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Five New Species and a New Record of *Fenestrulina* (Bryozoa: Cheilostomatida: Fenestrulinidae) in Korean Waters

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ABSTRACT

Fenestrulina malusii (Audouinm, 1826) has long been considered a cosmopolitan species and is recognized as a species complex comprised of several cryptic species since scanning electron microscope (SEM) is utilized for bryozoan taxonomy. Many new species thus have been separated from *F. malusii* with comprehensive morphological characteristics. For this reason, a taxonomic revision on two Korean species of *Fenestrulina*, *F. malusii* and *F. mutabilis*, has been required. This study aims to investigate *Fenestrulina* collected from 19 localities in Korean waters from 1985 to 2023. As a result of the present study, Korean *Fenestrulina* was found to be of six species. Of them, *F. delicia* Winston, Hayward and Craig, 2000, is added to the Korean bryozoan fauna; the other five species are new to science. All six species were provided with a detailed description and SEM images.

Keywords: *Fenestrulina*, *F. malusii*, *F. mutabilis*, Korea, new species, new record

INTRODUCTION

To date, 66 Recent species of *Fenestrulina* Jullien, 1888 have been recorded worldwide (https://www.marinespecies.org; 26 Nov 2024). Most of these species have increased with the detailed key characters by using Scanning Electron Microscopy to identify bryozoans having calcified exoskeletons by Hayward (1980), Gordon (1984, 1989), Hayward and Taylor (1984), Moyano (1985), Hayward and Ryland (1990), Vieira and Stampar (2014), and Figuerola et al. (2018). Of *Fenestrulina* species added newly to the bryozoan fauna, some new species especially have been separated from *Fenestrulina malusii* (Audouin, 1826) with its comprehensive morphological characteristics. *F. malusii* had long been considered a cosmopolitan species (Soule et al., 1995; Dick et al., 2005) since it was first described from Egypt (Audouin, 1826). Because the detailed morphological characters could be observed by utilizing scanning electron microscope (SEM), this species recognized as a species complex comprised of several cryptic species became a problematic bryozoan species, leading to thorough revision (Hayward and Ryland, 1999; Souto et al., 2010). Considering the distribution of *F. malusii*, the species found in the Northeast Pacific has resulted in four new species, *F. blaggae*, *F. eopacifica*, *F. farnsworthi*, and *F. morrisae* (Soule et al., 1995). *F. malusii* in China and Japan became *F. orientalis* and *F. sinica*, respectively (Liu et al., 2003; Grischenko et al., 2007). De Blauwe et al. (2014) noted that macrofaunal analysts misidentified the arrival of non-native *F. malusii* in the UK for a considerable period and confirmed that this species was not *F. malusii* but *F. delicia*. Until recently, only two species of the genus *Fenestrulina* were known in Korean waters: the presumed cosmopolitan *F. malusii* and the Indo-Pacific *F. mutabilis* (Rho and Lee, 1980; Rho and Seo, 1984; Seo, 2005; Chae and Seo, 2019; Seo and Kil, 2019). The Korean authors have undoubtedly identified the specimens of this genus as two species so far. As aforementioned, *F. malusii* in Korean waters is also likely to be reviewed. This study thus aims to investigate the Korean *Fenestrulina*, including the review of *F. malusii* and *F. mutabilis*, which have already been reported.

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MATERIALS AND METHODS

All specimens for taxonomic study on Korean *Fenestrulina* (Bryozoa: Cheilostomatida: Fenestrulinidae) were collected from 19 localities in Korean waters from 1985 to 2023, preserved in 95% ethanol, and have been kept at the collection of Woosuk University. For identification, the external features of the zooid were observed under a stereomicroscope (Stemi SV6; Carl Zeiss, Germany), and a part of the specimen was bleached and cleaned in hot aqueous sodium hypochlorite, washed, dried and gold coated (MCM-100; SEC, Korea), and was observed with a SEM (SNE-3200M Mini; SEC) at 15 kV accelerating voltage. Measurements were made on SEM images of zooids using Image J (National Institutes of Health, Bethesda, MD, USA). The sampling localities of the specimens mentioned in this study are given in Fig. 1. The distribution data in the present study were obtained from the cited reference, the Bryozoa Home Page website (https://www.bryozoa.net; 10 Oct 2024) and World Register of Marine Species (https://www.marinespecies.org; 10 Oct 2024). The holotypes of *Fenestrulina cracens* n. sp. (MABIK IV00175057), *F. lunata* n. sp. (MABIK IV00175058), *F. rugosa* n. sp. (MABIK IV00175055), and *F. spissa* n. sp. (MABIK IV00175056) and the specimen of *F. delicia* (MABIK IV00175054) are stored in the National Marine Biodiversity Institute of Korea (MABIK), Seocheon, Korea. The holotype of *F. monopora* n. sp. (NIBRIV0000904152) is also deposited at the National Institute of Biological Resources (NIBR), Incheon, Korea. The remainder of the materials are kept in the collection of Woosuk University, Korea.

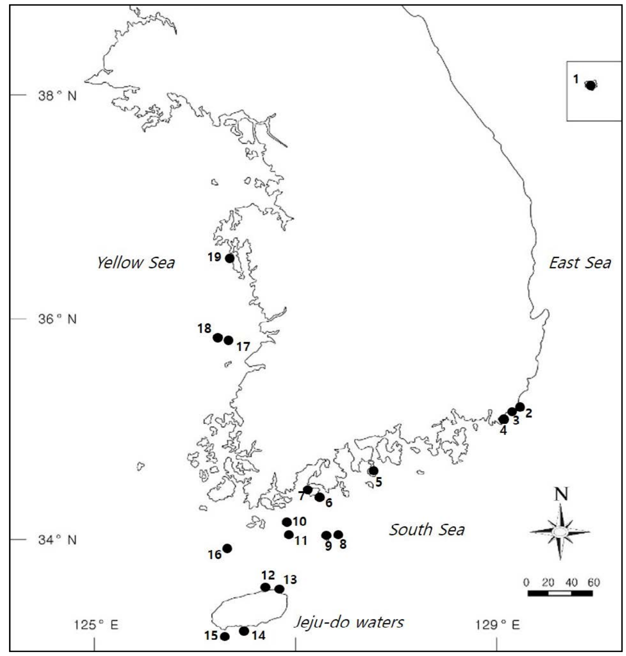

Fig. 1. A map of the collection localities in this study. 1, Ulleungdo Island, Ssangjeongcho; 2, Songjeong port; 3, Mipo; 4, Busan port; 5, Dolsando Island; 6, Naedalgseom Island; 7, Daehwado Island; 8, Sangbakdo Island; 9, Geomundo Island; 10, Chenogsando Island; 11, Yeosedo Island; 12, Gimnyeong; 13, Hangwon; 14, Museom Island; 15, Marado Island; 16, Chujado Island, Yongdumbeong; 17, Heukdo Island; 18, Jikdo Island; 19, Cheongpodae.

RESULTS

Phylum Bryozoa Ehrenberg, 1831
Class Gymnolaemata Allman, 1856
Order Cheilostomatida Busk, 1852
Suborder Flustrina Smitt, 1868
Superfamily Schizoporelloidea Jullien, 1883
Family Fenestrulinidae Jullien, 1888
Genus *Fenestrulina* Jullien, 1888

[1]***1. *Fenestrulina cracens* n. sp. (Fig. 2)**

Fenestrulina malusii: Seo, 2005: 440, pl. 169-141A; Seo and Kil, 2019: 222; Chae and Seo, 2019: 213.

Etymology. Latin "*cracens*" is slender, alluding to this new species's slender and long spines.

Material examined. Korea: Busan-si: Mipo, 22 Jul 1985; Jeollanam-do: Yeosu-si, Dolsando Island, 11 Jul 2002; Holotype, MABIK IV00175057, Goheung-gun, Daehwado Island, 23 Jun 2008; Paratype, Gyeongsangbuk-do: Ulleungdo Island, Ssangjeongcho, 24 May 2023.

Substratum. Stone and shells of oyster (*Crassostraea* sp.).

Description. Colony encrusting, unilaminar, coherent, more or less circular (Fig. 2A, E). Autozooids (Fig. 2B, C) rounded-hexagonal to oval with smooth lateral walls inward-sloping and slightly overlapping frontal wall, leaving furrow between zooids, longer than wide, 0.29-0.36 (0.32±0.02) mm long, 0.17-0.30 (0.21±0.02) mm wide. Frontal wall (Fig. 2B, C) slightly convex, with smooth gymnocyst forming ridge from proximal end of zooid to one-third of orifice and running inwards along proximal margin of orifice, smooth (although some fine wrinkles visible) and imperforate in central area proximal to ascopore with small umbo below ascopore in central region; 19-35 stellate pores in a single marginal row (11-22) in ridge, one to two (5-10) rows between ascopore and orifice, and three pores between oral spines above orifice. Orifice semi-elliptical, transverse-

Korean name: [1]*늘씬가시방사이끼벌레 (신칭)

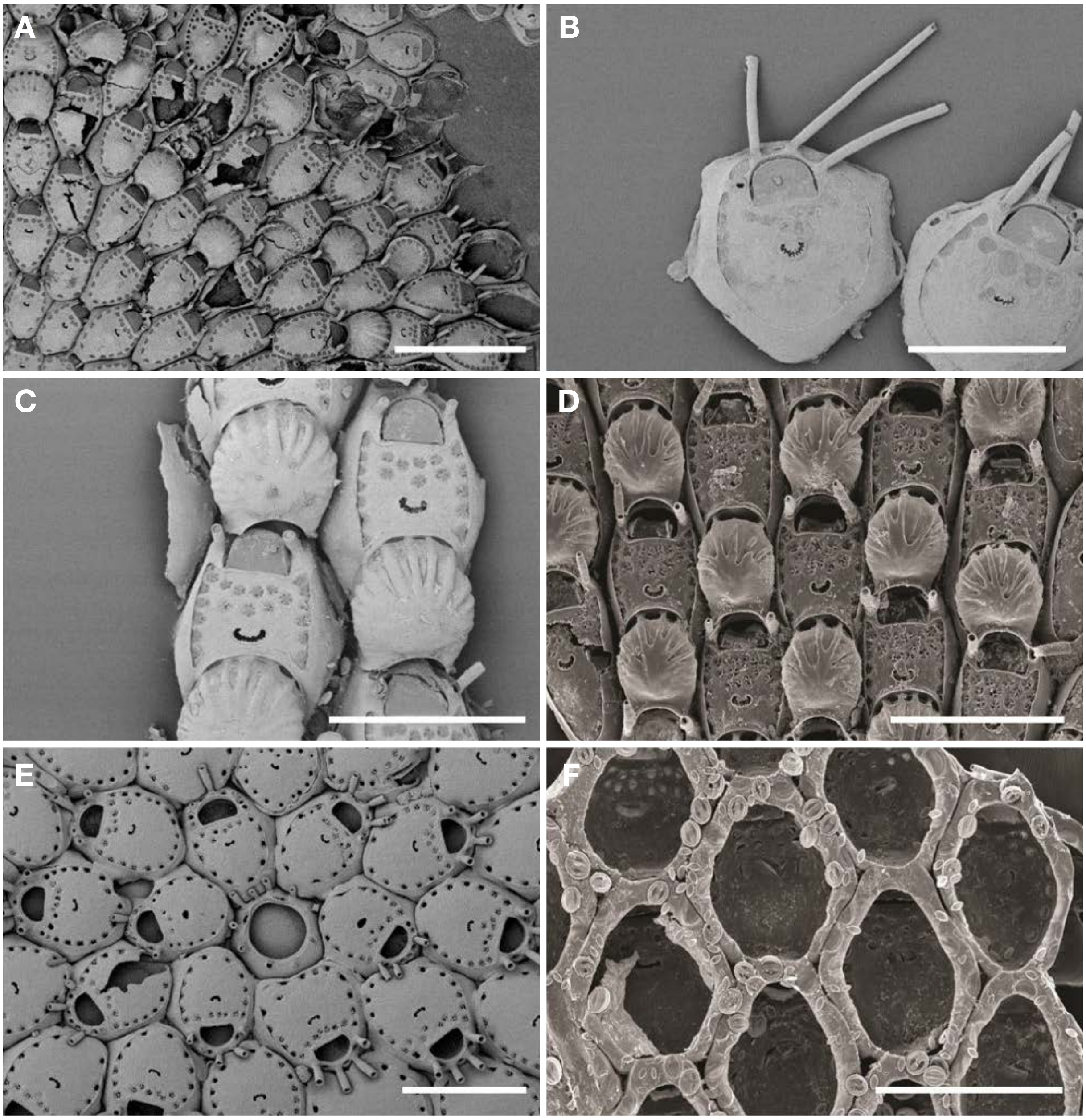

Fig. 2. *Fenestrulina cracens* n. sp. A, Zooidal arrangement, from Mipo; B, Detailed zooids showing long oral spines, operculum, and well-developed, smooth, and raised rim of non-perforate calcification around zooid, from Daehwado Island; C, Mature zooids showing with radially ribbed and umbonated ovicells, two oral spines and ascopores, from Daehwado Island; D, Ovicell with two oral spines, from Dolsando Island; E, Ancestrula and periancestrular zooids with three to four spines, from Mipo; F, Basal surface of colony with uncalcified diamond-shaped, from Dolsando Island (cited from Seo, 2005). Scale bars: A, D, F=0.5 mm, B=0.2 mm, C, E=0.3 mm.

ly D-shaped, wider than long, 0.04–0.07 (0.06±0.006) mm long, 0.08–0.10 (0.09±0.005) mm wide; proximal margin straight or slightly concave, with a minute triangular condyle at either proximal corner. Operculum (Fig. 2B, C) semi-elliptical, wider than long, 0.04–0.06 (0.05±0.009) mm long, 0.08–0.10 (0.09±0.007) mm wide. Three to four long, jointed hollow spines around distal curvature of orifice in non-ovicellate zooids (Fig. 2B), two in ovicellate zooids (Fig. 2C), located close to proximal corners of ovicell, 0.008–0.016 (0.012±0.002) mm in diameter, three or four in periancestrular zooids. Ascopore (Fig. 2C) below orifice by distance about equivalent to length of orifice, situated in

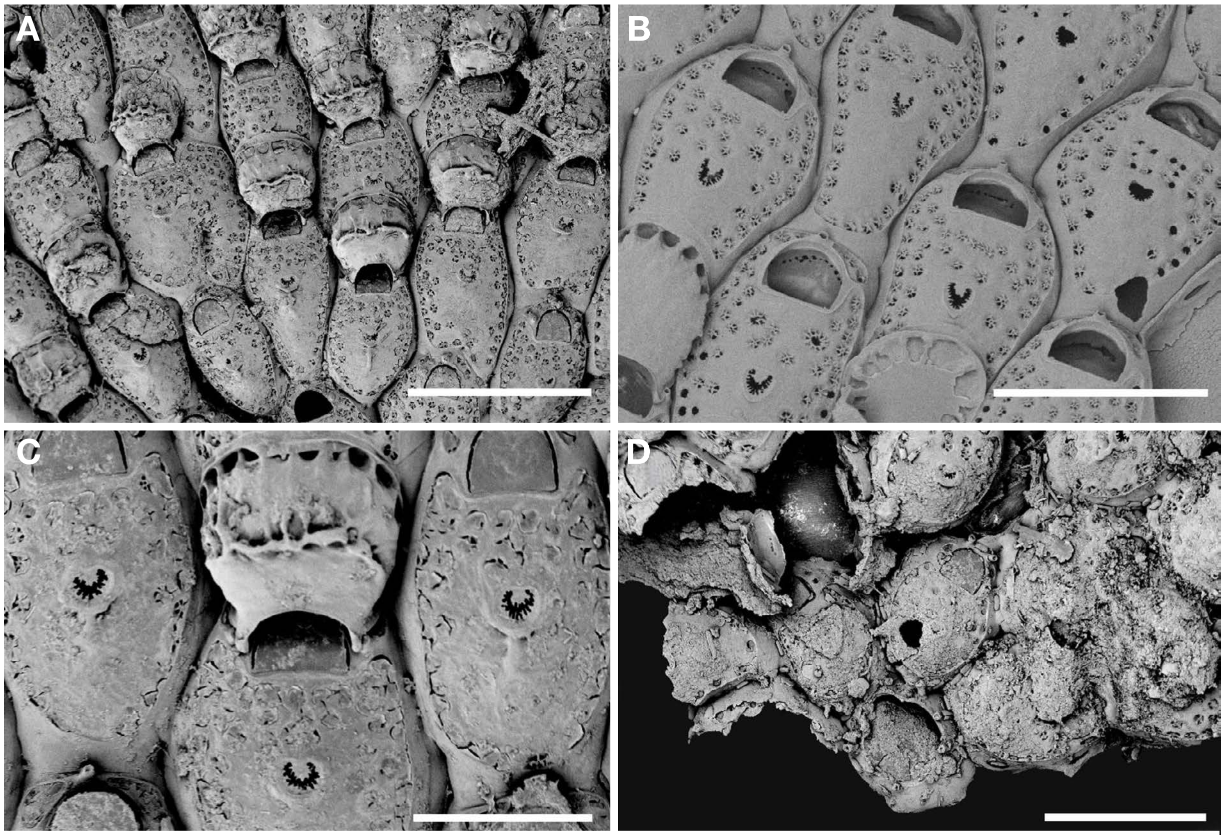

Fig. 3. *Fenestrulina delicia* Winston, Hayward, and Craig, 2000. A, Zooidal arrangement, from Busan Port; B, Immature zooids showing orifice, single oral spine, ascopores and pores, from Chengpodae; C, Mature zooid with ovicell showing radial furrows at distal half and irregular transverse ridges, from Busan Port; D, Ancestrula and periancestrular zooids, from Busan Port. Scale bars: A=0.5 mm, B, C=0.3 mm, D=0.1 mm.

frontal wall centrally, crescentic with inner border serrated, wider than long, 0.01–0.02 (0.01±0.003) mm long, 0.03–0.05 (0.04±0.005) mm wide; smooth rim oval to reniform. Ovicell (Fig. 2C, D) hemispherical, prominent, conspicuous, smooth, slightly wider than long or equal, 0.15–0.18 (0.17±0.009) mm long, 0.15–0.19 (0.18±0.01) mm wide, often umbonate, a peripheral row of marginal pores and radially ribbed to frontal umbo with slightly furrows, curves slightly outward along each side of orifice at proximal corners as lappets, closed by operculum. No avicularia. Lateral wall of zooids with two distal and two distolateral basal pore chambers. Basal wall (Fig. 2F) uncalcified, diamond-shaped. Ancestrula (Fig. 2E) tatiform, circlular, 0.18–0.28 (0.23±0.04) mm in diameter, with smooth, narrow gymnocyst and large, circlular opesia, 0.14–0.19 (0.16±0.03) mm in diameter, two hairpin-shaped with one or pores distally, with ten, jointed hollow spines around opesial margin, and surrounded by seven periancestrula zooids.

Remarks. This species was previously referred to as *F. malusii*. The most striking difference between *Fenestrulina cracens* n. sp. and *F. malusii* is a smooth raised rim of non-perforate calcification around the zooid shown in *F. cracens*. The ovicell of this new species shows radiating ridges on its frontal surface in contrast to the almost smooth ovicells in *F. malusii*. Also, *F. cracens* differs from *F. malusii* in having 3–4 oral spines, skinny and almost flat-rimmed ascopore, and circular ancestrula. As stated earlier, most morphological features of *F. cracens* are identical to those of *Fenestrulina spissa* n. sp. except for the shape of the ovicell and spine number.

Distribution. Korea (South Sea and East Sea).

[1]*2. *Fenestrulina delicia* Winston, Hayward, and Craig, 2000 (Fig. 3)

Fenestrulina delicia Winston, Hayward, and Craig, 2000: 417, figs. 13–15; Dick et al., 2005: 3761, fig. 22A–D; De

Korean name: [1]*달링방사이끼벌레 (신칭)

Blauwe et al., 2014: 45, fig. 2; Wasson and De Blauwe, 2014: 2, fig. 3; López-Gappa and Liuzzi, 2016: 510, fig. 2a–d; López-Gappa et al., 2022: 388, fig. 29.

Material examined. Korea: Busan-si: MABIK IV00175 054, Busan Port (3 pier), 14 Aug 2009; Chungcheongnam-do: Taean-gun, Cheongpodae, 12 Jul 2010.

Substratum. Shell (*Mytilus galloprovincialis*).

Description. Colony encrusting, unilaminar, more or less circular. Autozooids (Fig. 3A, B) rounded-hexagonal to oval, longer than wide, 0.34–0.53 (0.41±0.04) mm long, 0.18–0.29 (0.23±0.03) mm wide, with smooth lateral walls sloping inwards, overlapping frontal wall and leaving furrow between zooids. Frontal wall (Fig. 3B) slightly inflated, smooth, and imperforate in central area below ascopore, with about 35–50 stellate pores in two to three rows between ascopore and orifice, a single row along proximal margin, one to two rows along lateral margins, a row of pores distal to orifice, visible in a pair of hairpin-shaped panels by a border. Orifice (Fig. 3B) semi-elliptical, D-shaped, wider than long, 0.05–0.08 (0.07±0.007) mm long, 0.08–0.10 (0.09±0.006) mm wide; proximal margin straight or slightly bowed and smooth, with minute triangular condyle at either proximal corner. Operculum semi-elliptical, wider than long, 0.06–0.08 (0.07±0.009) mm long, 0.081–0.088 (0.08±0.002) mm wide. Non-ovicellate zooids with one to three short spines (Fig. 3B), ovicellate zooids with two short spines on each side of proximal corner of ovicell (Fig. 3C). Ascopore (Fig. 3B, C) separated from orifice 1.0–1.5 orifice length away, situated centrally to area, i.e., about half length of zooids, longer than wide, 0.03–0.05 (0.04±0.004) mm long, 0.03–0.04 (0.03±0.001) mm wide, irregular in size and shape, slightly raised in outer peripheral margin forming lowered umbo; proximally directed V-shape to U-shaped robust projection, inner edge deeply serrated, with irregularly branched. Ovicell (Fig. 3C) hemispherical, prominent, conspicuous, longer than wide, 0.19–0.24 (0.22±0.01) mm long, 0.14–0.17 (0.15±0.008) mm wide, with a row of marginal pores, a raised margin and irregular transverse ridge on frontal surface, thin and raised basal flanges at proximal corners and curving outward along each side of orifice, closed by zooidal operculum; frontal surface with indistinct radiating ridges between marginal pores and transverse ridge, with smooth and slightly flat surface below transverse ridge. No avicularium. Ancestrula (Fig. 3D) tatiform, oval, with ten spines around opesial margin, surrounded by six periancestrular zooids.

Remarks. The characteristics in the Korean specimen are identical to those from the Atlantic by Winston et al. (2000), apart from the fact that Korean specimens are about two-thirds smaller than those of Winston et al. (2000) in the size of zooid, orifice and ovicell.

Fenestrulina delicia is very similar to *F. sinica* Liu, Liu, and Sun, 2003 reported from China, except for the shape of the ancestula. In the shape of the ancestrula, the former is tatiform; the latter resembles autozooids. Our specimens are indeed *F. delicia* not only because of morphological features but also because its ancestula is tatiform.

Distribution. Atlantic and Pacific coasts of North America (Winston et al., 2000; Dick et al., 2005), Europe (De Blauwe, 2009; Wasson and De Blauwe, 2014), Quequén harbour (López-Gappa and Liuzzi, 2016), Argentina (López-Gappa et al., 2022), and Korea (Yellow Sea and South Sea in this study).

[1]*3. *Fenestrulina lunata* n. sp. (Fig. 4)

Etymology. Latin "*lunata*" alludes to this new species's crescent-shaped ascopore.

Material examined. Korea: Holotype, MABIK IV0017 5058, Jeju-do: Jeju-si, Haengwon, 16 Jun 2010; Paratype, same data as for holotype.

Substratum. Sponge.

Description. Colony encrusting or forming erect-foliaceous, unilaminar. Autozooids rounded-hexagonal, separated by deep grooves, revealing vertical walls or smooth lateral walls sloping inward, longer than wide, 0.41–0.50 (0.47±0.02) mm long, 0.19–0.24 (0.21±0.01) mm wide (Fig. 4A, B). Frontal wall (Fig. 4E) almost flat or slightly convex, smooth, hyaline/porcelanous, with numerous 36–52 stellate pores, 0.009–0.02 (0.01±0.003) mm in diameter; a row of pores (25–30) along border between frontal wall and lateral walls, two rows (sometimes three rows, 5–8) between ascopore and orifice; a few scattered (6–14) laterally with no pores in mid-proximal region of frontal wall below ascopore, sometimes two rows. Orifice (Fig. 4C, D) D-shaped, wider than long, 0.08–0.10 (0.09±0.006) mm long, 0.10–0.12 (0.11±0.006) mm wide, occupying approximately one-fifth length of zooid; proximal margin straight with a minute triangular condyle at either proximal corner (Fig. 4C). Operculum (Fig. 4D) D-shaped, wider than long, 0.07–0.08 (0.07±0.005) mm long, 0.09–0.11 (0.11±0.006) mm wide. Three short hollow spines around distal rim of orifice in non-ovicellate zooids (Fig. 4D), one at either proximolateral corner of ovicell in ovicellate zooids (Fig. 5F). Ascopore (Fig. 4B, E) situated at two-fifths length of zooid below orifice, very thin, crescentic, lacking denticles, smile-shaped, 0.04–0.06 (0.05±0.005) mm wide. Ovicell (Fig. 4F) raised,

Korean name: [1]*초승달방사이끼벌레 (신칭)

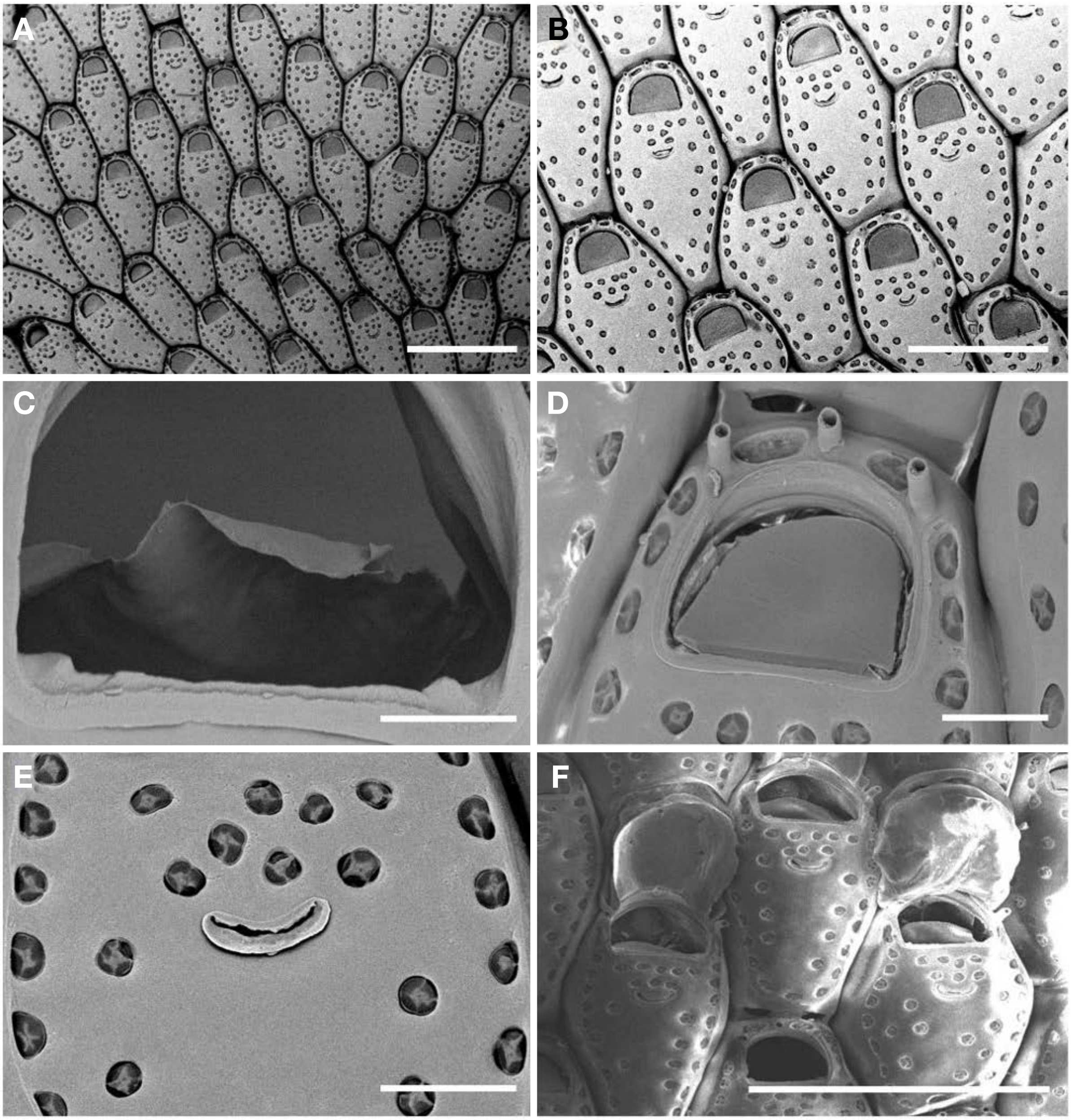

Fig. 4. *Fenestrulina lunata* n. sp. (A–F), from Haengwon. A, Zooidal arrangement; B, Immature hyaline/porcelanous zooids; C, Detailed minute triangular condyle at either proximal corner; D, Detailed immature zooid showing orifice, operculum, three oral spines, and pores around orifice; E, Detailed smile-like ascopore lacking denticles; F, Mature zooids with ovicell showing uneven surface and two oral spines, and developing ovicell. Scale bars: A=0.5 mm, B, F=0.3 mm, C=0.03 mm, D, E=0.05 mm.

prominent, frontal slightly flat as pressed, with a few and indistinct marginal pores in smooth and uneven surface, longer than wide, 0.16–0.18 (0.17±0.01) mm long, 0.12–0.24 (0.13±0.01) mm wide; ectooecial rim thick; proximal corners curved outward. No avicularium. Basal wall smooth, with an uncalcified area of variable size (usually longer than half length of zooid) in its distal part, such as oval or rectangular. Ancestrula not seen.

Remarks. This species resembles *Fenestrulina specca* from New Zealand (Gordon, 1989) in having the hyaline/porcellanous zooids and a few scattered pores frontally, but shows the differences in having the thin and lacking denticles semi-lunate 'smile-like' ascopore, and three oral spines, whereas *F. specca* has a broadly C-shaped ascopore with minutely denticulate and mainly four oral spines on autozooids. The most distinctive feature of this species is its ascopore shape. The ascopore of the genus *Fenestrulina* is usually crescent-shaped with serrated or sometimes reticulated. However, this new species has a unique, thin, semi-lunate 'smile-like,' lacking denticles.

Distribution. Korea (Jeju waters).

[1]***4. *Fenestrulina monopora* n. sp. (Fig. 5)**

Fenestrulina mutabilis: Seo, 2005; 442, pls. 171B–173A (parts); Seo and Kil, 2019: 224; Chae and Seo, 2019: 213.

Etymology. The species name combines the Greek *monos* (single) and *poros* (hole), referring to the single rootlet-chamber hole below the uncalcified area in the basal surface.

Material examined. Korea: Busan-si: Songjeong port, 21 Dec 2012; Jeollanam-do: Yeosu-si, Sangbaekdo Island, 17 Jul 2024; Goheung-gun, Naedalgseom Island, 24 Jun 2008; Wando-gun, Yeosedo Island, 29 Jul 2016; Cheongsan Island, 4 Feb 2020, 39 m in depth; Jeju-do: Jeju-si, Gimnyeong, 15 Jul 1991; Chujado Island, Yongdumbeong, 24 Sep 2021; Jeollabuk-do: Gunsan-si: Holotype, NIBRIV0000904152, Heukdo Island, 6 Oct 2015; Paratype, Jikdo Island, 7 Oct 2015.

Substratum. Shells and ropes.

Description. Colony encrusting or erect, bilamellar-foliaceous, back-to-back (Fig. 5A). Autozooids (Fig. 5A, B) in alternating series, rounded-hexagonal to oval, longer than wide, 0.33–0.76 (0.50±0.11) mm long, 0.20–0.33 (0.24±0.03) mm wide; smooth lateral walls sloping inward, leaving furrow between zooids, margin of lateral gymnocyst forming border between frontal wall and lateral wall, sometimes folding inward. Frontal wall (Fig. 5B, C) almost flat or slightly convex, covered with 55–100 stellate pores except below ascopore in central area, 0.01–0.02 (0.01±0.004) mm in diameter; single row along margin of zooid, single or two rows around orifice, two or three rows between ascopore and orifice. Orifice (Fig. 5B, C) semicircular, transversely D-shaped, wider than long, 0.05–0.10 (0.08±0.01) mm long, 0.07–0.12 (0.10±0.01) mm wide, broader than non-ovicellate zooids (Fig. 5G); proximal margin straight or slightly concave, condyles scarcely evident; occasionally marginal autozooid without orifice (Fig. 5B). Operculum (Fig. 5B) semicircular, wider than long, 0.03–0.08 (0.06±0.01) mm long, 0.07–0.12 (0.10±0.01) mm wide, with heavy and marked sclerite along margin. Non-ovicellate zooids with 0–3 short, hollow spines (Fig. 2C, D); ovicellate zooids with 2 spines (Fig. 5G), one at each proximolateral corner of ovicell (Fig. 5G). Ascopore (Fig. 5C) below orifice, distant slightly shorter than length of zooidal orifice from orifice, 0.03–0.05 mm across, depressed slightly from frontal surface with crescentic opening and denticulate edge; broad shelf proximally directed. Ovicell (Fig. 5E–G) raised, prominent, conspicuous, longer than wide, 0.14–0.24 (0.19±0.03) mm long, 0.12–0.22 (0.17±0.03) mm wide, ribbed radially with strong furrows, imperforate except for large marginal pores inside raised border; when strongly calcified, furrows obscured and rugose; its proximal corners slightly curved outward. No avicularium. Basal wall of zooid (Fig. 5H) smooth, sometimes with fine wrinkles proximally, with varied-sized uncalcified area (usually longer than half length of zooid) in its distal part; oval, diamond-shaped, or rectangle, and often with a rootlet-chamber pore proximally, 0.03–0.04 (0.04±0.004) mm in diameter; Ancestrula in small zooidal shape with three distal spines, single row of marginal stellate pores, and 1–2 rows between orifice and ascopore.

Remarks. Rho and Seo (1984) first recorded *Fenestrulina mutabilis* with many stellate pores distributed on the frontal wall and uncalcified areas on the basal wall distally in Korean waters. *Fenestrulina monopora* n. sp. from Korean waters differs from *F. mutabilis* in the following features: (1) the zooid in the new species is rounded distally, whereas *F. mutabilis* has truncated ends; (2) 0–3 oral spines in *F. monopora* versus 2–4 spines in *F. mutabilis*; (3) the stellate pores of *F. monopora* did not distribute in the triangular zone below the ascopores, while the stellate pores distributed over all frontal wall in *F. mutabilis*; (4) *F. monopora* ovicells have radial ribs and strong furrows, whereas the ovicells in *F. mutabilis* have fine radiating striations (see Hasting, 1932); (5) *F. monopora* sometimes has single rootlet chamber below the uncalcified area, while *F. mutabilis* has two basal holes, one on each broadest side of the zooid.

F. monopora is most similar to *F. commensalis* Vieira and Stampar, 2014 described from the southwestern Atlantic, in having rootlet-chamber pores in the basal wall, single spine, and the shape and distribution of frontal pores. However, *F. monopora* has an oval uncalcified area in the distal part of the basal wall, 0–3 oral spines encrusting or erect colony and an ovicell surface with strong furrows, whereas *F. commensalis* has no uncalcified area at the basal wall, single spine, encrusting colony and smooth surface of ovicell.

Distribution. Korea (Yellow Sea, South Sea, and Jeju waters).

[2]***5. *Fenestrulina rugosa* n. sp. (Fig. 6)**

Onchoporella selenoides: Rho and Kim, 1981: 67, pl. 6, fig. 7 (?); Seo and Rho, 1989: 210; Seo, 2005: 445, pls. 175–176 (in part); Seo and Kil, 2019: 254.

Korean name: [1]*한구멍방사이끼벌레 (신칭), [2]*주름방사이끼벌레 (신칭)

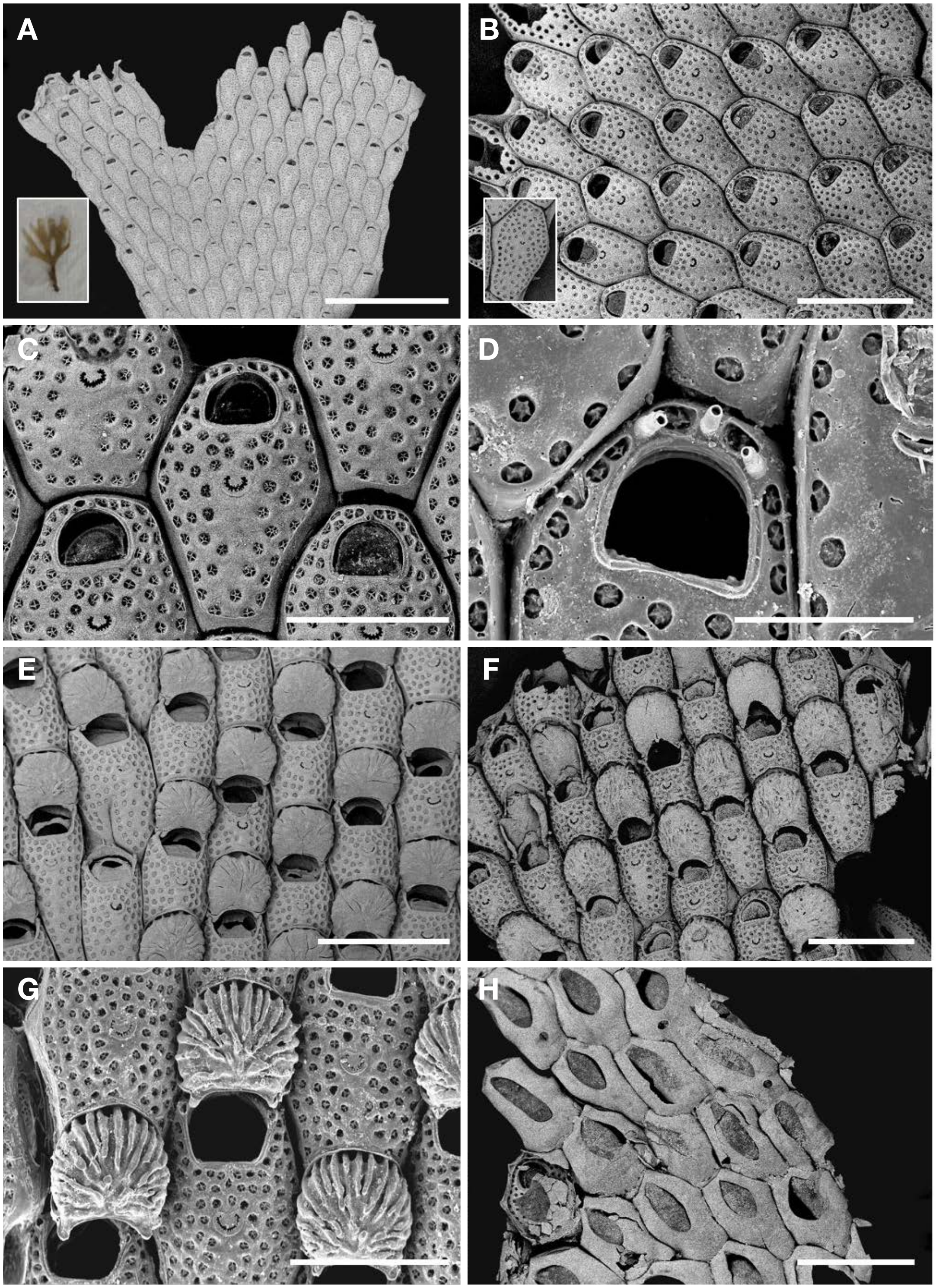

Fig. 5. *Fenestrulina monopora* n. sp. A, Zooidal arrangement of erect colony (white box), from Yeosedo Island; B, Zooids, from Yeosedo Island: white box indicates zooid without orifice, from Heukdo Island; C, Immature zooids showing orifice with operculum, one or two oral spines, ascopore and pores, from Heukdo Island; D, Immature zooid, showing orifice, three oral spines and pores, from Gimnyeong; E, Mature zooids with prominent calcified ovicells, from Naedalgseom Island; F, Mature zooids with long and very calcified ovicells, from Yongdumbeong; G, Mature zooids with radially ribbed ovicells showing strong furrows and lappets to flank at proximal corners, from Gimnyeong (cited from Seo, 2005); H, Basal surface of colony with uncalcified area of various size and pores below uncalcified area, from Heukdo Island. Scale bars: A=1 mm, B, E, G, H=0.5 mm, C, F=0.3 mm, D=0.2 mm.

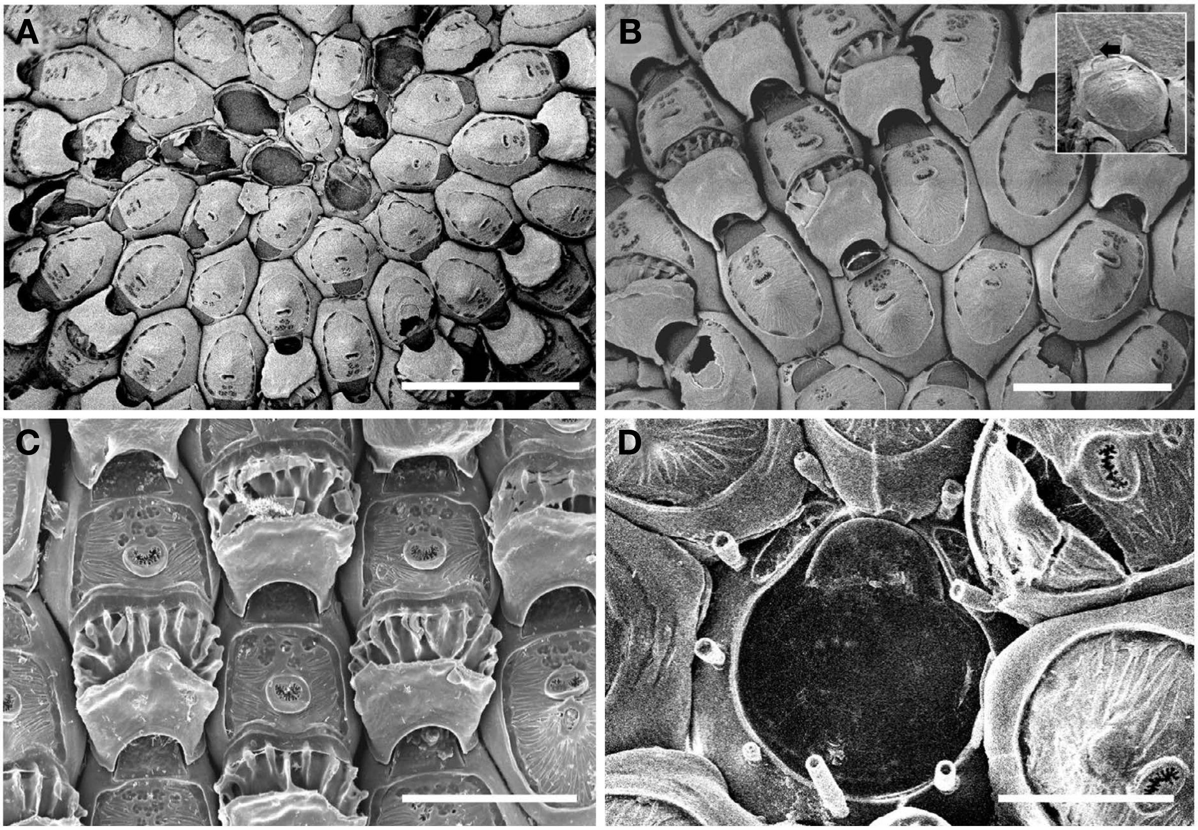

Fig. 6. *Fenestrulina rugosa* n. sp., from Mipo. A, Arrangement of zooids with ancestrula; B, Zooids: the white box indicates zooid with single oral spine; C, Mature zooids with ovicells showing strong furrows at distal half, wrinkled frontal surface and ascopores; D, Ancestrula with eight spines. Scale bars: A=0.5 mm, B, D=0.3 mm, C=0.2 mm.

Etymology. The species name alludes to the Latin *ruga* (wrinkle) of the frontal surface.

Material examined. Korea: Busan-si: Holotype, MABIK IV00175055, Mipo, 22 Jul 1985; Jeollanam-do: Yeosu-si: Gemundo Island, 16 Jun 2020; Jeju-do: Paratype, Seogwipo-si, Munseom Island, 10 Sep 2016.

Substratum. Algae.

Description. Colony unilaminar, encrusting (Fig. 4A). Autozooids (Fig. 6A, B) in alternating 6 series, rounded-hexagonal to elongate, longer than wide, 0.28–0.33 (0.31±0.02) mm long, 0.16–0.24 (0.20±0.02) mm wide, with smooth lateral walls inward-sloping and overlapping frontal wall, leaving furrow between zooids. Frontal wall (Fig. 6A–C) inflated, convex, glossy, with smooth gymnocyst forming a narrow circling ridge along each side from proximal margin of zooid to proximal corner of orifice and running inwards along proximal end of orifice, with umbo below ascopore in middle of frontal surface, rugose towards center delicately, with large stellate pores in 2–8 (one to two rows) between ascopore and orifice, 9–20 (one row: half-hidden, not round and irregular in shape) lateral and proximal margins along border between lateral and frontal walls, and 3–6 (single row) distal to orifice, headband-shaped, obscured by ovicells; frontal imperforate between ascopore and proximal zooidal margin. Orifice semicircular, transversely D-shaped, wider than long, 0.04–0.06 (0.04±0.006) mm long, 0.07–0.09 (0.08±0.006) mm wide, broader in ovicellate zooids than in non-ovicellate zooids; proximal margin straight, condyles scarcely evident. Operculum semicircular, wider than long, 0.03–0.04 (0.04±0.003) mm long, 0.07–0.09 (0.08±0.004) mm wide. Non-ovicellate zooids with 0 or single mid-distal hollow spine, no spine visible in ovicellate zooid (Fig. 6B, C). Ascopore (Fig. 6C) crescent-shaped, below orifice, about half length of zooids away, wider than long, 0.02–0.09 (0.58±0.01) mm long, 0.04–0.09 (0.07±0.01) mm wide, surrounded by oval-shaped, slightly raised border; opening crescentic, with branched denticles both proximally directed tabula and margin. Ovicell (Fig. 6B, C) raised, prominent, conspicuous, longer than wide, 0.18–0.31 (0.25±0.04) mm long, 0.14–0.28 (0.22±0.04) mm wide, immersed basally, marked with a row of marginal pores, less than distal half ribbed radially with strong furrows merging with a distinct and irregular transverse ridge in middle of frontal surface, smooth proximal half from transverse ridge, and narrower, extending slightly curved outward along orifice, covering half of preceding zooid; sometimes central umbo fused with distal rim of ovicell distal to ovicellate zooid. No avicularium. Ancestrula (Fig. 6D) tatiform, circular, 0.20 mm diameter with circular opesia, 0.14 mm in diameter, with eight spines around opesial margin, surrounded by seven periancestrular zooids. No avicularium.

Remarks. *Fenestrulina rugosa* n. sp. is similar to *F. farnsworthi* Soule, Soule and Chaney, 1995 in sharing morphological features, such as small zooid, numbers, shape and position of pores, and tatiform ancestrula. On the other hand, *F. farnsworthi* shows the differences in having a smooth frontal wall with no umbo and an ancestrula with 12 spines.

F. rugosa is similar to *F. sinica* Liu, Liu and Sun, 2003 from China. However, the former has a tatiform ancestula and a delicately rugose frontal wall, while the latter has an autozooidal-shaped ancestrula and smooth frontal surface. The delicately rugose frontal wall of *F. rugosa* is a unique characteristic.

Since Ortmann (1890) first reported *Onchoporella selenoides* in Japanese waters, Hirose (2010) redescribed *O. selenoides* using Ortmann's Japanese specimen. Specimens of *O. selenoides* collected at Mipo on 22 Jun 1985 in Seo (2005) were reexamined and showed differences from *O. selenoides* from Japan. This specimen instead shows a similarity to *F. rugosa* described in this study. Japanese *O. selenoides* showed differences from *F. rugosa* in the following features: the zooid of *O. selenoides* is more than twice the size of one of *F. rugosa*; the ovicell of *O. selenoides* has strong furrows on the surface extended to the distal margin, and *O. selenoides* has much narrower proximal smooth part of ovicell than *F. rugosa*. Additionally, *O. selenoides* has larger ascopores than *F. rugosa*. Thus, *O. selenoides* from Mipo (Seo, 2005) is synonymized with this new species. Unfortunately, another specimen from Seogwipo in Rho and Kim (1981) used for the first report in Korea could not be reexamined because of the loss of the specimen. However, the authors suppose this also is not *O. selenoides*, but *F. rugosa*.

Distribution. Korea (South Sea and Jeju waters).

[1]***6. *Fenestrulina spissa* n. sp. (Fig. 7)**

Etymology. Latin "*spissa*", thick, alluding to the thick spine of this species.

Material examined. Korea: Jeollanam-do: Yeosu-si, Geomundo Island, 16 Jun 2020; Jeju-do: Holotype, MABIK IV00175056, Seogwipo-si, Marado Island, 4 Jul 2015; Paratype, same data as for holotype.

Substratum. Algae.

Description. Colony encrusting in one or two layers (Fig. 7A, B). Autozooids (Fig. 7C, D) rounded-hexagonal to oval with smooth lateral walls inward-sloping and slightly overlapping frontal wall, leaving furrow between zooids, longer than wide, 0.23–0.31 (0.26±0.02) mm long, 0.12–0.17 (0.15±0.01) mm wide. Frontal wall (Fig. 7C, D, G) smooth, inflated, prominently raised below ascopore in central region; smooth gymnocyst forming a narrow ridge along each side from proximal margin of zooid to proximal margin of orifice and running inwards along proximal margin of orifice, with 15–26 stellate pores; stellate pores in a marginal row, two (sometimes three) rows between ascopore and orifice, three distal to orifice. Orifice semicircular, transversely D-shaped, wider than long, 0.03–0.05 (0.0.4±0.006) mm long, 0.05–0.07 (0.06±0.007) mm wide, broader in ovicellate zooids than in non-ovicellate zooids; proximal margin straight or slightly concave, with minute triangular condyle at either proximal corner. Operculum (Fig. 7D, F) semicircular, wider than long, 0.03–0.04 (0.04±0.003) mm long, 0.05–0.06 (0.05±0.002) mm wide. Three to four thick, long, jointed hollow spines (Fig. 7C, D, F) around distal curvature of orifice in non-ovicellate zooids, sometimes middle one or two spines thinner than rest, two in ovicellate zooids close to proximal corners of ovicell, four or five in periancestrular zooids (Fig. 7H). Ascopore (Fig. 7E, F) below orifice by a distance about equivalent to or slightly shorter than length of orifice, when frontal wall prominent, a little closer to orifice, and its proximal part rised slightly along prominence, crescentic, transversely C-shaped, wider than long, 0.008–0.02 (0.01±0.004) mm long, 0.02–0.03 (0.03±0.005) mm wide, with median process distally and 10–15 short denticles on proximal edge. Ovicell (Fig. 7C, F, G) hemispherical, prominent, conspicuous, smooth, wider than long, 0.10–0.14 (0.12±0.01) mm long, 0.11–0.16 (0.14±0.01) mm wide, a peripheral row of marginal pores with short, radial ribs intercalated between marginal pores, leaving smooth zone along proximal margin and curving slightly outward along orifice at proximal corners, and not closed by zooidal operculum. No avicularium. Lateral wall of zooids with two distal and two distolateral basal pore chambers. Ancestrula (Fig. 7H) tatiform, circular, 0.16 mm in diameter, with smooth, narrow gymnocyst and large, circular opesia, 0.10 mm diameter, with ten thick, jointed hollow spines around opesial margin, and surrounded by seven periancestrular zooids.

Remarks. *Fenestrulina spissa* n. sp. resembles *Fenestrulina pauciporosa* Winston and Jackson, 2021 from Jamaica (Ca-

Korean name: [1]*굵은가시방사이끼벌레 (신칭)

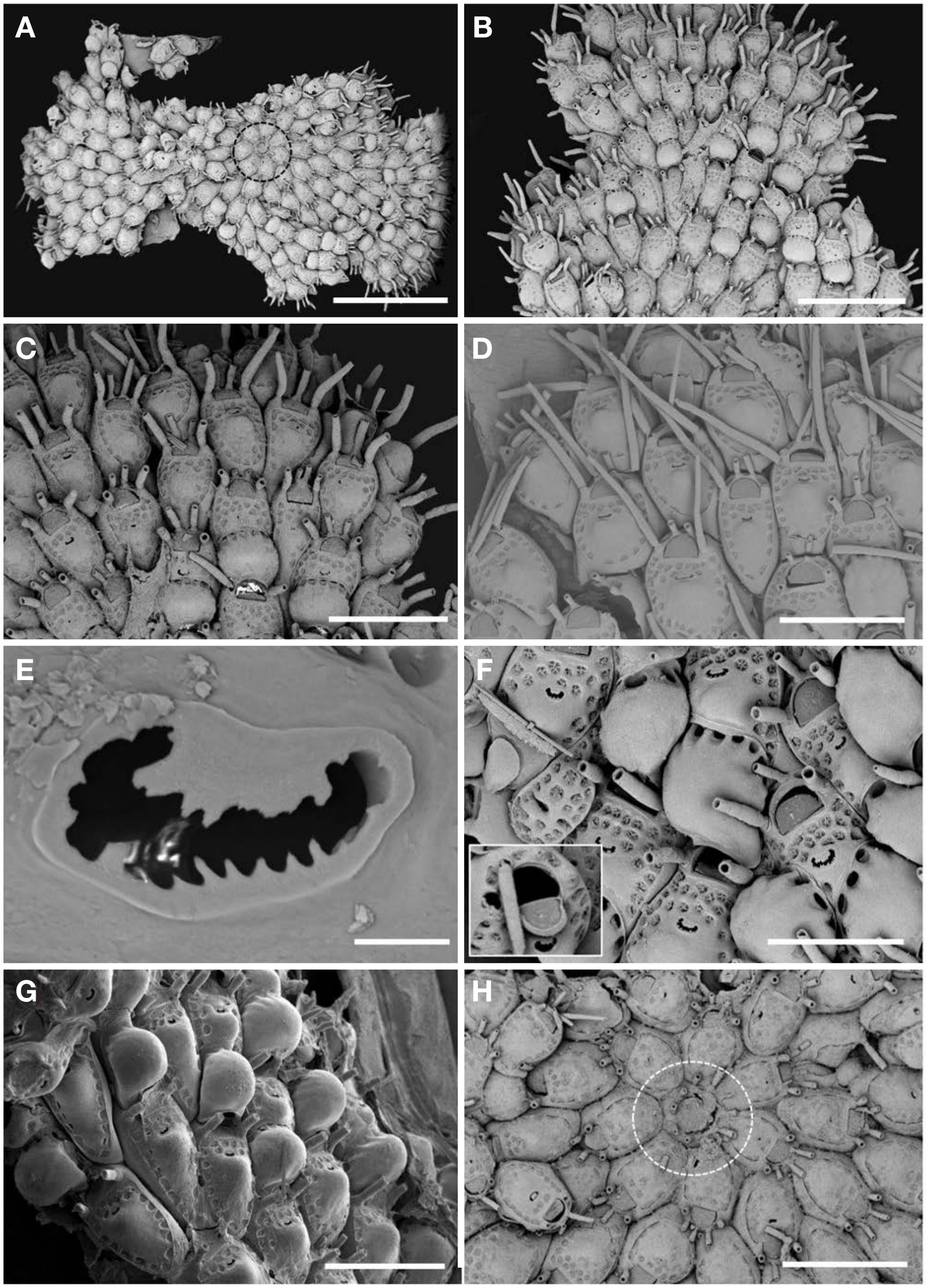

Fig. 7. *Fenestrulina spissa* n. sp. (A–F, H), from Marado Island. A, Colony showing ancestrula (black circle); B, Zooidal arrangement; C, Zooids showing middle one or two thinner than rest of oral spines, with prominent frontal surface and smooth ovicells; D, Immature zooids with long oral spines; E, Detailed Ascopore; F, Detailed orifice with oral spines and operculum (opened white box), and smooth ovicells; G, Mature zooids showing smooth ovicells and prominent frontal surface below ascopore, from Geomundo Island; H, Ancestrula (white circle) and periancestrular zooids with four to five spines. Scale bars: A = 1 mm, B = 0.5 mm, C, D, G = 0.1 mm, E = 0.01 mm, F, H = 0.2 mm.

Table 1. Characteristics of Korean *Fenestrulina* species

	F. cracens n. sp.	*F. delicia*	*F. lunata* n. sp.	*F. monopora* n. sp.	*F. rugosa* n. sp.	*F. spissa* n. sp.
Colony						
Forms	Encrusting Unilaminar	Encrusting Unilaminar	Encrusting or erect Unilaminar	Encrusing or erect Bilamellar	Encrusting Unilaminar	Encrusting Unilaminar
Oral spines						
Number	3–4	1–3	3	0–3	0–1	3–4
Shape	Long, jointed hollow	Short, hollow	Short, hollow	Short, hollow	Hollow	Thick, long, jointed hollow
Ascopores	Crescent-shaped	Crescent-shaped Robust projection	Crescent-shaped Smile-like, lacking denticles	Crescent-shaped	Crescent-shaped	Crescent-shaped 10–15 short denticles on proximal edge
Frontal wall	Smooth	Smooth	Hyaline	Smooth	Rugose delicately	Smooth
Pores (stellate)	19–35	35–50	36–52	55–100	12–28	15–26
Ovicells	Smooth, radial ribs, often umbonate	Irregular transverse ridge	Smooth, uneven surface	Radial ribs with strong furrows	Irregular transverse ridge	Smooth, short radial ribs

ribbean Sea) in the shape of zooids, having several spines (3–4), a single row of marginal pores, some pores above the orifice (3–4), and smooth ovicells. However, *F. spissa* has thicker jointed spines, a transversely elongated ascopore, and more pores between the orifice and ascopore. *F. spissa* is similar to *F. sinica* Liu and Liu, 2001 from China in the shape of zooids with smooth lateral walls overlapping the frontal wall. However, the transversally ridged ovicells and small autozooid-shaped ancestrula distinguish *F. sinica* from *F. spissa*. Also, *F. spissa* shows the differences from *F. cracens* in several characters. Whereas the former has the smooth surface of the ovicells, three to four thicker oral spines and one or two layered colonies, the latter has the radially ribbed surface of the ovicells, three to four oral spines and unilamellar colonies.

Distribution. Korea (South Sea and Jeju waters).

DISCUSSION

Six *Fenestrulina* species are reported in this study. *F. delicia* is newly added to the Korean bryozoan fauna, and the other five species are new to science. Up to date, only two species of Korean *Fenestrulina*, *F. malusii* and *F. mutabilis*, have been widely distributed in all sea areas of Korea in previous studies (Rho and Lee, 1980; Rho and Seo, 1984; Seo, 2005; Chae and Seo, 2019; Seo and Kil, 2019). Observing the morphological characteristics of key characters, such as the number of spines, the shape of ascopores, the distributional pattern of frontal pores, the surface of frontal walls, and the shape of ovicells, is significant in distinguishing the species reported herein (Table 1). However, without an adequate understanding and careful consideration of the morphological variations in *Fenestrulina*, the report with most Korean *Fenestrulina* specimens so far followed the preceding studies. According to recent studies, these two species need to be rechecked because they are considered a species complex (Soule et al., 1995; Liu et al., 2003). *F. malusii* from the eastern Pacific was concluded as an *F. malusii* species complex by Soule et al. (1995). *F. malusii* is known to be found only in the Atlantic and Mediterranean Sea, and Japanese *F. malusii* was different from *F. malusii s. str.* and referred to as *F. sinica* by Liu et al. (2003).

In terms of worldwide distribution and substrata of *Fenestrulina* species, *F. delicia* encrusted on the shell (*Mytilus* sp.) or algae (*Agarum cribrosum*) (Winston et al., 2000) was known to be highly invasive and spreading offshore, attaching to natural substrata and fouling the artificial hard substrata in Western Europe (De Blauwe et al., 2014). López-Gappa and Liuzzi (2016) reported *F. delicia* for the first time in the Southern Hemisphere (Quequén Harbour, Argentina) with high-density colonies, noting that this species has the potential to continue dispersing through maritime traffic or plastic debris and to become a stable component of neighboring harbors in the area. *F. delicia*, new to the Korean fauna in this study, was found on the shell of *Mytilus galloprovincialis* in the port (Busan) and intertidal zone (Cheongpodae). Busan Port is Korea's largest representative international trade port in the South Sea and the sixth-largest port in the world (World Shipping Council, 6 Sep 2024). This invasive species is expected to be brought in through ports where it is introduced and spread across the rocky intertidal zone, a stable substratum environment. Continuing investigations are underway to determine how far this invasive marine species could spread in Korean ports and seawaters.

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCES

Audouin JV, 1826. Explication sommaire des planches de polypes de l'Egypte et de la Syrie, publiees par Jules-Cesar Savigny. In: Description de l'Egypte, ou recueil des observations et des recherches qui ont été faites en Egypte pendant l'expédition de l'armée française (Ed., Audouin JV). Histoire Naturelle, 1:225-244.

Chae HS, Seo JE, 2019. Fouling Bryozoa of Korean ports and harbours. Animal Systematics, Evolution and Diversity, 35:204-217. https://doi.org/10.5635/ASED.2019.35.4.033

De Blauwe H, 2009. Mosdiertjes van de Zuidelijke bocht van de Noordzee: Determinatiewerk voor België en Nederland. Vlaams Instituut voor de Zee (VLIZ), Oostende, pp. 1-445.

De Blauwe H, Kind B, Kuhlenkamp R, Cuperus J, Van der Weide B, Kerckhof F, 2014. Recent observations of the introduced *Fenestrulina delicia* Winston, Hayward & Craig, 2000 (Bryozoa) in western Europe. Studi Trentini di Scienze Naturali, 94:45-51.

Dick MH, Grischenko AV, Mawatari JF, 2005. Intertidal Bryozoa (Cheilostomata) of Ketchikan, Alaska. Journal of Natural History, 39:3687-3784. https://doi.org/10.1080/00222930500415195

Figuerola B, Gordon DP, Cristobo J, 2018. New deep Cheilostomata (Bryozoa) species from the Southwestern Atlantic: shedding light in the dark. Zootaxa, 4375:211-249. https://doi.org/10.11646/zootaxa.4375.2.3

Gordon DP, 1984. The marine fauna of New Zealand: Bryozoa: Gymnolaemata from the Kermadec Ridge. New Zealand Oceanographic Institute Memoir, 91:1-198.

Gordon DP, 1989. The marine fauna of New Zealand: Bryozoa: Gymnolaemata (Cheilostomida Ascophorina) from the western south Island continental shelf and slope. New Zealand Oceanographic Institute Memoir, 97:1-158.

Grischenko AV, Dick MH, Mawatari SF, 2007. Diversity and taxonomy of intertidal Bryozoa (Cheilostomata) at Akkeshi Bay, Hokkaido, Japan. Journal of Natural History, 41:1047-1161. https://doi.org/10.1080/00222930701391773

Hayward PJ, 1980. Cheilostomata (Bryozoa) from the South Atlantic. Journal of Natural History, 14:701-721. https://doi.org/10.1080/00222938000770591

Hayward PJ, Ryland JS, 1990. Some Antarctic and Subantarctic species of Microporellidae (Bryozoa: Cheilostomata). Journal of Natural History, 24:1263-1287. https://doi.org/10.1080/00222939000770751

Hayward PJ, Ryland JS, 1999. Cheilostomatous Bryozoa. Part 2. Hippothoidea - Celleporoidea. Synopses of the British Fauna (New Series). Field Studies Council, Shrewsbury, 14:1-416.

Hayward PJ, Taylor PD, 1984. Fossil and recent Cheilostomata (Bryozoa) from the Ross Sea, Antarctica. Journal of Natural History, 18:71-94. https://doi.org/10.1080/00222938400770091

Hirose M, 2010. Cheilostomatous Bryozoa (Gymnolaemata) from Sagami Bay, with notes on bryozoan diversity and faunal changes over the past 130 years. PhD dissertation, Department of Natural History Sciences, Hokkaido University, Sapporo, Japan, pp. 1-177.

Liu H, Liu X, Sun S, 2003. Seven new species of genus *Microporella* and *Fenestrulina* collected from the cultured shell and their floating cages in Chinese waters. Studia Marina Sinica, 45:202-222.

López-Gappa J, Liuzzi MG, 2016. High density of the alien bryozoan *Fenestrulina delicia* in the fouling assemblage of a South American harbour (Argentina). Marine Biodiversity, 46:509-513. https://doi.org/10.1007/s12526-015-0380-2

López-Gappa J, Liuzzi MG, Castro KL, Bobinac M, Schwindt E, 2022. Fouling bryozoans in Argentine harbours (Southwest Atlantic): new records and the description of a new species. Zootaxa, 5205:374-400. https://doi.org/10.11646/zootaxa.5205.4.4

Moyano GHI, 1985. Briozoos marinos Chilenos. V. Taxa nuevos o poco conocidos. Boletín de la Sociedad de Biología de Concepción, 56:79-114.

Ortmann AE, 1890. Die Japanische Bryozoenfauna. Bericht über die von Herrn Dr. L. Döderlein in Jahre 1880-81, gemachten Sammlungen. Archiv für Naturgeschichte, 56:1-74.

Rho BJ, Kim HK, 1981. A study on the marine Bryozoans in

Korea 3. Stenolaemata and Gymnolaemata. Journal of Korean Research Institute for Better Living, 27:57-80.
Rho BJ, Lee KH, 1980. The marine invertebrate fauna in the Gogunsan Island and Bian Island. The Report of the KACN, 18:115-124.
Rho BJ, Seo JE, 1984. A systematic study on the marine bryozoans in Korea 4. Journal of Korean Research Institute for Better Living, 33:73-98
Seo JE, 2005. Illustrated encyclopedia of fauna and flora of Korea, Vol. 40. Bryozoa. Ministry of Education and Human Resources, Seoul, pp. 1-596 (in Korean).
Seo JE, Kil HJ, 2019. Bryozoa of Korea: Cheilostomata. National Institute of Biological Resources, Incheon, pp. 1-310 (in Korean).
Seo JE, Rho BJ, 1989. A systematic study on the marine Bryozoans in Korea 6. Ascophora. Korean Journal of Systematic Zoology, 5:205-223.
Soule DF, Soule JD, Chaney HW, 1995. Taxonomic atlas of the benthic fauna of the Santa Maria Basin and Western Santa Barbara Channel, Vol. 13, The Bryozoa. Santa Barbara Museum of Natural History, Santa Barbara, CA, pp. 1-344.
Souto J, Reverter-Gil O, Fernández-Pulpeiro E, 2010. Gymnolaemate bryozoans from the Algarve (southern Portugal): new species and biogeographical considerations. Journal of the Marine Biological Association of the United Kingdom, 90:1417-1439. https://doi.org/10.1017/S0025315409991640
Vieira LM, Stampar SN, 2014. A new *Fenestrulina* (Bryozoa, Cheilostomata) commensal with tube-dwelling anemones (Cnidaria, Ceriantharia) in the tropical southwestern Atlantic. Zootaxa, 3780:365-374. https://doi.org/10.11646/zootaxa.3780.2.8
Wasson B, De Blauwe H, 2014. Two new records of cheilostome Bryozoa from British waters. Marine Biodiversity Records, 7:e123. https://doi.org/10.1017/S1755267214001213
Winston JE, Hayward PJ, Craig SF, 2000. Marine bryozoans of the Northeast coast of the United States: new and problem species. In: Proceedings of the 11th International Bryozoology Association Conference (Eds., Herrera Cubilla A, Jackson JBC). Smithsonian Tropical Research Institute, Balboa, pp. 412-420.

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