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FIRST TRIAL ON VEGETATIVE PROPAGATION OF RED MANGROVE, *RHIZOPHORA MUCRONATA* AND SPURRED MANGROVE, *CERIOPS TAGAL* IN THE UNITED ARAB EMIRATES

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ABSTRACT

The existing *Rhizophora* mangroves trees at Abu Al Abyad Island, are healthy but fail to flower and produce viable propagules. The present study evaluated air layering as an alternative vegetative propagation method for *Rhizophora mucronata* and *Ceriops tagal* at Abu Al Abyad Island, UAE, as part of the Aquaculture and Marine Studies Centre's efforts to diversify local planting-material production. The 11-month trial involved 29 treatments across 18 mother plants, using a cocopeat-swamp clay mixture (1:1), Aloe Vera gel and a commercial rooting product. Nineteen treatments developed sufficient roots for separation, achieving an overall success rate of 65.5%, with 63.0% for *R. mucronata* (17/27) and 100% for *C. tagal* (2/2). Following separation, plants were established through direct field planting near mother plants and green shade-net-house cultivation. Both groups initially experienced leaf shedding; however, shade-net-house plants subsequently showed drying symptoms, while field-planted plants which received approximately six hours of natural tidal water exposure demonstrated early bud development. These findings provide preliminary evidence of successful air-layering propagation in both species and suggest that direct field establishment may be more favourable under the observed conditions. Further long-term monitoring is required to assess survival, growth and the technique's potential for supporting larger-scale mangrove restoration programmes in the UAE.

Keywords: Air Layering; Mangrove Restoration; Vegetative Propagation; *Rhizophora Mucronata*; *Ceriops Tagal;* Tidal Environment

1 INTRODUCTION

The coastal waters and the island of Abu Al Abyad support ecologically important mangrove habitats that contribute to biodiversity, fisheries productivity, and environmental resilience. The dominant naturally occurring mangrove species in the island is *Avicennia marina* (grey mangrove), which is well adapted to the hypersaline and thermally stressful conditions characteristic of the Arabian Gulf. Its extensive distribution reflects its physiological tolerance and capacity for establishment in harsh coastal environments. In comparison, *Rhizophora mucronata* (red mangrove) and *Ceriops tagal* (spurred mangrove) are much less widely represented in Abu Al Abyad. *Rhizophora mucronata* develops prominent stilt roots that provide physical support in intertidal sediments and create habitats for aquatic organisms. *Ceriops tagal*, a member of the family Rhizophoraceae, develops characteristic root structures and is associated with sheltered intertidal environments across its broader Indo-West Pacific distribution **[1]**. Their complex aerial root systems create structurally diverse habitats that support marine and terrestrial organisms while protecting coastal environments against erosion, wave action, and other physical disturbances **[2, 3].** The presence of only a limited number of mature plants of these species in the island creates an opportunity to investigate alternative methods of producing planting material. This challenge is particularly relevant to Abu Al Abyad Island, where the existing populations of *Rhizophora mucronata* and *Ceriops tagal* are relatively limited. Historical records indicate that 1,060 *R. mucronata* plants sourced from Pakistan were introduced to Abu Dhabi in 2008, including 68 plants at Abu Al Abyad and 992 at Ras Ghanadah. The subsequent establishment of the species in the emirate was documented by Yousif and Sen in 2020 **[4]**. Current field survey at Abu Al Abyad indicates approximately 52 living *R. mucronata* and 50 *C. tagal* plants. The two species also exhibit differences in propagule development, dispersal and establishment strategies **[5].** Maintaining and increasing these local populations requires additional approaches for producing planting material. Earlier the Aquaculture and Marine Studies Centre (AMSC) had investigated reproductive approaches through open-pollination and open hand-cross-pollination trials involving 14 healthy *Rhizophora* trees, approximately 3.5 m in height, between March and May 2024. Flowers were monitored twice weekly. Although pollen germination was observed, strong winds affected the flowers during a critical developmental stage, and mature propagules were not obtained. Previous research done elsewhere, on *Rhizophora* has examined the relationship between wind pollination and propagule formation, highlighting the importance of reproductive conditions in successful propagule production **[6]**. These observations were specific to that trial and highlighted the importance of investigating complementary propagation methods that are less dependent on successful seed and propagule production. Many earlier studies have investigated vegetative propagation and air layering in different mangrove species, demonstrating the potential of this approach as a complementary propagation technique **[7, 8, 9, 10]**. However, their restricted availability in the island and where flowering, fruiting, or viable propagule production is absent, presents a significant challenge for restoration programmes, to support continuous nursery operations. Such reproductive limitations, if persistent, could restrict natural regeneration and threaten the long-term maintenance of the existing local population. The reproductive performance and propagule availability of C. *tagal* similarly require systematic evaluation under local conditions. These circumstances highlight the need to develop reliable vegetative propagation methods capable of producing healthy planting material independent of seasonal flowering and propagule availability. It was against this background, the AMSC initiated investigations into vegetative propagation through air layering, a horticultural technique in which roots are induced on a selected branch while it remains attached to the mother plant. The present study presents the results of an approximately 11-month field trial conducted at Abu Al Abyad Island on successful air-layering propagation of *R. mucronata* and *C. tagal,* successfully producing rooted saplings.

2 MATERIALS AND METHODS

2.1 Air-Layering method

The trial was conducted at Abu Al Abyad Island, Abu Dhabi, UAE. During November 2025 eighteen mother plants were selected: 16 *R. mucronata* plants (ranging in height from 1.46 to 2.94 m) and 2 *C. tagal* (ranging in height from 0.80 and 0.94 m). A total of 29 air layering was applied: 27 on *R. mucronata* and two on *C. tagal*. For *R. mucronata*, healthy, well-grown mother plants approximately 1-2 m tall were selected, with at least five branches available for treatment. Suitable twigs were approximately 10-15 mm in diameter. Cocopeat and swamp clay were mixed in a 1:1 ratio to form the rooting medium. Cocopeat was selected for its water-absorption and moisture-retention properties, while swamp clay provided the mineral component of the mixture. Using a sterile cutter, an approximately 35-mm-long section of bark was removed from each selected branch without cutting through the branch. The exposed area was carefully scraped to remove residual cambial tissue. Fresh Aloe Vera gel was applied to the treated region as part of the field protocol to avoid fungal infection. The rooting mixture was placed around the treated area in a transparent plastic bag and secured above and below the incision using ties or weather-resistant tape. The package was covered with cotton cloth to reduce direct sunlight exposure and excessive heating. The covering was moistened approximately every 3-4 days to maintain suitable moisture conditions. Each air layer was tagged for identification and monitoring. ROOTEX-4 rooting product was prepared at 20 mL per litre of water, and approximately 30 mL of the prepared solution was applied to each treated branch at intervals of 15-20 days, according to the field protocol (Figure 1).

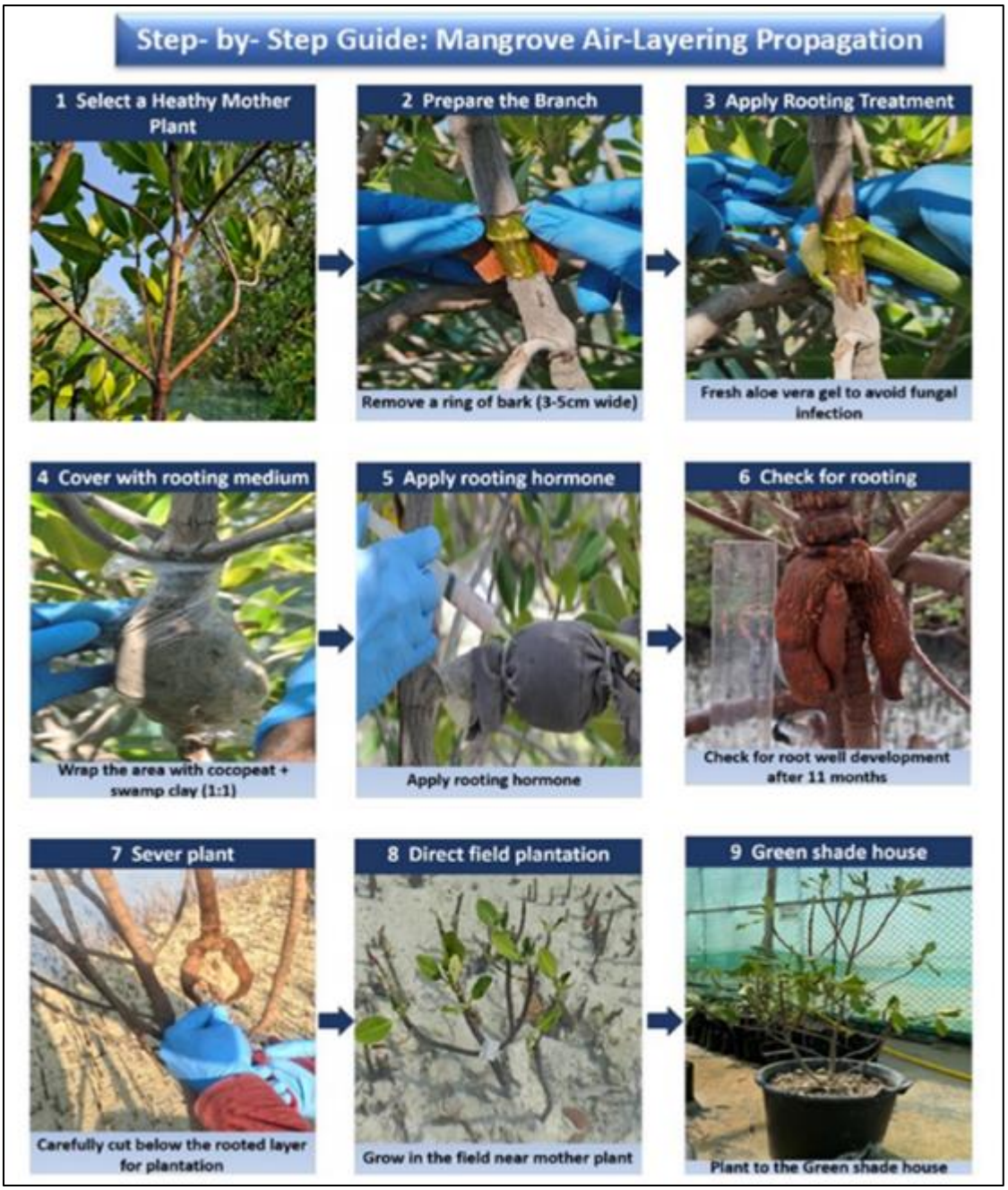


Figure 1: Sequential photographs showing branch selection, bark removal, application of Aloe Vera gel, placement of the cocopeat-swamp-clay mixture, plastic wrapping, cloth covering, check for rooting and sever plant

2.2 Monitoring and evaluation

Air layered plants were monitored for approximately 11 months to evaluate root development and determine the suitability of treated branches for separation. Root development was initially expected within approximately 4-5 months. However, the monitoring period was extended to assess the performance of the treatments under different seasonal environmental conditions. A successful treatment was defined as an air-layered branch that developed sufficient roots to permit separation from its mother plant. Treatments were classified as successful or unsuccessful according to the recorded field observations.

The propagation success rate was calculated using the following equation:

$$\text{Success rate (\%)} = \left(\frac{\text{Number of successful air-layering treatments}}{\text{Total number of air-layering treatments}} \right) \times 100$$

2.3 Planting the rooted branches

After the 11-month treatment period, successfully rooted branches were carefully separated from their mother plants after assessment of root development and general plant condition. The separated plants were divided into two establishment groups:

- *Direct field planting*: Plants were established near their respective mother plants and individually tagged. They were exposed to natural tidal conditions, receiving approximately six hours of tidal water exposure under the observed field conditions.
- *Green shade-net-house cultivation*: The remaining plants were transferred to a green shade-net house for establishment under comparatively sheltered conditions.

Both groups were monitored using common assessment parameters, including leaf condition, survival, plant height, leaf production, new shoot development, and overall plant health. Particular attention was given to leaf shedding, drying symptoms, and the development of new growth. Changes in leaf condition were recorded during the first two weeks, followed by additional observations over the subsequent ten days. The responses of field-planted and shade-net-house plants were compared descriptively.

2.4 Statistical analysis

Air-layering success was evaluated using only descriptive statistics and expressed as the percentage of treatments that developed sufficient roots for separation from the mother plants. The uncertainty associated with rooting success proportions was estimated using 95% Wilson score confidence intervals. Differences in rooting success between *Rhizophora mucronata* and *Ceriops tagal* were explored using a two-sided Fisher's exact test because of the small sample size and the presence of a zero-frequency cell. Statistical significance was assessed at $p < 0.05$. Since multiple air-layering treatments were applied to some mother plants, the analysis was considered exploratory, and potential within-plant dependence was acknowledged. Post-separation establishment responses were evaluated descriptively because individual quantitative survival and growth data were not available.

3 RESULTS

A total of 19 successful air-layering treatments were recorded from 29 treatments, corresponding to an overall propagation success rate of 65.5%. For *R. mucronata*, 17 of the 27 treatments developed sufficient roots for separation, giving a success rate of 63.0%. Both treatments conducted on *C. tagal* were successful, representing a recorded success rate of 100%. The results demonstrate that air layering produced rooted planting material from both species under the existing environmental conditions during the present trial (Table 1. Figure 2 and 3).

Table 1: Air-layering outcomes recorded at Abu Al Abyad Island

Parameter	*R. mucronata*	*C. tagal*	Overall
Mother plants	16	2	18
Air-layering treatments	27	2	29
Successful treatments	17	2	19
Unsuccessful treatments	10	0	10
Success rate (%)	63.0	100.0	65.5

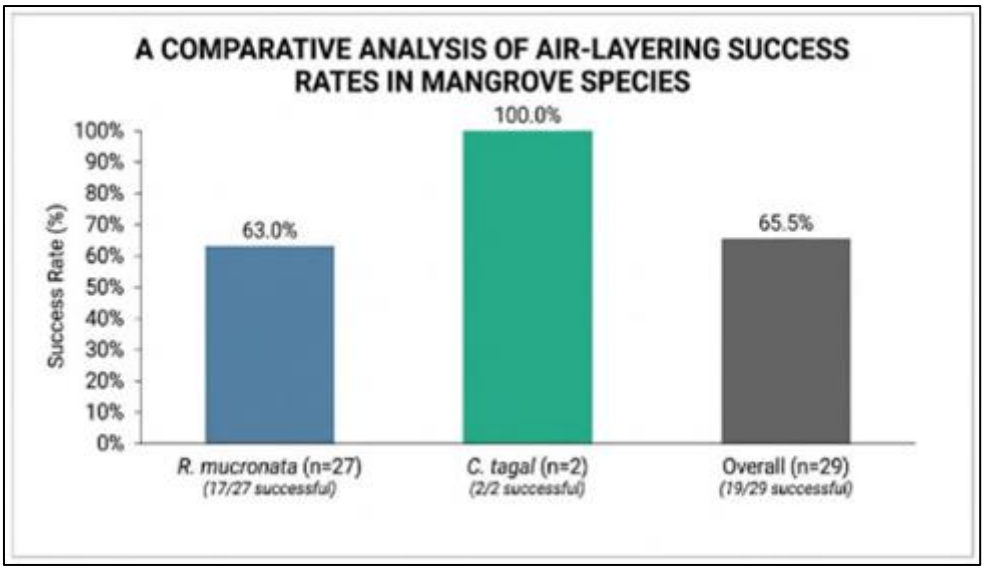


Figure 2: Air-Layering outcomes derived from 18 mother plants. Data presented as success percentages alongside total trial sample size (n).



Figure 3: *Rhizophora mucronata* and *Ceriops tagal* with root development

3.1 Mother-plant and separated-plant measurements

Recorded mother-plant heights ranged from 1.46 to 2.94 m for *R. mucronata*. The two *C. tagal* mother plants measured 0.80 and 0.94 m. Branch numbers ranged from 9 to 19 for *R. mucronata* and were seven and ten for *C. tagal*. Recorded separated-plant heights ranged from 41 to 81 cm for *R. mucronata* and were 40 cm for both *C. tagal* records (Table 2).

Table 2: Recorded plant measurements

Plant No	Species name	Mother plant height (m)	Air layering treatments	Successful Air-Layering	Separated plant branch height (cm)	No of Branches	Leaf count	
							leaf bud	Leaf
1	*Rhizophora mucronata*	1.80	3	1	53	9	7	8
2	*Rhizophora mucronata*	2.10	1	0	41	10	6	7
3	*Ceriops tagal*	0.80	1	1	40	10	5	3
4	*Ceriops tagal*	0.94	1	1	41	15	3	0
5	*Rhizophora mucronata*	2.68	1	1	81	15	7	11
6	*Rhizophora mucronata*	1.80	3	2	67	15	9	3
7	*Rhizophora mucronata*	1.46	1	0	53	10	8	9
8	*Rhizophora mucronata*	2.60	2	2	43	11	9	9
9	*Rhizophora mucronata*	1.80	2	2	45	12	12	7
10	*Rhizophora mucronata*	1.90	1	1	65	19	16	12
11	*Rhizophora mucronata*	2.00	1	0	58	16	15	2
12	*Rhizophora mucronata*	2.42	1	0	50	19	17	8
13	*Rhizophora mucronata*	2.10	1	0	48	09	10	3
14	*Rhizophora mucronata*	2.70	3	2	47	11	11	8
15	*Rhizophora mucronata*	2.42	3	2	43	18	13	5
16	*Rhizophora mucronata*	2.94	2	2	62	10	8	21
17	*Rhizophora mucronata*	2.70	1	1	62	10	7	7
18	*Rhizophora mucronata*	2.69	1	1	40	07	10	25
Total			29	19				

3.2 Comparative establishment performance

Following the re-planting in the field planting near their mother plants and green shade-net-house cultivation, in the first two weeks of monitoring, plants in both groups began shedding older leaves. During the subsequent ten-day monitoring period, the shade-net-house plants began showing signs of drying, which was associated with insufficient water availability. In contrast, the directly planted mangroves received approximately six hours of natural tidal water exposure. These plants maintained better visible condition and began showing signs of new growth through the development of existing buds. The observed responses indicated better initial establishment of directly planted mangroves compared with plants maintained in the shade-net house (Table 3; Figure 4).

Table 3: Qualitative comparison of the initial establishment responses.

Observation	Direct field planting	Green shade-net house
Initial leaf shedding	Observed	Observed
Subsequent plant condition	Comparatively better	Drying symptoms observed
Water availability	Natural tidal exposure (6 hours)	Insufficient water (observed conditions)
Existing bud development	New growth observed	No comparable new growth observed
Initial establishment response	More favourable	Less favourable

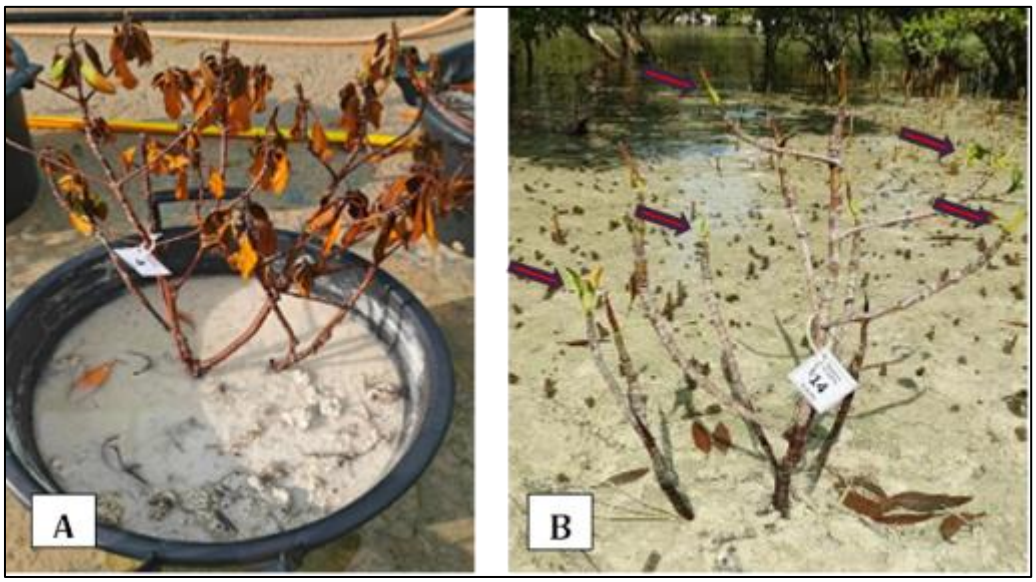


Figure 4: (A) Leaf shedding and drying in shade-net-house plants, (B) Development of existing buds in directly planted plants near the mother plants.

3.3 Statistical evaluation

The overall rooting success rate was 65.5% (19/29 treatments), with a 95% Wilson confidence interval of 47.3-80.1%. *Rhizophora mucronata* exhibited a rooting success rate of 63.0% (17/27; 95% CI: 44.2-78.5%), whereas *Ceriops tagal* exhibited 100% success (2/2; 95% CI: 34.2-100.0%). A two-sided Fisher's exact test did not identify a statistically significant association between species and rooting success ($p = 0.532$). However, the small sample size for *C. tagal* and the potential non-independence of treatments from the same mother plant limit the interpretation of this comparison. The findings therefore provide only preliminary evidence of successful propagation in both species rather than evidence of differences in their rooting capacity.

4 DISCUSSION

A total of 19 successful rooting treatments out of 29 resulted in an overall rooting success rate of 65.5%, providing preliminary evidence that air layering can generate additional planting material directly from established mother plants. Differences in rooting success appeared to be associated with the positioning of air-layering treatments at different tidal elevations. Treatments positioned within the tidal inundation zone, where the rooting medium was naturally exposed to seawater during high-tide periods, achieved 100% rooting success. In contrast, treatments positioned above the tidal inundation zone relied primarily on manual watering to maintain moisture within the rooting medium and showed comparatively lower rooting success. This variation may partly be explained by differences in moisture availability, particularly under the elevated atmospheric temperatures experienced during the 2026 El Niño-associated period. Higher temperatures may have accelerated moisture loss from the rooting medium in treatments that depended on manual watering, potentially creating less favourable conditions for root development. These observations highlight the importance of maintaining adequate and consistent moisture within the rooting medium during the air-layering process under hot and arid coastal conditions. Natural tidal inundation may therefore provide a moisture-regulating advantage for mangrove air-layering treatments under extreme coastal temperatures, potentially

reducing dependence on manual watering and improving rooting outcomes. Although both treatments of *C. tagal* successfully developed roots, the 100% success rate recorded for *C. tagal* was based on only two treatments and should not be interpreted as evidence of greater propagation performance than that of *R. mucronata*. The observed difference between the two species is therefore insufficient to establish species-specific differences in rooting capacity.

5 CONCLUSION

Air layering offers an opportunity to produce rooted planting material directly from established mother trees without relying on seed or propagule production. Consequently, this technique could diversify local planting-material production and provide an additional propagation option to support future mangrove restoration programmes in Abu Al Abyad, Abu Dhabi. The results should be interpreted with caution, in the context of the preliminary nature of the study. The relatively small overall sample size, particularly for *C. tagal*, the absence of controlled comparisons of rooting-medium moisture and composition, differences in water availability between establishment conditions, and the limited post-separation monitoring period restrict the extent to which broader conclusions can be drawn. Nevertheless, this study provides preliminary evidence that air layering can serve as an additional propagation strategy for local mangrove restoration programs.

Recommendations

Future investigations should focus on involving larger sample sizes, replicated trials across different tidal elevations, standardised moisture conditions and long-term assessments of post-separation survival and growth necessary to optimise the protocol and establish its suitability for larger-scale mangrove planting-material production in the island of Abu Al Abyad, Abu Dhabi, United Arab Emirates.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study

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