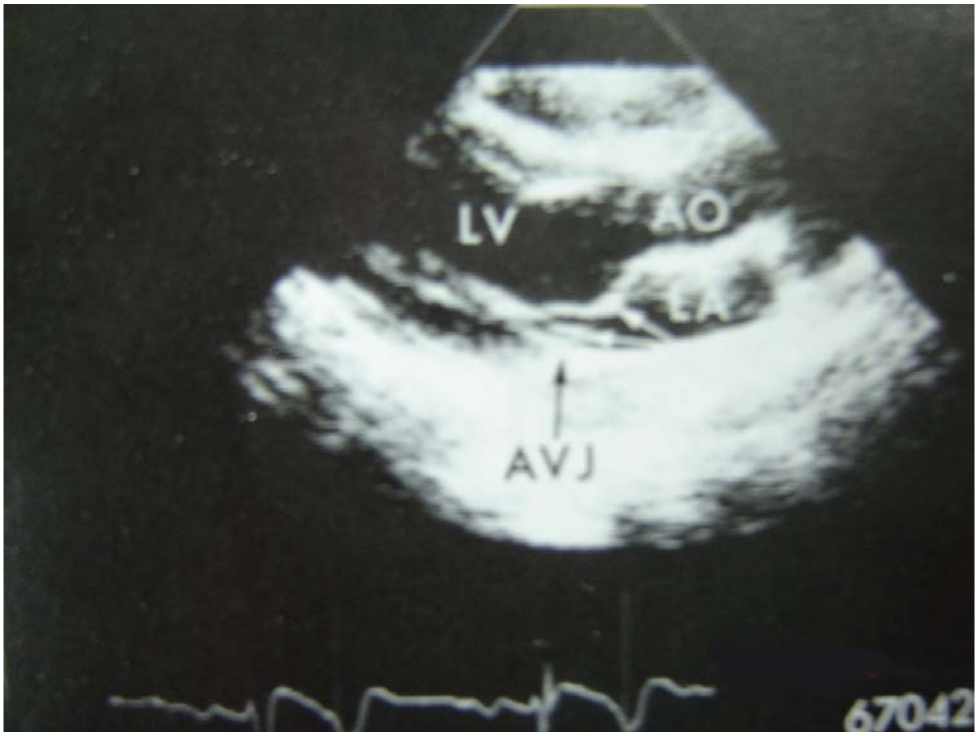


Fig 42. Mitral valve prolapse – 2 dimensional long axis echo of a patient with mitral valve prolapse. Both the anterior and posterior leaflets (arrows) curve into the left atrium

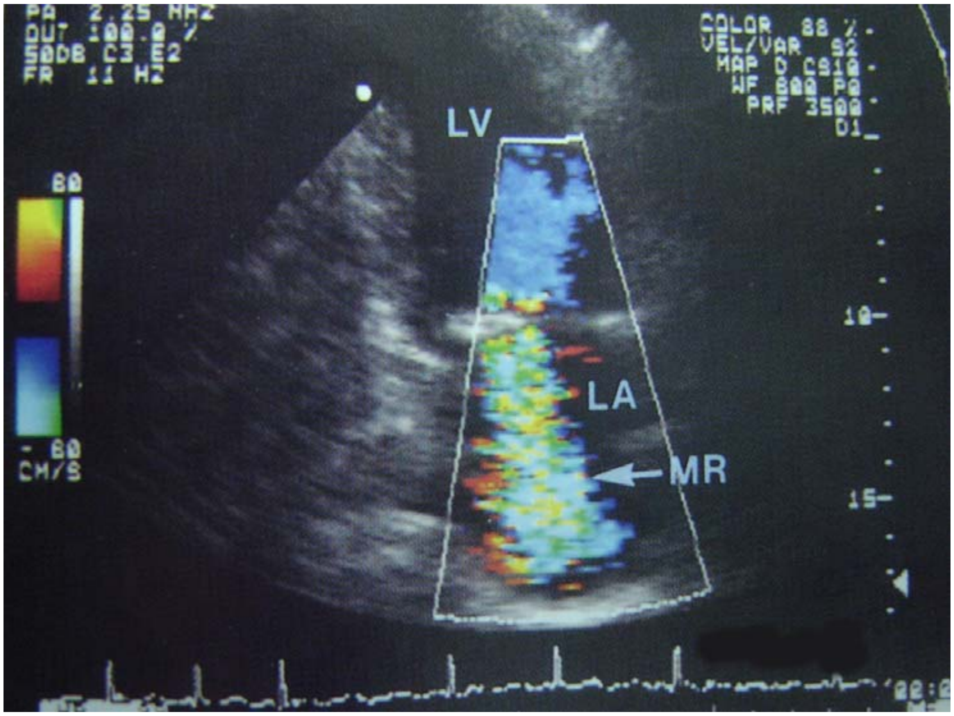


Fig 43. Mitral regurgitation – The Doppler jet is displayed in a variance mode, which produces the a multicolored, some what greenish jet (MR) within the left atrium.

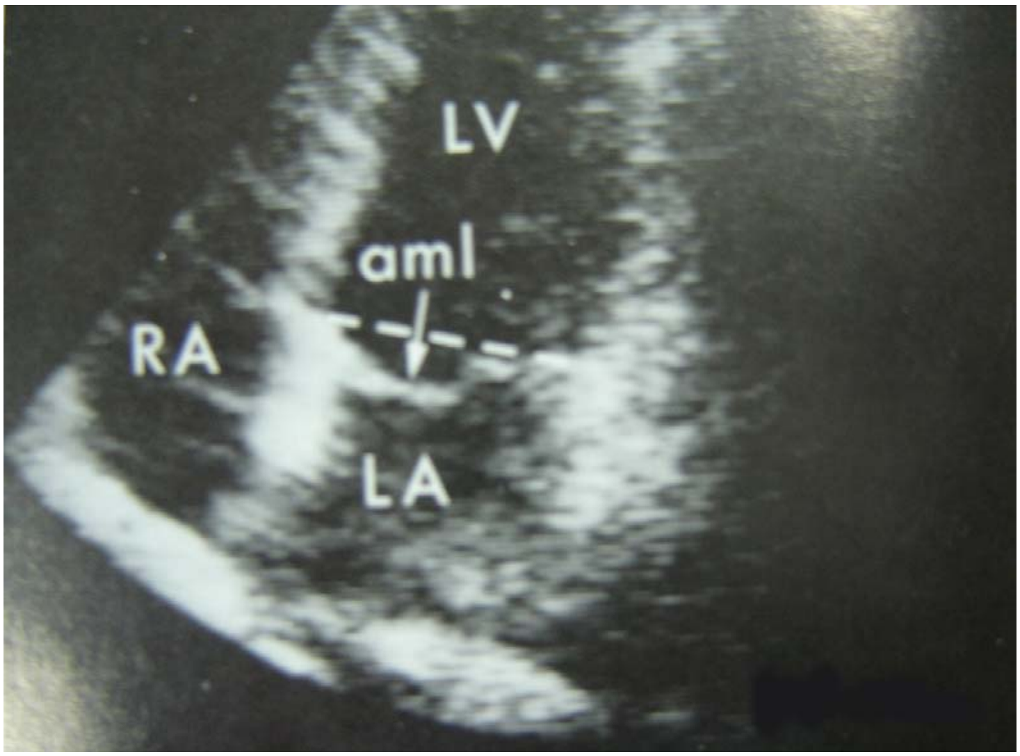


Fig 44. Mitral valve prolapse – Demonstrating a curved anterior mitral leaflet(aml) that extend beyond the plane of the mitral annulus(dotted line).