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STUDY ON CORROSION BEHAVIOUR OF MILD STEEL AGAINST ORGANIC COMPOUNDS OF *ADHATODA VASICA* LEAVES

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ABSTRACT: To compete with ecosystem hazards, there is a need to replace available chemical inhibitors and its utilization with green inhibitors is highly necessary. This present study assessment that the two compounds namely vasicine and vasicinone were isolated from the leaves extract of Adhatoda vasica plant. On controlling the rate of Mild Steel in 1.11 N HCl green inhibitor vasicine and vasicinone was studied at 303K. Using weight loss method and electrochemical studies the corrosion rate and inhibitor efficiency were calculated. On affecting both anodic and cathodic plots on the Tafel curve, the mechanism of corrosion inhibiton implies that different energy barriers formed over the metal surface. The result revealed that the inhibitor efficiency increases as the concentration of the inhibitor concentration. Also, it was found that the corrosion inhibition behaviour of vasicine is high when compared with vasicinone in 1.11N HCl.

Keywords: Mild steel, Corrosion Inhibitors, ecofriendly, Vasicinone, Vasicine.

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1.INTRODUCTION

In a metal or alloy a uniform corrosion will takes places over the surface due to chemical and or electrochemical reaction which is known as general corrosion. The rate of corrosion can be estimated for equipment by immersed in the sample material in a particular medium but this will not tell us any technical view of problem. In order to prevent major corrosion the following process to be followed such as proper design, alloying material, coating material and inhibitor. Most of the concentrated mineral acids were used for pickling ad descaling process. In India most of plant materials were used as medicinal shrubs especially Adhatoda vasica is one of the most remarkable

one. Due to the presence of bronchodilator alkaloids, which mainly consist of vasicine, quinolone and vasicinone in the plant leaves[1]. Most valuable properties like antiseptic, anti-inflammatory activities are available in the isolated compound from Adhatoda vasica leaves. It is a quinolone type alkaloid[2-4]. Adhatoda vasica is the principal source of this vasicine and vasicinone compound. For more than 2000years this plant has been used in India[5]. Materials like plastic, ceramics and other metals are also corroded. Many actions were taken for the prevention of corrosion especially the metals like steel, cooper, aluminium, zinc and tin during transportation they loss their properties due to corrosion[6]. According to GDP of India an approximately 6% were spent for corrosion prevention process. Organic compounds are toxic in nature and very expensive to both human beings and environments[7] and therefore, the usage of organic inhibitors as corrosion inhibitors are limited. Therefore researcher made their effort to develop cost-effective and non- toxic inhibitors to avoid damages for human beings and to the environment. Using plant extract which is used as corrosion inhibitors due to its availability of source accepted by the environment. In the prevention of mild steel the research area is mainly focused and give more importance to the addition of environmentally friendly and ecologically acceptable, plant products which are inexpensive, readily available and renewable source of materials[8-10]. Several authors have reported the use of the natural products as the potential corrosion inhibitors for various metals and alloys under different environments[11-16].

Medium	**Name of the inhibitor**	**Inhibition efficiency %**
1M HCl	Extract of Antrographis paniculata[11]	98.1
0.5 M H_2SO_4	Thespesia populnea[12]	86.73
0.5M H_2SO_4	Mangifera indica Leave Extracts[13]	96.2
1MHCl	Datura metal[14]	98.69
1MHCl	Natural oil extracted from Pennyroyal Mint[15]	80
2MHCl	Extract of Allamanda Blanchetii[16]	49.49

Based on this evaluation in my investigation, the corrosion inhibiton of mild steel in 1.11N HCl solution in the absence and presence of Vasicine and Vasicinone inhibitor isolated from ethanol extract of *Adhatoda Vasica* leaves at 303K temperatures have been studied by weight loss method and Electrochemical method.

2. MATERIALS AND METHODS

2.1 Weight loss method

Mild steel strips were cut into pieces of 5 × 1 cm^2 having the following percentage composition Fe = 99.703, Ni = 0.021, Mo = 0.010, Cr = 0.037, S = 0.014, p = 0.009, Si = 0.006, Mn = 0.183, C = 0.017[17].The surface of the electrodes were polished effectively on the different grade of emery papers of grade from400-1200 grit then degreased with a combination of Hydrochloric acid, 20 gm

of Antinomy oxide and 50 gm of Tin (II) chloride powder[18]. Using the following formula the weight loss was calculated.

$$\text{Corrosion rate} \quad K = \frac{8.76 \times 10000\ W}{ATD}$$

$$\text{Inhibition efficiency} \quad IE\% = \frac{W_U - W_I}{W_U} \times 100$$

$$\text{Surface coverage} \quad \theta = \frac{W_U - W_I}{W_U}$$

Where T is a time of exposure in h, W is a weight loss of test specimen in g, A is an area of the test specimen in cm^2, D is the density of material in g cm^3 and W_U and W_I are the corrosion rates for mild steel in the absence and presence of inhibitor respectively at the same temperature[19].

1.2 Electrochemical studies

Using conventional three electrode system electrochemical measurements were carried out. The working electrode was mild steel of 1 cm^2 area and the rest portions were covered with Araldite. A rectangular platinum foil of 1 cm^2 was used as counter electrode and saturated calomel electrode (SCE) as a reference electrode. Measurements were performed using CH electrochemical analyzer Model CHI 608D/ E instrument[20]. Impedance measurements were carried out with three electrode system. All the three electrodes were immersed in 1.1N HCl without and with the inhibitor. Open circuit potential was measured about 30 min after the immersion of working electrode to the test solution. The experiments were carried out in the frequency range of 10 kHz to 0.01 Hz using CH Electrochemical analyzer (Model CHI 608 D/E)[21]. The real and imaginary parts of the impedance were plotted in Nyquist plots. Using this formula impedance value was calculated.

$$C_{dl} = \frac{1}{2\pi f_{max} \times R_{ct}}$$

$$IE\ \% = \frac{R_{ct\ (i)} - R_{ct}}{R_{ct}} \times 100$$

The potentiodynamic polarization measurements were carried out with the three-electrode system (working electrode, platinum electrode and saturated calomel electrode). The working electrode was polished with various grades of emery papers, washed with doubly distilled water and degreased with trichloroethylene[22]. All the three electrodes were immersed in 1.11N HCl solution without and with inhibitors (isolated vasicine and vasicinone). The polarization measurements were carried out at ± 200 mV from the open circuit potential at a scan rate of 2 mV/s. Potentiodynamic polarization measurements were initiated about 30 min after the working electrode was immersed in the solution to stabilize the steady-state potential. The plot of E Vs. log I was made from which

corrosion current density, corrosion potential, anodic and cathodic Tafel slopes values were calculated.

$$IE\% = \frac{I_{corr} - I_{corr\ (i)}}{I_{corr}} \times 100$$

2.3 Solutions

Electrolytes and the solution were prepared using AR grade chemicals using double distilled water bubbled with nitrogen gas for 30 minutes for Deareation process.

2.4 Preparation of Acid mediums

2.4.1. Hydrochloric Acid

Hydrochloric acid solution was prepared using double distilled water. It was standardized by titrating against Na_2CO_3 solution and its normality was found to be 1.11N.

2.4.2 Preparation of Inhibitor

1000 ppm of the isolated vasicine, vasicinone were obtained from *Adhatoda vasica* extract (crude) solutions were prepared by dissolving 1gm of isolated vasicine, vasicinone extract in 30 mints respectively in one liter of 1.11 N HCl. This stock solution was diluted to 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 ppm using 1.11 N HCl solution.

3. RESULTS AND DISCUSSION

3.1 Weight loss measurement

The corrosion behaviour and inhibiton efficiency of mild steel in 1.11N hydrochloric acid with vasicine and vasicinone was given in Figure 1(a & b), which was studied by weight loss method at 303K. From the graph, it was observed that the weight loss of mild steel in the acid decreases with increasing concentration of additives, which suggesting that the additives are corrosion inhibitor for mild steel in 1.11 N HCl. The values of corrosion rate and inhibition efficiency in absence and presence of difference concentration of inhibitor used in 1.11N HCl solutions at 303K for 1 hours were given in Table 1.

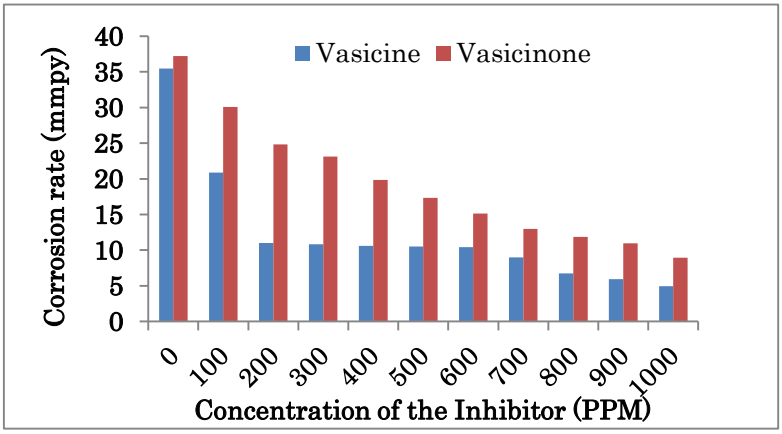

Figure 1(a): Comparison of Corrosion Rate of mild steel in 1.11N HCl using Vasicine and Vasicinone inhibitor

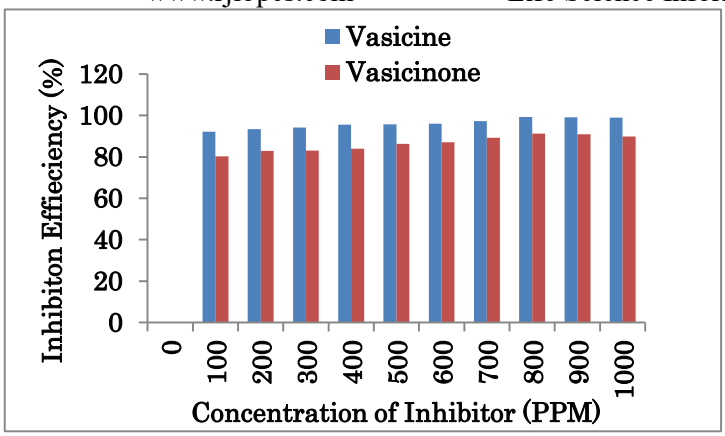

Figure 1 (b): Comparison of Inhibition Efficiency of mild steel in 1.11N HCl using Vasicine and Vasicinone inhibitor

Table 1: Comparison of mild steel in 1.11N HCl using Vasicine and Vasicinone inhibitor

Concentration of theInhibitor (ppm)	Corrosion Rate (mmpy)		Inhibiton Efficiency (%)	
	Vasicine	Vasicinone	Vasicine	Vasicinone
Blank	35.47	37.21	---	---
100	20.89	30.10	92.17	80.16
200	10.99	24.85	93.39	82.89
300	10.83	23.13	94.21	83.03
400	10.60	19.84	95.61	84.02
500	10.51	17.32	95.75	86.26
600	10.42	15.12	96.01	87.01
700	8.98	12.98	97.23	89.23
800	6.75	11.85	99.25	91.25
900	5.93	10.94	99.03	90.89
1000	4.96	8.95	98.89	89.86

From **Table 1**, it was clear that the corrosion rate was decreased with increasing concentration of inhibitor and inhibition efficiency increased with increasing the concentration of the inhibitor[23]. The maximum corrosion inhibition efficiency of Vasicine and Vasicinone was 99.25 % and 91.25 respectively in 1.11N HCl the efficiency at 303K. On comparing both the inhibitor, the efficiency is high in Vasicine than Vasicinone.

3.2 Electrochemical Studies

3.2.1. Electrochemical Studies

A.C. impedance measurements were carried out at room temperature for corrosion of mild steel in 1.11N HCl after immersion of electrodes, the Nyquist plots for mild steel in uninhibited acid and for the all concentrations of studied inhibitors are shown in **Figure. 2 (a &b)**. The impedance parameters and the IE% are given in **Table 2**. The charge transfer resistance (R_{ct}) value for mild

steel in uninhibited 1.11N HCl shows very low value and significantly changes after the addition of inhibitor. The R_{ct} values increases by the addition of studied inhibitors at optimum concentration. The fact is advocated by the increase in inhibitor efficiency. The semicircular nature of Nyquist plots obtained for all experiments indicates that the corrosion of mild steel is controlled by charge transfer process [24].

Table 2: A.C. Impedance parameters of mild steel electrode immersed in 1.11N HCl in the absence and presence of the inhibitors

Inhibitors	Parameters					
	R_{ct} (ohm cm^2)		C_{dl} ($\mu F\ X10^{-5}$)		Inhibition Efficiency (%)	
	Vasicine	Vasicinone	Vasicine	Vasicinone	Vasicine	Vasicinone
Blank	12	13	231.02	231.02	-	-
100	211	65	177.31	177.31	94.31	85.31
200	240	71	166.15	166.15	95.00	86.00
300	275	76	154.74	154.74	96.64	87.64
400	350	80	121.10	121.10	96.70	88.70
500	364	85	116.72	116.72	96.83	89.83
600	371	95	112.58	112.58	96.87	91.87
700	376	100	90.83	90.83	96.89	93.89
800	389	135	83.21	83.21	98.23	95.01
900	383	120	87.52	87.52	98.03	92.03
1000	380	105	93.41	93.41	97.54	91.64

Generally in solution ions are controlling whereas in the metal side, electrons control the charge distribution[25]. From the Table 2 the capacitance of the electrical double layer (C_{dl}) decreases in the presence of the inhibitors.

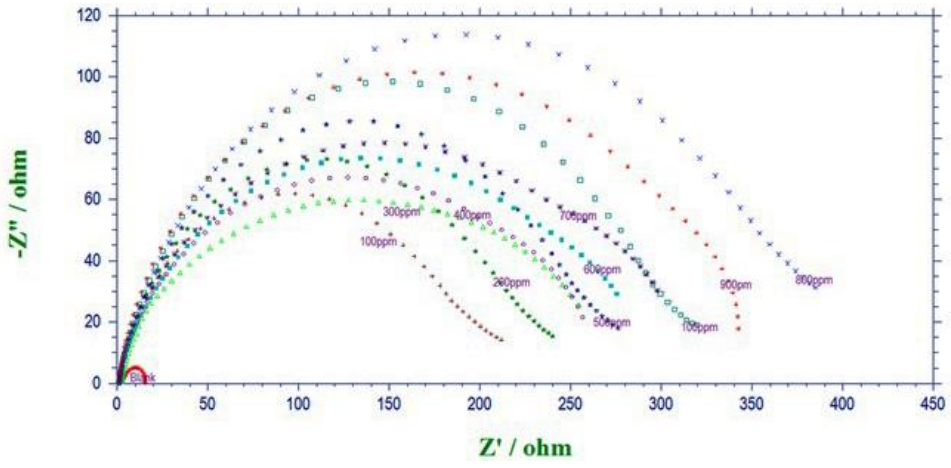

Figure 2(a): Nyquist plots for mild steel in 1.11N HCl with Vasicine inhibitor

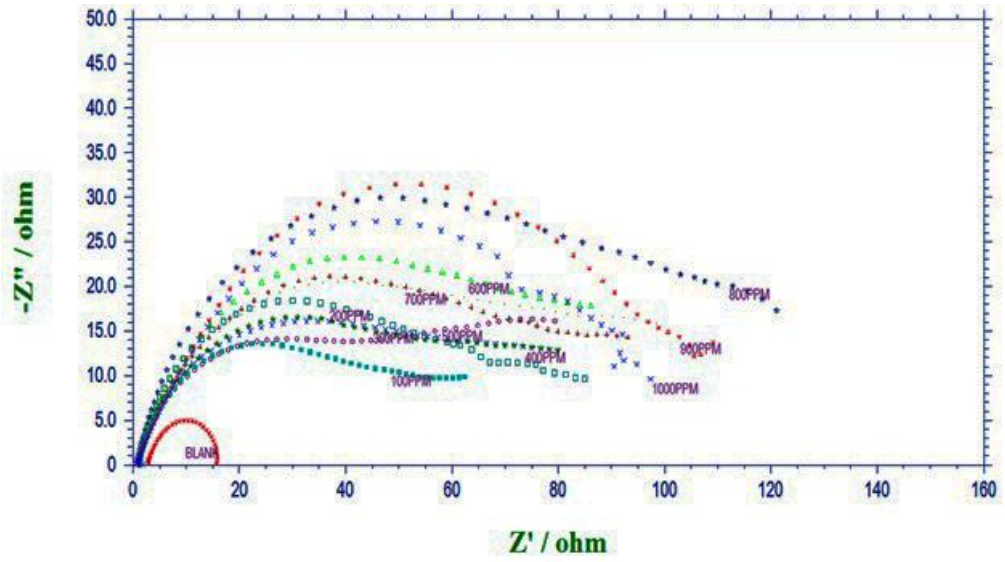

Figure 2(b): Nyquist plots for mild steel in 1.11N HCl with Vasicinone inhibitor

Decrease in the (C_{dl}) which can result from a decrease in local dielectric constant and / or an increase in the thickness of the electrical double layer, suggests that the inhibitor molecule may act by adsorption at the metal/solution interface[26].

3.2.2 Potentiodynamic polarization studies

The potentiodynamic polarization curves for mild steel in 1.11 N HCl without and with various concentrations of vasicine and vasicinone are shown in **Figure 3(a&b)** and represented in **Table 3**. Polarization studies revealed that the corrosion current density (I_{corr}) markedly decreased with the addition of vasicine and vascinone. On addition of inhibitorst he corrosion potential shifts to less negative values.

Table-3. Potentiodynamic Polarization parameters of mild steel electrode immersed in 1.11N HCl in the absence and presence of the inhibitors

Concentration of the Inhibitors	Vasicine Inhibitor					Vasicinone inhibitor				
	E_{corr} (mV)	Tafel slopes (mV/dec)		I_{corr} ($\mu A/cm^{-2}$)	Inhibition efficiency (%)	E_{corr} (mV)	Tafel slopes (mV/dec)		I_{corr} ($\mu A/cm^{-2}$)	Inhibition efficiency (%)
		-βa	-βc				-βa	-βc		
Blank	-0.459	5.50	3.56	1550	-	-0.450	5.50	3.56	1550	-
100	-0.460	5.77	3.97	93.88	93.94	-0.461	5.77	3.97	93.88	84.14
200	-0.462	5.84	4.04	89.43	94.23	-0.469	5.84	4.04	89.43	85.19
300	-0.477	6.00	4.20	88.09	94.32	-0.477	6.00	4.20	88.09	86.23
400	-0.482	6.01	4.21	81.99	94.71	-0.482	6.01	4.21	81.99	87.02

500	-0.483	6.06	4.26	75.02	95.15	-0.483	6.06	4.26	75.02	88.26
600	-0.484	6.09	4.29	62.40	95.91	-0.484	6.09	4.29	62.40	90.01
700	-0.488	6.11	4.31	58.11	96.16	-0.488	6.11	4.31	58.11	92.23
800	-0.494	6.16	4.36	29.92	99.69	-0.501	6.16	4.36	29.92	95.12
900	-0.498	6.19	4.39	31.77	98.33	-0.490	6.19	4.39	31.77	93.19
1000	-0502	6.22	4.42	40.82	97.95	-0.485	6.22	4.42	40.82	91.76

Moreover, the values of anodic and cathodic Tafel slopes are slightly changed indicating that this behavior reflects the inhibitors ability to inhibit the corrosion of mild steel in 1.11N HCl with vasicine and the adsorption of vasicine molecule on both anodic and cathodic plots[27-30].

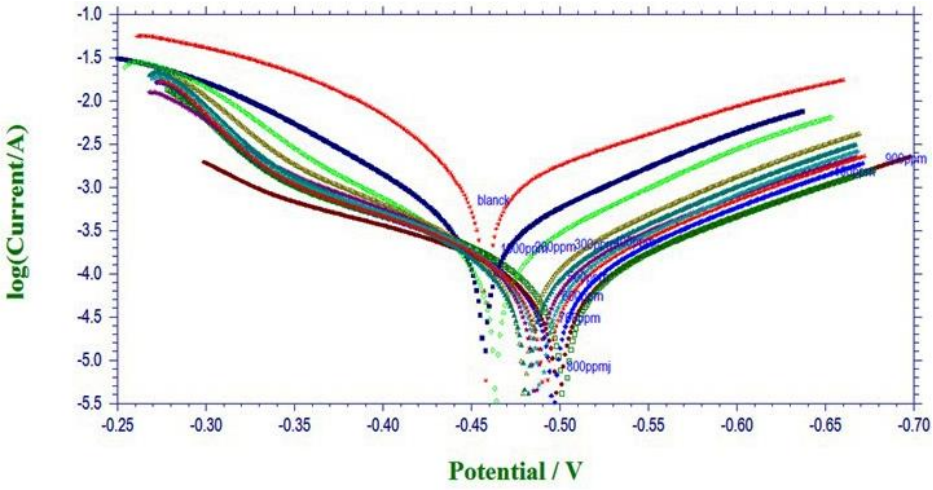

Figure 3 (a): Potentiodynamic polarization curves for mild steel in 1.11 N HCl with vasicine

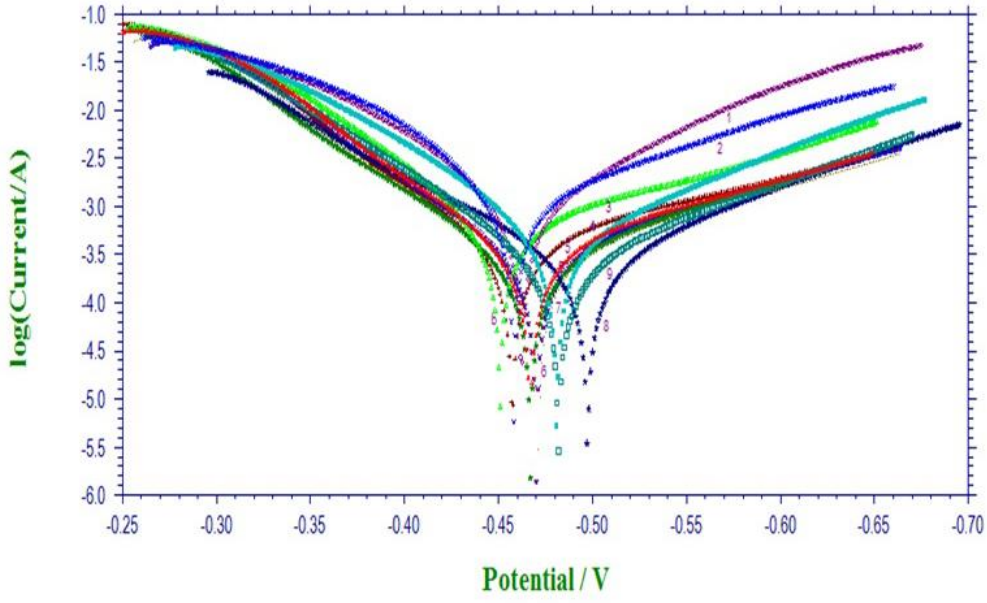

Figure 3(b): Potentiodynamic polarization curves for mild steel in 1.11 N HCl with vasicinone

It was observed that the inhibition efficiency was found to be increased with an increase in the concentration of vasicine from 100 ppm to 800 ppm and then decreased even up to 1000 ppm. The maximum inhibition efficiency of 99.69% was observed at 800 ppm in vasicine compound.

4. CONCLUSION

The main findings of this research were, the natural inhibitor namely vasicine and vasicinone isolated from ethanol extract of *Adhatoda vasica* leaves acts as a good inhibitor in preventing mild steel material in 1.11N HCl. As the inhibitor concentration increases the efficiency also increases but the rate of corrosion decreases upto 800ppm then the value. From the weight loss analysis, it has been concluded that all the studied inhibitor effectively inhibit the corrosion of mild steel at 303 K. When comparing the inhibiton efficiency of Vasicine and Vasicinone, it shows 99.25% and 91.25% in 1.11N HCl at 303K, Weight loss results were confirmed by electrochemical analysis like A.C.Impedance measurement and polarization studies. From the electrochemical studies it has been revealed that the inhibitor efficiency of vasicine and vasicinone was good in 1.11N HCl. On comparing the inhibition efficiency result calculated from weight loss method and electrochemical method Vasicine shows a better result than Vasicinone.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No Animals/Humans were used for studies that are base of this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The authors confirm that the data supporting the findings of this research are available within the article.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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