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Understanding Bipartite Patella: From Anatomy to Treatment Strategies

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ABSTRACT

Introduction: this review article describes the Bipartite patella as a developmental variant resulting from the incomplete fusion of the secondary ossification centres. Although frequently asymptomatic, it may present with knee pain and functional limitation, often mimicking acute fractures.

Review: aims to synthesise current knowledge on its anatomical basis, diagnostic modalities, and management options, with emphasis on clinically relevant and novel perspectives. A narrative review of literature was conducted using PubMed, Scopus, and Google Scholar databases. Selected articles were analysed for prevalence, clinical presentation, imaging characteristics, and treatment outcomes. The prevalence of bipartite patella is 1-2%, with male predominance and bilateral involvement in nearly half of cases. The superolateral location (Saupe type III) is most common. Imaging reliably differentiates bipartite patella from acute fractures, with radiographs showing smooth corticated margins and MRI providing insight into marrow oedema and soft tissue pathology. Most cases respond to conservative management (rest, NSAIDs, physiotherapy), while surgery-such as fragment excision, lateral release, or vastus lateralis detachment-is reserved for refractory cases. Surgical intervention generally restores pre-injury activity.

Conclusion: recognition of bipartite patella as a benign anatomical variant is essential to avoid misdiagnosis and unnecessary intervention. Novel aspects of this review include emphasis on its biomechanical role in patellar stability and updated surgical outcomes. Understanding these factors supports tailored treatment and highlights areas for future biomechanical and long-term outcome research.

Keywords: Bipartite patella; Patellar fracture differential; Knee biomechanics.

Introduction

The patella is the largest sesamoid bone in the human body that develops in the tendon of the quadriceps femoris muscle, which ossifies as a mass of cartilage at around 3 to 5 years of age, fusing to form a single bone at puberty: 10–11 years for girls and 11–13 years for boys[1]. Hormonal control, genetics, and localised mechanical stress all affect the rate and degree of ossification[2].

Sesamoid bones and accessory bones are congenital anatomical variations. Accessory bones originate from the primary bone's ossification centre and are developmental variants that manifest as a secondary centre. It might be isolated from the main bone or the one adjacent to it. Avulsion fractures are frequently mistaken for them. These bones are susceptible to infections, displacement or may develop connective tissue illnesses as a result of painful fractures[3-6].

Sesamoid bones are characterised by their rounded or oval shapes and smooth edges[7,8]. They are often embedded within tendinous structures and at joint surfaces, where they serve biomechanical functions such as increasing mechanical leverage, reducing friction, and protecting tendons from excessive strain. While usually painless, sesamoid bones can cause discomfort due to overuse, congenital defects, fractures, dislocations, or irritation of the surrounding soft tissues[3]. The sesamoid bones of the lower limb include the patella, fabella, cyamella, and os peroneum; the sesamoid bone of the digital region is the hallux sesamoid; and the sesamoid bones of the upper limb are the two at the 1st metacarpophalangeal joint, the 1st interphalangeal joint sesamoid, the 2nd metacarpophalangeal joint sesamoid, and the 5th metacarpophalangeal joint sesamoid[9]. Numerous conditions can mimic accessory ossicles and sesamoid bones, which may be mistaken for fractures and require distinction on the basis of both history and imaging. To reduce unnecessary orthopaedic consultations and misdiagnoses, it is vital to understand these bones and their clinical significance. Patella is securely affixed to the knee's extensor mechanism and lodged within the quadriceps tendon. The fibres of the quadriceps femoris create vertical ridges that define its anterior surface Figure 1. It is separated into three areas: the inferior third, which tapers to the apex encased by the patellar ligament; middle third, which exhibits vascular orifices and striations; and superior third as base, where the quadriceps tendon inserts[10]. The posterior surface bears facets for articulation with the femur at the patellofemoral joint. The largest oval facet

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on the posterior surface is covered with the body's thickest hyaline cartilage, which measures 4-5 mm in the centre. It is separated into medial & lateral halves, which correspond to the femoral trochlea, by a vertical midline ridge as shown in Figure 2. While the lowest fourth is non-articulating and penetrated by vascular foramina, the superior three-fourths constitute the articular part[11,12].

The tendon of Quadriceps femoris (rectus femoris anteriorly, vastus medialis and lateralis centrally, and vastus intermedius posteriorly) is received by the uneven base of the patella as shown in Figure 1. For the patellar ligament, the apex creates a rounded protrusion as shown in Figure 2. The medial border is thicker along its lateral boundaries and serves as an attachment point for the patellomeniscal, patellotibial, and medial patellofemoral ligaments (MPFL), all of which provide patellar stability. The lateral patellar retinaculum, which is made up of deep transverse and shallow oblique layers, is received by the thinner lateral border[10]. The MPFL, which is closely connected to the vastus medialis, stretches from the medial femoral epicondyle to the superomedial patella. During 0–30° of knee flexion, it serves as the main soft tissue that prevents lateral patellar dislocation[13-15]. The trochlea becomes increasingly important for patellar stability after 30° of knee flexion[14]. Acute lateral patellar dislocation frequently results in damage to the MPFL; while initial injuries are regularly treated conservatively, repair may be necessary in recurring instances[16,17].

The patella initially emerges as a condensation of rounded cells inside the quadriceps muscle around the 20 mm embryonic stage. The synovial cavity is absent and patella is separated from the femur by loose mesenchymal tissue. This condensation gets denser and expands by 23–24 mm stage, at which point the femoral surface below starts to develop. The patella becomes cartilaginous during the 30- to 32-mm stage, and remains connected with the quadriceps femoris tissue resting on top of the anterior distal femur. Movement is transitorily eliminated by the formation of a primitive articular disc by 35 mm, when the free tissue between the patella and femur condyles condenses and their perichondria unite. At around 40 mm embryonic stage, the synovial cavity of the patellofemoral joint emerges, initially on the medial side and then expanding laterally and centrally, as the disc thins into a double cell layer that defines the articular cartilages. The patella eventually forms as an intramuscular sesamoid bone inside the quadriceps, subsequently gaining a free articular surface when the primitive joint plate forms and resolves[18].

If the ossification centres of the patella fail to fuse, the patella may remain split into two or more separate parts. When the upper lateral part of the patella remains unfused, it is known as a bipartite patella, while a third fragment may also be appreciated in a tripartite variant[19].

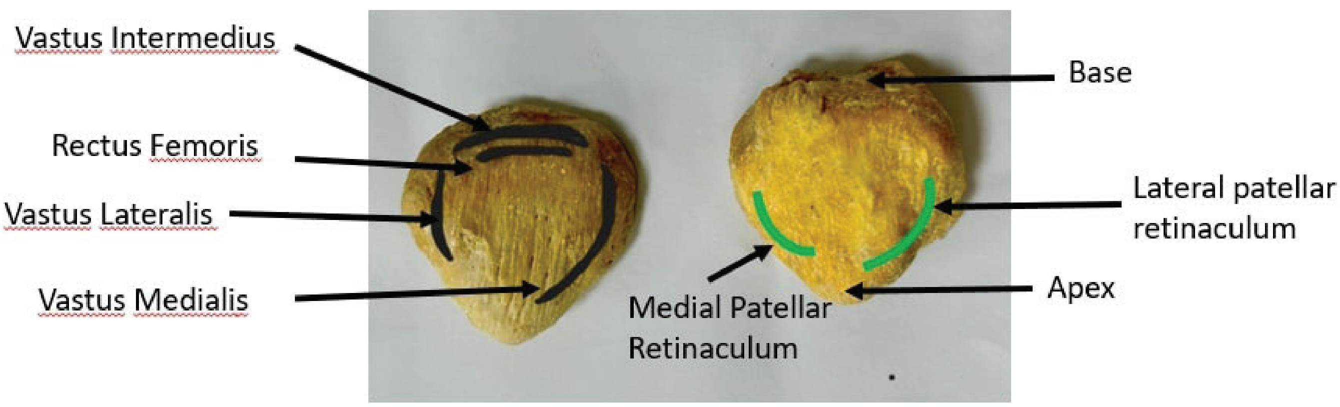

Figure 1. Showing the Anterior view of Right and Left Patella.

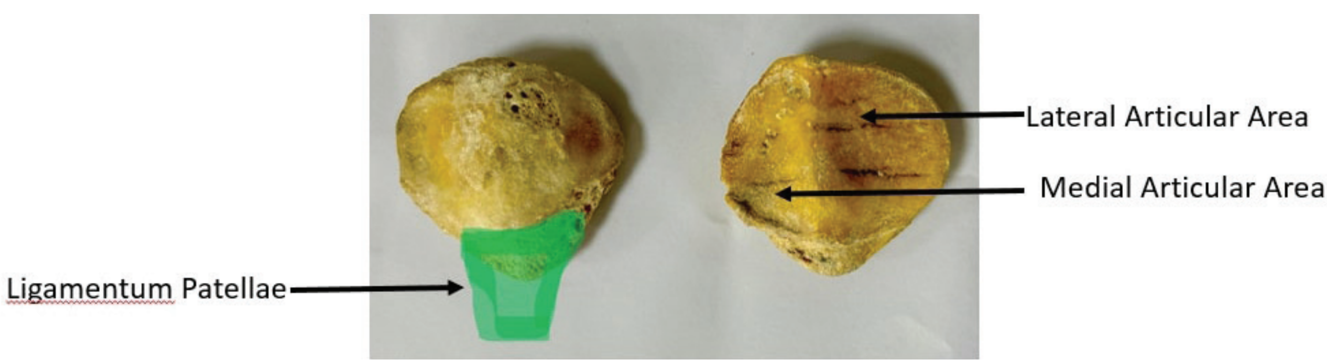

Figure 2. Showing the Posterior view of Right and Left Patella.

Its prevalence in the population ranges from 1% to 2%, with a male-to-female ratio of about 9:1, and is bilateral in up to 43% of cases[19]. Most cases are asymptomatic and are incidentally discovered on imaging; however, anterior knee pain is a sign in a few patients, particularly after trauma, sports injuries, or overuse[20]. Saupe classification defines the bipartite patella based on the position of the secondary ossification centre: type I: lower pole ~1%, type II: lateral edge ~20-25% and type III: superolateral segment ~75% [21] as shown in Figure 3. A new classification for the developmental abnormality of ossification known as patella partita was recently introduced by Oohashi *et al*. This categorisation was based on the quantity of pieces (bipartite, tripartite, and multipartite) and their placement (superolateral or lateral)[22] as shown in Figure 4.

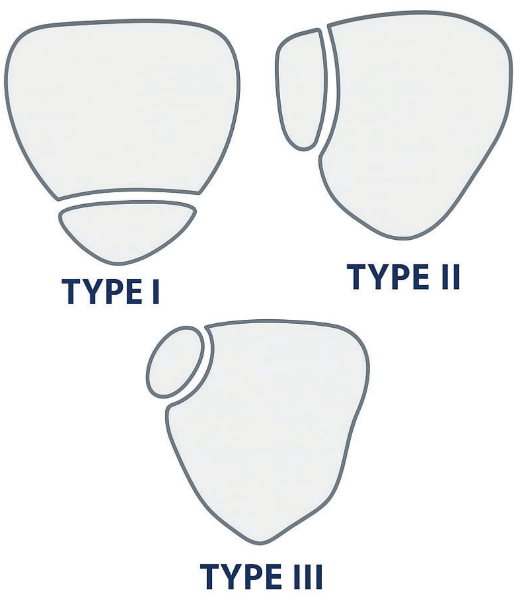

Figure 3. Saupe classification.

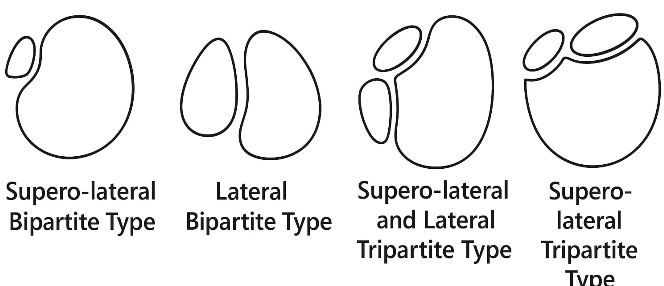

Figure 4. Classification given by Oohashi *et al*.

Clinical spectrum of Bipartite Patellar Pain, Patellar Fractures & Treatment Modalities. shows that Bipartite patella may present as anterior knee discomfort in young, active individuals after trauma, overuse, or demanding sports activities. Patients usually complain of uneasiness and pain with any knee action that activates the quadriceps' extension mechanism, such as squatting, leaping, and ascending stairs. Physical examination of the knee joint often exhibits localised tenderness over the patella's superolateral pole. There may be a palpable defect or an odd prominence. The patient may have a hematoma or effusion above the auxiliary fragment, a larger-than-normal patella, and/or impaired quadriceps function. Two fundamental mechanisms—single, direct trauma or recurring small injuries—are acknowledged as the causes of symptoms[23]. Nonsurgical management is the primary approach for treating symptomatic bipartite patella. The majority of patients improve with rest and reduced participation in athletic activities. Along with the use of nonsteroidal anti-inflammatory drugs (NSAIDs), physical therapy typically includes isometric stretching exercises for the quadriceps muscles. A local steroid injection could be enough to relieve pain without the need for surgery in the patient with bipartite patella symptoms[24]. In patients who have not responded well to nonsurgical alternatives, surgery is necessary. Several surgical techniques have been suggested, such as subperiosteal detachment of the vastus lateralis insertion, lateral retinacular release, and excision of the fragment[23]. 16 individuals with symptomatic bipartite patella had their surgical excision outcomes assessed by Bourne and Bianco. Thirteen individuals experienced remarkable outcomes and resumed their prior levels of activity[25].

In a study by Ogata, 13 patients (15 knees) underwent subperiosteal removal of the vastus lateralis. The accessory piece was extracted after separation in five individuals due to excessive mobility at the chondro-osseous junction. The piece in the remaining was left in place following the procedure. Two patients achieved fair outcomes overall, whereas eleven patients (affecting 13 knees) experienced excellent results. After surgery, all patients experienced immediate pain relief and were able to resume their full physical activities two to six months later[26].

Bipartite patella can often be confused with patellar fractures. The generic classification of patellar fractures based on the fracture pattern is transverse fracture of the mid patella (most common), comminuted fracture, vertical fracture (least common), osteochondral defect usually from the medial facet and patellar sleeve fracture in children[27] as shown in Figure 5. The treatment modalities are non-operative or operative, depending on the severity of the fracture.

Non-operative: Degree of fracture displacement and integrity or dysfunction of knee's extensor mechanism dictates the course of treatment. Non-operative therapy could be appropriate for individuals with an intact extensor mechanism and a nondisplaced or mildly displaced fracture. For four to six weeks, a Zimmer knee splint is often required. During this time, the patient is often permitted to bear weight while wearing a splint[27].

Operative: Surgery is necessary for around one-third of patellar fractures; the most prevalent reasons are joint incongruity and a fracture gap larger than

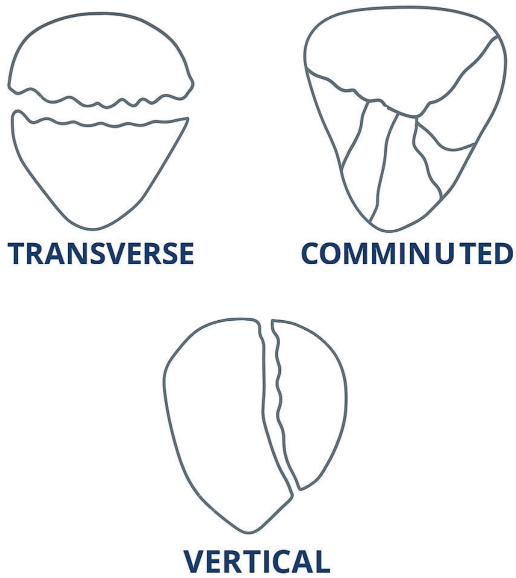

Figure 5. Patellar Fractures.

3 mm. Early mobilisation and the restoration of the patient's anatomy are the objectives of fracture fixing. Following fracture fixation of patella, union usually occurs within 8–12 weeks. Tension band wire, cannulated screws & locking plates are required to fix the fracture fragments[28].

Biomechanics & Stability, improving the quadriceps muscle group's mechanical efficiency and regulating joint response forces during movement, the patella plays a crucial part in knee biomechanics. As a sesamoid bone in the extensor mechanism, it amplifies the force of extension, especially between 30° and 60° of knee flexion, by increasing the moment arm of the quadriceps tendon. A well-coordinated system of both static and dynamic stabilisers keeps the patella stable. While ligaments such as medial patellofemoral ligament (MPFL) and medial patellotibial ligament (MPTL) resist lateral displacement, particularly in the initial 0–30° range, the bony architecture of the trochlear groove offers major constraint beyond early flexion. The quadriceps, particularly the vastus medialis obliquus (VMO), which opposes lateral tracking forces, control dynamic stability. Patellar instability can result from disruption in any of these elements, whether from trochlear dysplasia, ligamentous damage, or neuromuscular imbalance. This can exacerbate disorders like chondromalacia or patellofemoral pain syndrome. Accurate diagnosis, rehabilitation, and surgery planning in patellar diseases depends on an understanding of these biomechanical concepts[29,30,31].

Several imaging modalities are used to assess disorders of patella and patellofemoral joint, with radiography being the primary technique due to its accessibility and diagnostic value.

1. Radiography (X-ray)- The first-line method for assessing patellar alignment and fractures is radiography (X-ray). It is widely available and cost-effective. However, non-displaced or stress fractures may be missed with limited soft tissue details. Views include:

Anteroposterior (AP): A broad summary of the patellar orientation[10].

Lateral: Evaluates fracture displacement and patellar height[32].

Merchant (Axial): evaluates the articular surfaces and patellofemoral congruence[10,33].

2. Computed Tomography (CT) - Superior for evaluating complex fractures, comminution, and articular surface involvement. It provides High-resolution bone detail and is useful for preoperative planning. However, the limitations are that, higher radiation dose is less sensitive for soft tissue pathology[34,35].

3. Magnetic Resonance Imaging (MRI) - Ideal for soft tissue evaluation and detecting occult fractures. It is also useful in detecting bone marrow oedema, cartilage defects, and tendinopathies. It is Costly and contraindicated in patients with metal implants[36,37].

4. Ultrasonography - Portability, affordability, great spatial resolution, dynamic imaging, and the capacity to direct percutaneous procedures when necessary are some advantages of US. Direct patient contact is another benefit of US, which makes it possible to compare with the contralateral knee and establish an instant clinical connection[38].

5. Bone Scintigraphy - Using an intravenous injection of technetium 99m (Tc99m) radiotracer, bone scintigraphy is a flexible diagnostic technique. In regions with elevated osteoblastic activity, this substance localizes to bone, eventually showing up on the scan as a thick, darkish region[39].

Separating bipartite patella from patellar fractures is a crucial part of clinical examination. A bipartite patella appears on radiographs with well-defined rounded edges at the non-union site, while a fracture usually shows uneven, sharp fracture lines and sometimes accompanied displacement[19,40]. A precise diagnosis is important to direct the right course of treatment and prevent needless procedures. The aim of the current article is to review articles on bipartite/ multipartite patella while excluding patellar fractures.

Material and Method

This study presents a comprehensive review of the literature on bipartite and tripartite patella from the year 2000 - 2025. The literature was collected using multiple scientific databases and electronic search engines, including PubMed, Google Scholar, Web of Science, Elsevier, Radiopedia. Relevant articles were identified through a systematic search strategy employing Boolean operators (AND, OR) in combination with key terms such as bipartite, tripartite, multipartite, sesamoid bone and patella ossification or management.

Each selected publication was critically appraised to assess the methodologies described, with emphasis on the objectives of this study. Literature related to bipartite, tripartite patella was included however, patellar fracture were excluded as shown in Figure 6.

Result

The superolateral pole, or Saupe type III, is the most often seen form of bipartite patella in imaging modalities such as radiography, MRI, USG, and CT, according to a study of 28 publications that included both case reports and retrospective analysis as shown in Table 1. The majority of Saupe type III patients were asymptomatic, while symptomatic presentations were also observed. The majority of case studies featured symptomatic people who had bilateral or multipartite involvement and usually presented with anterior knee discomfort.

Discussion

Bipartite patella, a developmental variant resulting from incomplete fusion of ossification centres during adolescence, remains a frequently under-recognised anatomical anomaly, with a reported prevalence of 1% to 2% in the general population[9]. The current review supports previous findings that Saupe type III,

Table 1. Shows previous literature on bipartite & tripartite patella.

S.No	Author(s)	Year	Modality	Sample Size	Findings	
1	Blankstein *et al.*[41]	2001	USG	14 (12-15 yrs; 5M, 2F)	Bipartite patella - 7 Superolateral Saupe type III	
2	Canizares GH[42]	2003	Case Report	32 males	B/L bipartite patella, Superolateral Saupe type III	Symptomatic
3	I.M. Omar & M. Schweitzer[43]	2004	MRI	50 (38M, 12F) Retrospective 400 Knee Mri data	50 bipartite patella 3 bipartite patella out of 400 MRI	
4	Eoin C. Kavanagh *et al.*[44]	2007	MRI	53 (40M, 13F; 13-68 yrs)	Saupe type III	Symptomatic
5	Yoshikazu Oohashi *et al.*[45]	2007	Bone scintigraphy	37	Saupe type II - 4 Saupe type III - 31 Saupe type II & III - 2 Right knee - 13 Left knee - 10 Bilateral - 7 Tripartite patella - 2	symptomatic-15, asymptomatic-22
6	Yoshikazu Oohashi *et al.*[22]	2010	MRI	111 patients	bipartite patellae - 131 Superolateral bipartite - 115 Lateral type - 16 Tripartite patella - 8 Right knee - 43 Left knee - 40 Bilateral bipartite patellae - 28	bipartite patellae - 46 symptomatic and 85 asymptomatic. Tripartite patella – 4 symptomatic and 4 asymptomatic
7	J. O'Brien *et al.*[46]	2011	MRI	25 (8F, 17M)	Saupe type III patella - 24 Saupe type I - 1 Bilateral bipartite patella - 14	Asymptomatic
8	Ozkan Kose *et al.*[47]	2015	Radiograph	897 (retrospective)	Superolateral bipartite - 9 Lateral type - 1 Tripartite patella - 1	Symptomatic - 2
9	Sebastian Zabierek[48]	2016	Radiograph	Case report, 35F	Bilateral bipartite patella, superomedial pole	Symptomatic
10	Fakhry Mahmoud Ebouda[49]	2016	MRI	Case report, 18M	Right bipartite patella, Saupe type II;	Symptomatic
11	Semra Duran *et al.*[50]	2016	MRI	1000	18 bipartite patella (12M,6F) Saupe type III Right knee - 10 Left knee - 6 Bilateral knees - 2	Patients, undergone knee MRI for any indication

12	Zeynep Maras Ozdemir[51]	2016	MRI	Case report, 29M	B/L multipartite patella;	Symptomatic
13	Ali Yeganeh *et al.*[52]	2017	Radiograph, CT, MRI	20	Superolateral - 8, Lateral - 5, Inferomedial - 7; Right knee - 11 Left knee - 5	Knee pain & joint stiffness, Decreased motion range
14	Jingyuan Ma *et al.*[53]	2017	Radiograph	Case report, 55M	Left bipartite patella, Saupe III	Symptomatic
15	A. Lagdid *et al.*[54]	2018	Radiograph, CT	Case report, 32M	Bilateral multipartite patella	Symptomatic
16	Pir Abdul Ahad Aziz Qureshi[55]	2018	Radiograph	Case report, 45F	Bilateral bipartite patella, Saupe type III;	Symptomatic
17	Tuba Akdag *et al.*[56]	2019	MRI	61 (44M, 17F)	Saupe type III - 59 Saupe type II - 2	Symptomatic - 10 Asymptomatic - 51
18	Henry Knipe[9]	2020	Radiograph	Case report, 16M	Right bipartite patella, Saupe III	Symptomatic
19	Mohammad Taghi Niknejad[20]	2021	Radiograph	Case report, 25M	Left bipartite patella, Saupe III	Symptomatic
20	Joseph Adetola Adedigba *et al.*[57]	2021	Radiograph	377 (158M, 219F)	7 bipartite patella Saupe type I - 2 Saupe type II - 2 Saupe type III - 3 Multipartite patella - 1	
21	Gni Liew[58]	2022	Radiograph	Case report, 35M	Right bipartite patella, Saupe II	Symptomatic
22	Mostafa Elfeky[59]	2022	USG, Radiograph	Case report, 30F	Right bipartite patella, Saupe III;	Symptomatic
23	Janani Gopalakrishnan[60]	2023	Radiograph	Case report, 28M	B/L bipartite patella, Saupe III;	Symptomatic
24	Mohammad Taghi Niknejad[61]	2024	Radiograph	Case report, 20M	Right bipartite patella, Saupe III	Symptomatic
25	Dafnee Nohemí Hernández Esturban[62]	2024	Radiograph	Case report, 50M	B/L bipartite patella, Saupe II	Symptomatic
26	Lam Van Le[63]	2025	Radiograph	Case report, 55M	B/L bipartite patella, Saupe III	Symptomatic
27	V. Ravi Kiran *et al.*[64]	2025	Radiograph	Case report, 50M	Left knee type III bipartite patella	Fall and fracture of the right knee asymptomatic before the traumatic event
28	V. Ravi Kiran *et al.*[65]	2025	Radiograph	Case report, 50M	Tripartite patella Right knee - Saupe type III Left knee - Saupe type III	Asymptomatic

involving the superolateral pole, is the most commonly observed variant, accounting for up to 75%–80% of documented cases[9,21,44,56].

A significant male predominance (up to 9:1) and bilateral occurrence in up to 43% of cases have been widely reported[3] emphasising the potential influence of hormonal and mechanical stress during development[2]. While most bipartite patellae are asymptomatic and incidentally discovered on imaging, trauma, sports-related stress, or repetitive knee movement can trigger pain, particularly when the synchondrosis becomes irritated[44,59,61].

Clinically, it is critical to distinguish between patellar fractures and symptomatic bipartite patella. In contrast to the uneven, sharp edges of acute fractures, radiographs usually show bipartite pieces with smooth, corticated borders[12]. MRI offers better resolution for assessing soft tissue disease, oedema, and chondral rupture when ambiguity remains[9,43,44].

Not all of the examined studies showed a consistent correlation between Saupe type and clinical presentation. The development of symptoms seems to be more influenced by activity level and recent trauma history than by fragment shape alone, even though Saupe type III predominated among both symptomatic and asymptomatic individuals[9,22,56]. For example, out of 131 bipartite patellae, Oohashi *et al.*[22] found 46 symptomatic and 85 asymptomatic instances, many of which had comparable anatomical distributions.

The age range of symptomatic persons is wide, ranging from teens [9,13] to patients in their 50s [54,62]. Although instances of multipartite patella are less frequent, but showed symptoms that could have been caused by mechanical disadvantage or joint stiffness[46,51,57].

When making a diagnosis, the imaging modality selection is crucial. Although MRI provides improved soft tissue detail and aids in identifying related symptoms such bone marrow oedema or chondral damage, radiography is still the first-line method[43,44]. According to Blankstein *et al.*, musculoskeletal ultrasonography is currently neglected despite offering a radiation-free substitute in younger populations[41].

The majority of management is still conservative, even with the wealth of literature. While symptomatic instances frequently react effectively to rest, NSAIDs, physical therapy, or local treatments, asymptomatic patients typically don't need any treatment at all. Surgery is uncommon and usually saved for individuals with fragment instability or unresolved, incapacitating conditions[51,61].

Conclusion

Incomplete fusing of secondary ossification centres causes bipartite and tripartite patella, which are developmental abnormalities that most commonly affect the superolateral pole (Saupe type III). Despite having a low incidence (1–2% of the population), they are frequently discovered by accident and, in most cases, do not exhibit any symptoms. Anterior knee discomfort and functional limitations are often the result of symptomatic presentations linked to trauma, repeated stress, or overuse. Radiography is the first-line imaging modality, while MRI offers useful soft tissue assessment. Accurate distinction from acute patellar fractures is crucial to prevent needless procedures. Surgery is only used in severe or chronic cases of fragment instability, while conservative therapy continues to be the mainstay of care. Further research on the natural history, biomechanical consequences, and best practices for managing bipartite and multipartite patella may be possible with bigger cohorts and more sophisticated imaging techniques.

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