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Fabella and cyamella of the human knee joint: discovery by dissection and ultrasound examination

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SUMMARY

Perhaps due to the lack of clinical relevance, several anatomical structures such as the fabella and cyamella of the knee have been overlooked or not included in anatomical textbooks, suggesting that they are not significant enough to be acknowledged. This occurs despite studies that have demonstrated recurrent presence of these particular structures. The purpose of the current study was to characterize the finding of two sesamoid bones from the human knee: the fabella and cyamella. The basis of this study used 111 knees of embalmed cadavers from 74 individuals from the donor bequest programme at The University of Sydney. Of these, 37 were paired knees and 37 were unilateral knees (39 female, 35 male). The mean age of the donors was 84 years (range 45-97 years). Comparative analysis using ultrasound imaging was performed followed by dissection to confirm findings. Overall, 63 fabellae were found, with 60.8% of the cadavers having at least one fabella (65.7% in male and 56.4% in female). Three cyamellae were found in three donors respectively. Considering all cadavers, the incidence of cyamellae was 2.7%, making this an incidental finding rather than an anatomical variant. Due to the low prevalence, imaging diagnostic techniques may be useful in identifying these anatomical structures and characterising their variations in detail.

Furthermore, they could provide an insight to these ‘forgotten’ structures and their potential roles in failure correlated with surgical techniques, misdiagnoses or prevalence of chronic pathologies of the knee.

Keywords: Sesamoid bones – Cyamella – Fabella – Knee – Variations

INTRODUCTION

The knee is the largest joint in the human body, allowing bipedalism with movements including extension and flexion, as well as medial and lateral rotations (Williams and Warwick, 1980). The knee joint is composed of three articular surfaces: two between the femur and tibia, and one between the patella and the patellar surface of the femur. Amongst these articular surfaces, a variety of structures including bones, ligaments, tendons and cartilage provide functional structure for the joint.

In human anatomy, the existence of sesamoid bones is well described, particularly for the distal portions of the lower limb, with the patella being the largest and best known. Sesamoid bones are found embedded within tendons, particularly in areas around joints and muscle attachments (Kawashima et al., 2007). They are named based on their resemblance to sesame seeds by Galen, circa 180 A.D. (Potter et al., 1992). The functions of sesamoid bones include distributing pressure, reducing friction on joints and altering the direction of muscle traction (Williams and Warwick, 1980). This action is similar to a pulley, in that it redirects the tendon (Sarin and Carter, 2000; Akansel et al., 2006; Dikes and Vijay, 2014).

Apart from the patella, there are other two sesamoid bones in the knee: the fabella and the cyamella. The fabella is embedded in the tendon of

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the lateral head of the gastrocnemius muscle posterior to the lateral condyle of the femur (Sutro et al., 1935). The cyamella is a small sesamoid bone, predominantly embedded in the popliteal tendon (Akansel et al., 2006). On rare occasions a fabella has also been described within the tendon of the medial head of the same muscle (Sutro et al., 1935).

These two sesamoid bones are generally not acknowledged or included in anatomical textbooks. The aim of this study was to anatomically characterize the fabella and cyamella of the human knee through their locations and relationships to other anatomical structures and morphology.

MATERIALS AND METHODS

Embalmed cadavers were randomly selected from the body donor program at The University of Sydney, Discipline of Anatomy and Histology. In total, 111 knees were examined, of which 37 were paired (74 knees), and another 37 from only one side of the donors. Of those studied, 39 were female and 35 male, with a mean age at death of 84 years and an age range of 45-97 years. Knees showing severe cases of osteoarthritis and/or the presence of prostheses were excluded from the study. Comparisons with ultrasound imaging were performed, followed by dissection.

The ultrasound examination was performed using a Toshiba Nemio ultrasound (SSA-550A) with a lineal transducer 7.5 and 12 MHZ frequency. The transducer was positioned at the posterolateral aspect of the knee in flexion, behind the biceps femoris tendon and above the gastrocnemius muscle, using the lateral condyle of the femur as a point of reference. The knee was extended and flexed to assist in determining the presence of the fabella; then, following the lateral condyle to the popliteal fossa, the popliteal muscle was observed. Using the fibular head as a reference point, the muscle was traced proximally toward its insertion point. With the knee extended, the transducer was placed on the lateral side of the knee in contact with the head of the fibula at the upper edge of the lateral condyle. Anterior rotation of the transducer was made until the lateral collateral ligament (LCL) was visible. The popliteal tendon could be observed deeper to the proximal parts of the LCL, which is the principle location of where the cyamella could be found.

The dissection was initiated by the removal of the skin and subcutaneous fat, followed by the reflection of the iliotibial tract and biceps femoris tendon on the lateral side. Medially, the semitendinosus, semimembranosus, sartorius and gracilis muscles were resected.

Identification of sesamoid structures was performed by palpation, followed by a more detailed dissection focusing on the fabellae and cyamellae. To facilitate this, the lateral and medial heads of the gastrocnemius muscle were reflected superiorly. A transverse cut was made half way between the popliteus muscle. The two halves were then reflected toward the attachment points respectively, thus, enabling confirmation of the ultrasound findings.

The cyamellae and fabellae that were found were removed and measured. Mitutoyo digital callipers were used to measure the height (superior to infe-

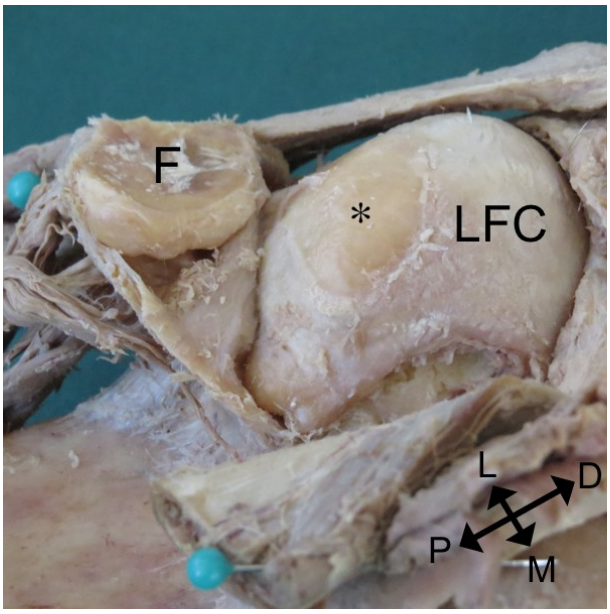

Fig 1. Posterior view of a dissected right knee showing an ossified fabella in the tendon of the lateral head of gastrocnemius muscle (reflected). The fabella (F) with a distinct articular facet creates an impression (*) on the lateral femoral condyle (LFC). P= proximal; D= distal; M= medial; L= lateral.

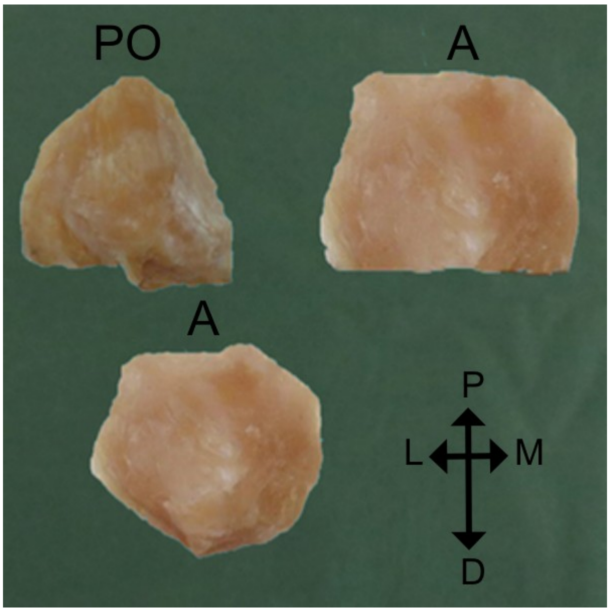

Fig 2. Variations in the shapes of the fabella. P= proximal; D= distal; M= medial; L= lateral; PO= posterior; A= anterior.

rior), thickness (anterior to posterior) and width (lateral to medial) of the sesamoid bones. The morphology of these bones was carefully documented.

RESULTS

This study considers ossified and cartilaginous fabellae and cyamellae. In total, 63 fabellae and 3 cyamellae were found (Table 1). The percentage of cadavers having at least one fabella was 65.7% in male and 56.4% in female; and the prevalence for combined genders was 60.8%. Considering our total sample size, the percentage of cyamella presentation was 2.7%.

The fabella is a palpable solid structure *in situ* and is clearly visible on a reflected tendon (Fig. 1). An impression was observed on the lateral femoral condyle in the presence of a fabella (Fig. 1). Such impression was not observed in the absence of a fabella. The lateral ossified fabella appeared to be round, triangular or rectangular in shape (Fig. 2) and ranged from 3.9 mm to 14.7 mm in length (Table 2).

The position of a fabella *in situ* was demonstrated on a lateral plain film (Fig. 3A). The fabella was highly visible when examined using projectional radiology, but the cyamella was not discernible due to its lower density compared to the surrounding structures. Ultrasound imaging clearly illustrated the cyamella and its boundaries (Fig. 3B).

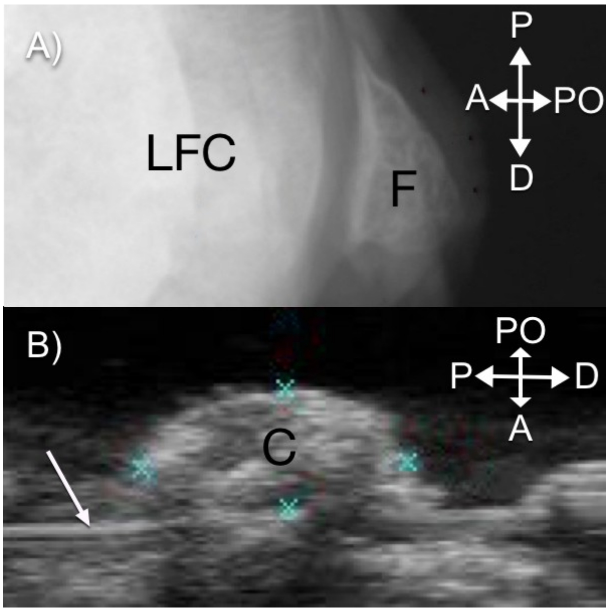

Fig 3. Radiography and ultrasound images of the fabella and cyamella in situ respectively. **A)** Lateral view of a knee showing the fabella (F) posterior to the lateral femoral condyle (LFC) within the tendon of the lateral head of the gastrocnemius muscle. It has a convex posterior surface and a flat anterior articular surface; **B)** Posterolateral view of the first cyamella. A needle (white arrow) inserted anterior to the cyamella (C) shows that the cyamella is not an attachment of the bone or the meniscus. P= proximal; D= distal; PO= posterior; A= anterior.

Table 1. Number of fabella and cyamella observed (n = 111).

	% Ossified	% Ossified and cartilaginous
Lateral Fabella	42.3	50.5
Medial Fabella	0.9	6.3
Total Fabella	43.2	56.8
Cyamella	1.8	2.7

Table 2. Measurements of the ossified fabellae (*n* = 48) and the two ossified cyamellae found.

Measurements (mm)	Fabella	Cyamella 1	Cyamella 2
Length ± SD	9.23 ± 2.89	0.825	0.712
Thickness ± SD	4.8 ± 1.93	0.349	0.297
Width ± SD	9.04 ± 3.04	0.491	0.514

Two out of the three cyamellae observed were ossified. The first ossified cyamella was discovered in a 79-year-old female right knee. Initial surface anatomy examination suggested that the structure was located deep to the LCL, without further indication of it being deep to or embedded within the popliteal tendon. The cyamella was in close contact with the lateral condyle of the femur above the lateral meniscus. Prior to dissection, an ultrasound examination was performed on the knee. Using a needle as an indicator, the cyamella showed no attachment to the bone or the meniscus. It was described as hyperechogenic under ultrasound examination and appeared to be ovoid in shape (Fig. 3B).

After the ultrasound examination, the knee was dissected with the aim to provide a description of the cyamella *in situ* (Fig. 4). The structure had bony characteristics and was embedded within the popliteal tendon. The anterior surface of the cyamella was in contact with a facet on the lateral condyle of the femur. The surface was concaved and reflected the shape of the condyle perfectly, and clearly followed the movement of the popliteal tendon. The posterior surface (the surface in contact with LCL) was presented as a convex shape.

There was no existing contact between the cyamella and LCL due to the cyamella being within the popliteal tendon.

The second ossified cyamella was discovered in a 95-year-old male left knee. The small bone was located within the popliteus muscle by dissection (Fig. 5).

In this case, the posterior surface was rough, however, the anterior surface of the bone has the characteristics of other sesamoid bones such as an articulating facet in contact with the lateral condyle of the tibia, providing smooth movement over the condyle for the popliteal tendon.

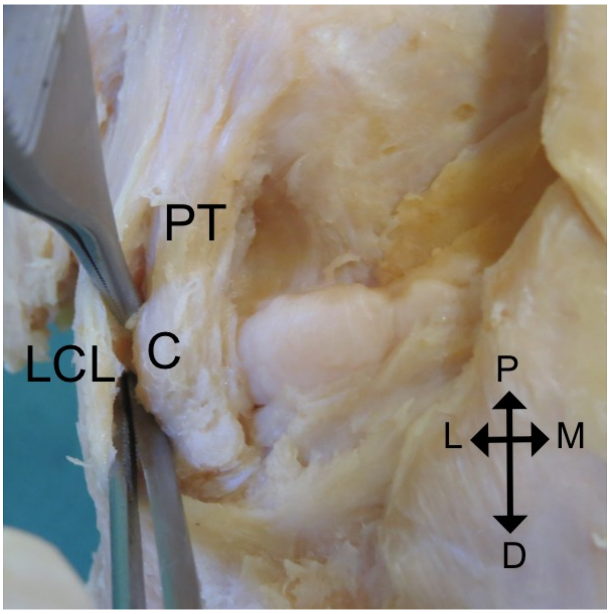

Fig 4. Anterolateral view of a dissected knee showing the first cyamella (C) embedded in the popliteal tendon (PT) medial to the lateral collateral ligament (LCL). P= proximal; D= distal; M= medial; L= lateral.

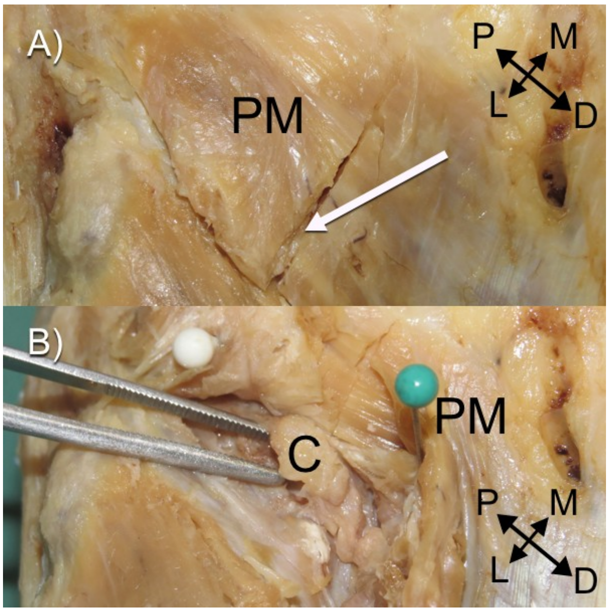

Fig 5. Posterior view of a dissected knee showing the second cyamella. A) The cyamella (C) is deep to the popliteus muscle (PM); B) The cyamella (C) is exposed within the popliteus muscle (PM). P= proximal; D= distal; M= medial; L= lateral.

This cyamella was found behind the head of the fibula, within the popliteus muscle, particularly within the thicker portion of its body (Fig. 6).

In the first cyamella, the specimen was an unpaired knee. However, in the second cyamella, the knees examined were from the same donor and the cyamella was only present in one of them. In both evaluated knees, arthrosis was observed, especially in the second cyamella where the cyamella was found. The length, width and thickness of the ossified fabellae and cyamellae are as shown in Table 2.

DISCUSSION

The fabellae observed in this study varied in sizes: ranging from 3.9 mm to 14.7 mm; and shapes: oval, triangular and rectangular. Considering only non-pathological cases, the length of a fabella can reach up to 15 mm (Barreto et al., 2012). Similar differences were also noted by Piyawinijwong et al. (2012).

In some domestic animals such as cats, dogs and rabbits, the presence of fabellae is categorized as a constant finding in both the medial and lateral heads of the gastrocnemius muscle (Akansel et al., 2006). However, the medial fabella is more rare in humans, as also mentioned by Sutro et al. (1935) who reported just one medial fabella in 106 knees. In the current study, the prevalence of a medial fabella is 0.9% if we consider only ossified medial fabellae; and 6.3% if we consider both ossified and cartilaginous medial fabellae

According to Duncan and Dahm, (2003) the fabella is present in approximately 10-30% of the population, whilst Kawashima et al. (2007) reported a frequency of 40.3% in male and 50% in female. They associated the higher incidence compared to previous reports with the incorporation of cartilaginous fabellae. In our study, we had higher incidence at 65% and 56.4%, respectively, with no statistically significant difference between genders (ANOVA, results not shown), similar to Tubbs et al. (2016), which also showed no differences in incidence between genders. The comparison between this current study and above-mentioned studies is based on the unit of analysis criteria being individuals, not knees.

The presence of fabella has not been repeatedly linked to clinical problems. However, according to Tabira et al. (2013), some related elements such as the presence of a bony fabella and the size of a fabella may influence the length and breadth of the common fibular nerve.

Hence, it is possible that these elements along with the anatomical relation between the fabella and the common fibular nerve could be predisposing factors to a clinical condition. Phukubye and Oyedele (2011) described the fabella as mostly bony; Chew et al. (2014) also showed that the fabella was mostly bony and lateral in 50% of the cases.

Sarin and Carter (2000) associated the fabella with osteoarthritis, which they proposed to be the final stage of endochondrial ossification. This explanation would clarify why it is not radiographically seen before 12-15 years old (Tubbs et al. 2016). Zeng et al. (2012) found that 57.9% of cartilagi-

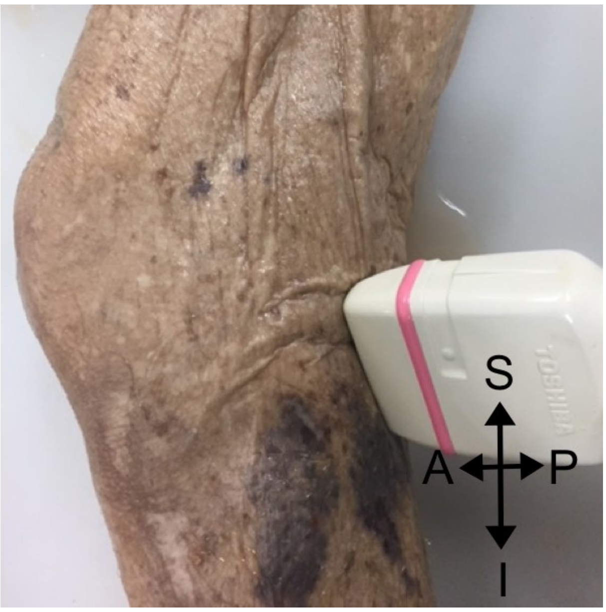

Fig 6. The cyamella was found behind the head of the fibula, within the popliteus muscle, particularly within the thicker portion of its body. S= superior; I= inferior; A=anterior; P= posterior.

nous fabellae were not visualized on radiographs; nevertheless, the radiological features of an ossified fabella are the same as those of a long bone.

The cyamella has been described as separate ovoid-shaped bone fragment seen posterior and inferior to the joint space of the knee, located near the proximal muscle tendon junction of the popliteus muscle and surrounded by its fibres (Akansel et al., 2006); and a structure within the popliteal muscle or even embedded in the proximal part of its tendon (Ghosh, 2011). The popliteal muscle characteristics are similar in primates as well as in most mammals. Ghosh (2011) described the origin of cyamella as the primitive femoro-fibular joint that disappeared when the fibular head lost its femoral attachment. It then receded inferiorly on the lateral aspect of the upper end of tibia to the present location in the superior tibio-fibular joint. The more primitive positions of the ossification of the fibular head receded with it too. These are represented by the cyamella when it is seen. The femoro-fibular meniscus also disappeared and attached to the popliteal muscle forming the popliteal tendon in which the cyamella is embedded.

The cyamella is not a frequent anatomical finding in humans, having only been reported by the use of MRI and CT in previous studies (Munk et al., 2009). However, a study in adult non-human primates showed that the cyamella is a common finding in several species such as *Prosimmi* and *Callitrichidae* but absent amongst *Gorillas* and with a varied presentation between *Atelidae* and *Pongo* genus (Le Minor, 1992). This leads us to believe that the absence of cyamella in human is a result of evolution.

Dykes and Vija (2014) explained that an antero-posterior radiograph of the right knee displayed a well corticated osseous structure adjacent to the lateral femoral condyle. No osteoarthritic features of the knee joint were present. A large 11 mm corticated bone over the lateral aspect of the right knee was identified on MR imaging. This structure lies deep to the lateral collateral ligament and iliotibial band, but superficial to the lateral meniscus. It was within the popliteal tendon and close to its tendonous insertion into the lateral femoral condyle, confirming the presence of a cyamella. This description is similar to our first case findings, where we found this small sesamoid bone under the lateral collateral ligament within the popliteal tendon, less than 10 mm away from its insertion at the lateral condyle of the femur.

One morphological characteristic of the cyamella is the presence of a smooth articular facet (Akansel et al., 2006). This description is consistent with our findings. This interface gives the tendon a smooth articulation to move across the lateral condyle of the femur and tibia and was found in both cases in this study. This description is similar to our second cyamella findings. Even though its posterior surface is irregular and not ovoid in shape as described by Akansel et al. (2006), its anterior aspect presents a smooth facet that allows it to slide when in contact with bone. Additionally, our anatomical description in cyamella 2 is in concordance with other findings described by Reddy et al. (2007). They observed a bony structure located at the tendomuscular junction of the popliteus muscle articulating at the posterior aspect of the lateral condyle of the tibia and lying close to the head of the fibula.

The cyamella could present differential diagnoses as mentioned by Dykes and Vija (2014) such as osteocartilaginous loose bodies, post traumatic bone fragments (osteophytes), meniscal cyst calcification, soft tissue tumours, heterotopic ossification and, less likely, osteochondroma or myositis ossificans. Our findings agree with the description regarding all sesamoid bones of the knee joint, where they are invested by fibrous tissue except for a smooth articular surface that forms a joint articulation with the lateral condyle of either the tibia or femur.

The low presentation of cyamella in our study and the possibility of extrapolating our findings to the general population reaffirm the statement made by Khana and Maldjian (2014), stating that the cyamella is a normal variant or posterolateral corner anomaly in humans. In other articles the cyamella has been described as a frequent finding in dogs and kangaroos, as well as in many primates, however, they are almost unknown in humans (Le Minor, 1992). In dogs, the distal displacement of the cyamella has identified this structure as a secondary clinical sign of ligament injuries, with only a couple of published papers mentioning these structures and some clinical relevance. Considering our findings regarding the size of cyamellas, this could influence the emphasis on the need of deeper analysis of its presence or absence. Considerations including it as a differential diagnose amongst knee pathologies should be mandatory in order to minimize biased clinical conclusions. Despite the fact the cyamella is considered absent except for some exceptional cases (Ghosh, 2011), this makes it an incidental finding and not an anatomical variant (Khanna and Maldijian, 2014).

The existence of most sesamoid bones depends on the endochondral ossification of the sesamoid cartilage, starting from tight aggregates of mesenchymal cells called precartilage condensations or primary precartilage structure. Later in development, between the ages of 3 and 12 years, most sesamoids undergo endochondral ossification (Sarin and Carter, 2000).

Gimerá et al. (2015) stated that the sesamoid bones could not be generated exclusively by orthostatic and mechanical forces or pathological processes. Hence, an interaction between mechanical and biological factors is more likely to lead to the development of a sesamoid bone.

In humans, the mineralization is a prerequisite in order to make an accurate radiological diagnosis, just as described by Arnbjerg and Heje (1993). They indicated that damaged non-mineralised fabellae, either traumatically or otherwise, are difficult to recognise on radiographs. In humans, this fact is known to have led to delayed or missed diagnoses of pathological conditions in non-mineralised fabellae, but certainly we cannot have the same conclusion in relation to cyamella. The only cyamellae that were considered were those with a clear distinguishable bony structure or consistency. Regarding fabellae, though in some knees cartilaginous ones were found, it was not the same situation for the cyamella.

In light of this current study, further research with larger sample sizes, considering not only the calcified cyamellae, as well as using other methods such as histological analysis, is definitely beneficial to solidify our findings.

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