



## Recovery of bacillary layer detachment associated with macula-off rhegmatogenous retinal detachment: Evidence of foveation mechanisms?

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### ARTICLE INFO

#### Keywords:

Retinal detachment  
Bacillary layer detachment  
Photoreceptors  
Foveation  
Fovea  
Optical coherence tomography

### ABSTRACT

**Purpose:** To describe the mechanisms of postoperative foveal restoration in three patients with bacillary layer detachment (BALAD) associated with macula-off rhegmatogenous retinal detachment.

**Observations:** BALAD associated with macula-off rhegmatogenous retinal detachment presented with two different morphologies: with an intact foveal roof (case 1) and *lamellar*, with an open foveal roof (cases 2 and 3). In case 1 visual acuity significantly improved and foveal morphology completely restored at postoperative month 6, with a marked increase in foveal thickness. Case 2 presented with a lamellar BALAD in a long-standing retinal detachment, and it was treated with scleral buckling with an unfavourable evolution into a full-thickness hole in the early postoperative period. It was then addressed with internal limiting membrane peeling and inverted flap, which resulted in the resolution of the lesion, but with limited postoperative visual and anatomical recovery. Case 3 lamellar BALAD was directly addressed with pars plana vitrectomy, ILM peeling and inverted flap, with a remarkable foveal anatomical restoration and visual acuity improvement over the follow-up period.

**Conclusions and importance:** The process of foveation may play a key role in the healing process of BALAD associated with rhegmatogenous retinal detachment. Lamellar BALAD should be considered and treated as a FTMH associated with retinal detachment. The two BALAD subtypes may represent different clinical stages of the BALAD spectrum.

### 1. Introduction

Bacillary layer detachment (BALAD) is a peculiar pathophysiological entity first described with optical coherence tomography (OCT) in inflammatory diseases, characterized by a split of the photoreceptors posterior to the external limiting membrane (ELM), presumably within the myoid zone of the photoreceptors.<sup>1</sup>

Morphologically, BALAD associated with retinal detachment may present with an intact foveal roof (Fig. 1) or with what was described as a “lamellar” configuration, in which the whole foveal roof is missing (Figs. 2 and 3).<sup>2</sup>

Recently, the spectrum of BALAD expanded to other non-inflammatory conditions such as rhegmatogenous retinal detachment, in which BALAD was considered a significant risk factor for

postoperative full-thickness macular hole (FTMH) formation, as described by Martins Melo et al.<sup>2</sup>

In a recent report, Spaide hypothesized that during the healing process of FTMH, the reconstitution of the foveal anatomy may be due to a process he described as “foveation”, i.e. the inward migration of parafoveal cones in response to injury, a process known to happen in foveal development after birth.<sup>3</sup>

We propose that the “lamellar” BALAD should be treated and considered as FTMH in the setting of a macula-off retinal detachment. Further, we suggest that foveation mechanisms may explain the postoperative restoration of foveal microanatomy in patients with BALAD associated with macula-off rhegmatogenous retinal detachment.

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<https://doi.org/10.1016/j.ajoc.2023.101923>

Received 17 April 2023; Received in revised form 20 July 2023; Accepted 22 August 2023

Available online 1 September 2023

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## 2. Findings

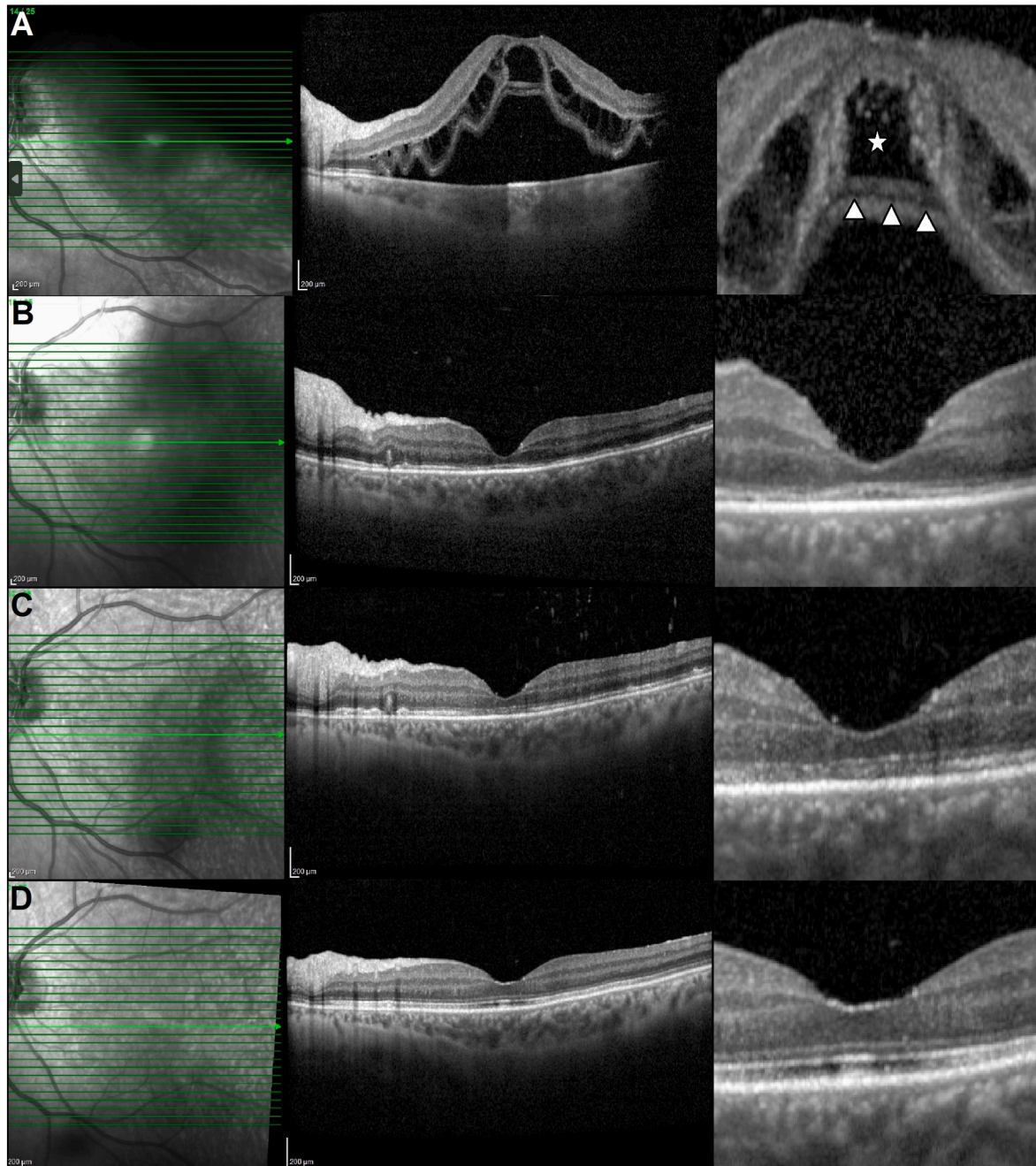
### 2.1. Case 1

This 54 years old female presented to the ophthalmology department complaining of central vision loss first noticed two days before, which was preceded by a 14-day history of flashes and floaters. Best corrected visual acuity (BCVA) was low, being 20/200 Snellen equivalent. The eye was phakic, and it was diagnosed with a macula-off RD, with a complete

posterior vitreous detachment, a superior causative horseshoe break at 12h. OCT examination revealed a BALAD with a split below the external limiting membrane and an intraretinal cystoid area separating photoreceptor inner and outer segment remnants from the intact foveal roof (Fig. 1, A).

The patient was treated with a standardized scleral buckling technique as previously published, subretinal fluid drain, cryopexy and air tamponade.<sup>4</sup>

At postoperative day 7, the retina was fully attached, and the OCT



**Fig. 1. Bacillary layer detachment (BALAD) associated with a macula-off retinal detachment (Case 1).** **A. Preoperative appearance.** A marked difference in optical coherence tomography (OCT) reflectivity marks the boundaries between outer and inner segments in the detached outer stip (white arrowheads). A hyporeflective cystoid space separates BALAD from the external limiting membrane (EZ) (white star). **B. Postoperative appearance, day 7.** The retina reattached immediately after scleral buckling surgery. The fovea appears abnormal both quantitatively, being 80  $\mu\text{m}$  thick at the foveal center, and qualitatively, having defects in both ellipsoid (EZ) and ELM bands and presenting with an abnormally thin ONL. **C. Postoperative appearance, 1 month.** The ONL appears thicker if compared to baseline, and both the EZ and ELM bands are slowly being reconstructed. **D. Postoperative appearance, month 6.** At six months from surgery, the foveal morphology appears physiologic. The central fovea is 166  $\mu\text{m}$  thick, doubling its thickness if compared to postoperative day 1. The EZ and ELM bands completely recovered their integrity. The complete ONL reconstitution supports the hypothesis of foveation process.

scan of the central fovea showed a marked thinning, with defect of both the ELM and the ellipsoid (EZ) bands (Fig. 1,B).

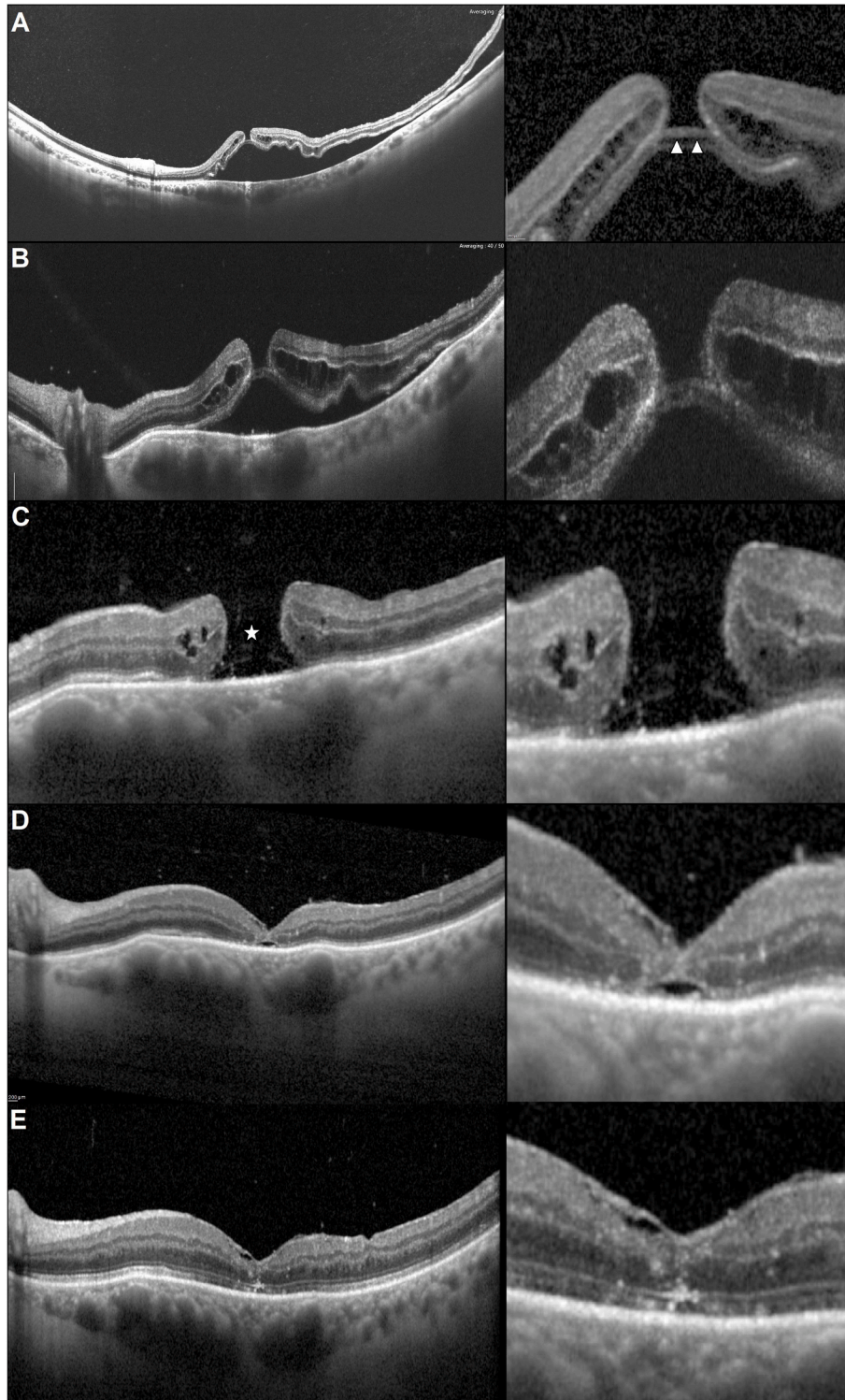
Over the follow-up period BCVA dramatically improved from 20/125 Snellen equivalent at postoperative week 1–20/25 Snellen equivalent at postoperative month 6.

The OCT morphology of the central fovea showed a remarkable reconstitution of the foveal thickness, which almost doubled from postoperative day 1 (80  $\mu\text{m}$ ) to postoperative month 6 (166  $\mu\text{m}$ ), as visible in Fig. 1C and D. Further, there was a complete restoration of the

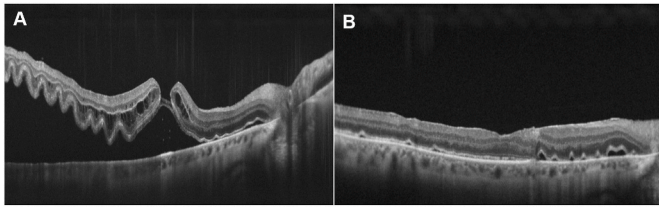
outer retina, with preserved ELM and EZ bands.

## 2.2. Case 2

This 65 years old male presented with a 10-days history of central vision loss accompanied by newly onset flashes and floaters in his emmetropic left eye. BCVA at presentation was low, being count fingers at 1 m. Upon examination, a macula-off RD with complete posterior vitreous detachment, a superior causative horseshoe break at 2h, and a



**Fig. 2. Lamellar bacillary layer detachment (BALAD) associated with a macula-off retinal detachment (Case 2).** A. **Preoperative appearance.** A lamellar BALAD is seen, consisting of a detached strip composed of remnants of photoreceptors outer and inner segments at the level of the central fovea, with an open foveal roof. Best corrected visual acuity (BCVA) was counting fingers at 1 m. B. **Postoperative appearance, day 1.** After scleral buckling surgery with limited subretinal fluid drain, the macula is still detached and the lamellar BALAD appears roughly unchanged if compared to baseline. C. **Postoperative appearance, Day 7.** At one week from surgery, the macula reattached, and lamellar BALAD evolved into a full thickness macular hole (FTMH). The outer strip remnants are still visible but start to degrade (white star). D. **Second surgery, postoperative day 7.** After a second surgery with pars plana vitrectomy, internal limiting membrane peel with inverted flap and air tamponade, the hole appears to be closed. The fovea looks thin, with an outer retina defect. The EZ band is not visible at the foveal center. BCVA improved to 20/125 Snellen Equivalents. E. **Second surgery, postoperative month 3.** At three months after the second surgery, the foveal morphology partially reconstructed, with a newly formed ELM band and a partially restored EZ band. Hyperreflective spots are seen within the outer nuclear layer. BCVA improved to 20/100 Snellen Equivalents.



**Fig. 3. Lamellar bacillary layer detachment (BALAD) associated with a macula-off retinal detachment (Case 3).** A. Preoperative appearance. A lamellar bacillary detachment is visible. Best corrected visual acuity (BCVA) was 20/125 Snellen Equivalents. B. Postoperative month 3. Three months after pars plana vitrectomy, internal limiting membrane peel with inverted flap and gas tamponade, the hole appears to be closed. The foveal morphology appears partially reconstructed, with an intact external limiting membrane band and a partially recovered ellipsoid band. Isolated outer retinal pockets of subretinal fluid remain throughout the macular region. BCVA increased up to 20/32 Snellen equivalent.

lamellar BALAD were noticed (Fig. 2, A).

The patient was treated with scleral buckling surgery as Case 1, but with limited subretinal fluid drain and gentle injection of air tamponade. At postoperative day 1, the macula was still detached, and the BALAD was unchanged compared to baseline (Fig. 2, B). At postoperative day 7 the retina completely reattached and a FTMH was present (Fig. 2, C). Remnants of degraded photoreceptors inner and outer segments were still visible at the base of the macular hole.

The FTMH was addressed with 25-g pars plana vitrectomy, ILM peeling with inverted flap and air tamponade performed two weeks after the first surgery. At postoperative day 7 the hole was closed, with a marked reduction in foveal thickness and a disruption of central EZ and ELM (Fig. 2, D). Over the follow-up period of three months, the outer retinal morphology improved, with partial restoration of both the ELM and the EZ bands, and a significant thickening of the foveal center (Fig. 2, E), if compared to the early postoperative period.

At postoperative month 3, BCVA improved up to 20/100 Snellen equivalent.

### 2.3. Case 3

This 57-year-old myopic patient presented with a three-day history of vision loss, preceded by PVD symptomatology, with a BCVA of 20/100 Snellen equivalent. Upon examination, it was diagnosed with a macula-off retinal detachment associated with a lamellar BALAD in his right pseudophakic eye.

This eye underwent 25-G pars plana vitrectomy with ILM peeling and inverted flap technique. At postoperative month 3, the retina was attached, with residual outer retinal corrugations (Fig. 3, B). The hole was closed, with a reconstructed ELM band and a partially disrupted EZ band.

At postoperative month 3, BCVA increased up to 20/32 Snellen equivalent.

### 3. Discussion

Bacillary layer detachment (BALAD) associated with macula-off rhegmatogenous retinal detachment (RRD) is a peculiar clinical entity important to recognize preoperatively, as it may influence choice of surgical strategy and impact postoperative functional and anatomic recovery. BALAD spectrum in RRD has been recently described by Martins Melo et al. in a consecutive series of patients and thought to generate due to mechanical tangential forces at the foveal region.<sup>2</sup> Such tractional insults may cause a disruption of the Müller cell cone with a consequent detachment of the external limiting membrane (ELM) and a split within the myoid of the photoreceptors.<sup>2</sup>

The preferred splitting location at the inner segment myoid of

photoreceptors in BALAD have been confirmed by Ramtohul et al. with the aid of OCT imaging and post-mortem histology analysis of a human eye. In the same report, the authors speculate that the surprising recovery of central photoreceptors after BALAD may be due to sophisticated healing mechanisms of photoreceptors themselves, which may be able to regenerate inner segments and inner cellular structures.<sup>1</sup>

However, the mechanical “split” of a photoreceptor cell within the inner segment myoid would signify a break of the cellular plasma membrane and a loss of most of the cell vital organelles and energy sources, configuring a potentially catastrophic and irreversible damage for the photoreceptor itself. Although photoreceptors have shown to possess great recovery capabilities, i.e. after reattachment, those features have been studied in cells which, although injured due to hypoxia and lack of nutrients, may still maintain their structural integrity. In such cases, photoreceptors are not mechanically torn apart in crucial areas for their survival such as in BALAD associated with retinal detachment, as illustrated in Fig. 4.<sup>5</sup>

The striking recovery of the foveal microanatomy we showed in our cases suggest that there may be further mechanisms of foveal healing apart from the resilience and regenerative properties of damaged central cones.

Although speculative, it is possible that the process of foveation hypothesized by Spaide in FTMH and consisting in the inward migration of parafoveal cones toward the central fovea,<sup>3</sup> may happen in the healing process of BALAD associated with rhegmatogenous retinal detachment, as schematized in Fig. 5.

As human highly specialized postmitotic cones cannot replicate, it is difficult to justify the remarkable anatomical and functional recovery of the central fovea seen in our cases just on the basis of central cones capability to heal after injury. Further, it is puzzling to explain the complete restoration of EZ and ELM bands if the ONL appears depleted of cells, as in the cases hereby reported. The centripetal migration of healthy cones from more peripheral areas of the fovea and parafovea may justify such clinical and morphological findings.

In an era in which the success of RRD surgery is no longer based on pure anatomical success, the understanding of the photoreceptor healing mechanism may help to better tailor the surgical strategy to optimize postoperative functional results, as suggested in a recent review.<sup>6</sup>

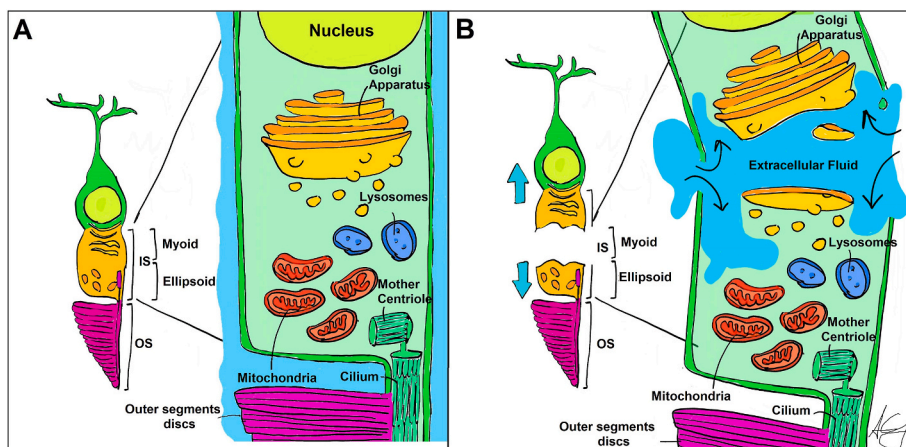
BALAD may present mainly in two forms: with an intact foveal roof, or with an open foveal roof, named “lamellar” by Martins Melo et al. Although the original terminology was preserved in the present report to avoid confusion, we feel that the term “lamellar” in the setting of BALAD retinal detachment may be inappropriate and overlap with the definition of lamellar macular holes, a distinct clinical entity.<sup>7</sup> In our series, the lamellar BALAD approached with scleral buckling led to the formation of a FTMH in the immediate postoperative period, suggesting that in this subtype of BALAD the structural integrity of the fovea and the Müller cell cone may be irreversibly compromised, as the outer strip of inner-outer segments remnants degrades once reattached to the RPE. Further, such anatomical junction does not appear to possess the mechanical strength to facilitate the borders reposition. Therefore, lamellar BALAD should be considered and treated as a FTMH associated with rhegmatogenous retinal detachment, and a direct approach with vitrectomy and ILM peel may be preferred to scleral buckling.

Consistent with our hypothesis, all lamellar BALAD included in Martin Melo et al. study population evolved into FTMH after retinal reattachment.<sup>2</sup>

Notably, lamellar BALAD may occur in emmetropic eyes, and not only in association with high myopia.

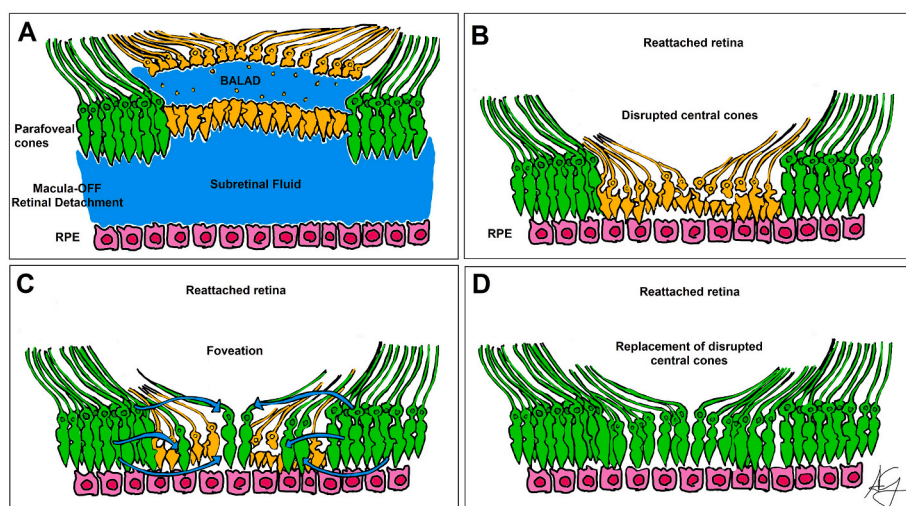
### 4. Conclusion

This report attempts to explain the recovery of BALAD associated with macula-off rhegmatogenous retinal detachment with the recently hypothesized foveation phenomenon, which may explain the foveal reconstitution and visual acuity gain after surgical repair. Lamellar



**Fig. 4. Location of bacillary layer detachment (BALAD) split. A. Physiologic conditions.** The inner segment myoid contains vital cellular organelles such as the Golgi apparatus, while the distal ellipsoid contains mitochondria, lysosomes, the mother centriole and the inner portion of the connecting cilium. Like all eukaryote cells, rods and cones possess an external cellular membrane which separates the inner structures of the cell from the extracellular space. **B. Presumed mechanism of BALAD detachment.** Previous research suggested that during BALAD, the photoreceptors split at the level of the inner segment myoid.<sup>1</sup> In such case, the integrity of the external limiting membrane would be irreversibly compromised, and the extracellular fluid would gain access to the inner cellular organelles. Vital structures such as Golgi apparatus and mitochondria may be irreversibly disrupted. Although photoreceptors have been shown great resilience after metabolic and hypoxic damage, a mechanical, structural disruption such as BALAD may potentially

signify a potentially catastrophic outcome leading to cellular death.



**Fig. 5. Foveation mechanism hypothesis. A. Bacillary layer detachment (BALAD).** For the purpose of this schematic illustration, only photoreceptors and retinal pigment epithelium cells are depicted. In BALAD associated with macula-off detachment, the foveal cones present a critical structural damage. **B. Retinal reattachment.** Once reattached, BALAD recovers but the central photoreceptors are irreversibly disrupted. **C. Foveation mechanism.** Healthy cones displace from adjacent parafoveal areas to the central fovea, integrating with the central retinal pigment epithelium. **D. Recovery.** Once the process is completed, the central fovea may be, at least partially, repopulated by healthy parafoveal cones, with a good anatomical and functional recovery.

BALAD should be considered and treated as FTMH associated with retinal detachment. BALAD with and without an intact foveal roof may represent different clinical stages of the same BALAD spectrum.

Although supported by recent research and clinical findings, the authors recognize that the hypothesis asserted is speculative; however, the foveation mechanism posited here is an intriguing and plausible explanation for the dramatic microstructural improvement which may be seen after BALAD surgical repair, and may be an important healing mechanism in other retinal conditions. Additional research is needed to further explore our hypotheses, while a broader semantic discussion is advisable to reach a consensus on BALAD terminology.

**Patient consent**

Consent to publish this case report has been obtained from the patient(s) in writing.

**Funding**

No funding or grant support.

**Authorship**

All authors attest that they meet the current ICMJE criteria for Authorship.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Acknowledgements**

None.

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