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Effect of ageing and tooth loss on sensory function of alveolar mucosa

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Abstract

Background: Maintaining quality of life of elderly denture wearers is one of the most crucial tasks for dentists in the super-aged society. Although external mechanical load on removable dentures has been investigated to minimise a risk of soreness caused by dentures, sensory perception of the alveolar mucosa remains obscure.

Objectives: This study aimed to investigate effect of ageing and tooth loss in sensory function on the alveolar mucosa for deep understanding of the characteristics of pain sensitivity in edentulous individuals.

Methods: Eighteen edentulous participants (ED), as well as 18 age-matched dentate participants (EC) and 18 young dentate participants (YC), participated in this study. Tactile detection threshold (TDT) and pain threshold (PT) were measured with von Frey filaments (0.125–512 mN). Mechanical pain sensitivity (MPS) after a 2-sec application of 1 kg palpation was assessed with a 0–50–100 Numerical Rating Scale (NRS) (0: no pain, 50: slight pain and 100: the worst pain imaginable). Furthermore, entropy scores of TDT, PT and NRS on MPS were calculated.

Results: In both maxilla and mandible, EC showed significantly higher TDT and PT, compared with YC, whereas ED showed significantly lower TDT and PT, compared with EC. NRS on MPS in ED was significantly higher than that in EC. The entropy scores of all the outcome parameters showed no significant difference between groups.

Conclusion: Both ageing and tooth loss can alter tactile and pain perception in the oral mucosa. This suggests that it might be beneficial to assess sensory function of the alveolar mucosa in edentulous patients clinically in prior to denture fabrication.

KEYWORDS
ageing, edentulous, entropy, pain threshold, tactile perception

1 | INTRODUCTION

It has been predicted that becoming a super-aged society is a serious problem worldwide.[1] Therefore, it is crucial for dentists to maintain oral function of elderly removable denture wearer, as ageing rate increases. It is particularly because healthy and normal oral function, such as mastication and swallowing properly and comfortably, is considered to be an important factor towards general and oral quality of life (QoL),[2,3] which, thus, could contribute to extension of healthy life expectancy.

A frequent complaint removable denture wearers claim, which leads them to a dental consultation, is soreness in the alveolar mucosa.[4] In order to minimise risk of such soreness, there has been a lot of research investigating effect of external mechanical load on the alveolar mucosa as a possible cause of the soreness denture wearers might experience. A clinical study suggested that pressure distribution on alveolar mucosa under a removable partial denture differed by location of occlusal rests.[5] In case of complete dentures, depending on occlusal position or scheme, the distribution of occlusal pressure is loaded on different areas of the maxilla and the mandible.[6] These findings indicate that the design or occlusal scheme of dentures needs to be well considered to avoid loading occlusal force unevenly on the alveolar mucosa.

Nevertheless, even though objective clinical assessments of a denture fit show no uneven load of the denture on the alveolar mucosa, as well as wrong occlusal scheme, there are cases where patients still complain about soreness. This indicates that not only the external load but also mechanical sensitivity of the alveolar mucosa should be considered in order to understand the cause of soreness removable denture wearers suffer from. However, sensory perception of the alveolar mucosa in removable denture wearers is not fully understood. A few past studies investigated pressure pain threshold or response to electrical stimulation on the alveolar mucosa in edentulous patients.[7–10] Here, it was shown that pressure pain threshold in the alveolar mucosa in edentulous individuals is site-dependent. However, prosthodontists still lack standardised assessment methods to assess sensory function of the alveolar mucosa. Such methods would be advantageous to assess sensory function of an edentulous patient prior to denture fabrication, in order to understand the patient's mechanical sensitivity of the alveolar mucosa. Recently, to understand pain distribution in a specific area such as muscle, entropy analysis has been applied.[11–14] Entropy analysis enables understanding of sensory function of painful condition in the orofacial region such as temporomandibular disorders (TMD) in a more straightforward way compared with other assessment methods. Entropy scores describe diversity of values in a specific area in a standardised manner and can therefore be compared a measured value with a reference value directly. Entropy scores of pain-related parameters in the alveolar mucosa have not been investigated yet. However, information on the entropy of such parameters can be useful to screen edentulous individuals in terms of sensitivity on the alveolar mucosa and predict prognosis of denture treatment. Therefore, the aim of this study was to investigate whether sensory function on the alveolar mucosa changes due to ageing and teeth loss and whether such parameters affects entropy scores of pain-related parameters. We hypothesised that ageing and tooth loss would affect mechanical sensitivity in the alveolar mucosa, resulting in change in entropy scores of the pain-related parameters.

2 | MATERIALS AND METHODS

2.1 | Participants

Eighteen edentulous participants (ED group: 8 men and 10 women, mean age ± SD: 79 ± 8 years old) and 18 age-matched dentulous controls (EC group: 8 men and 10 women, mean age ± SD: 77 ± 4 years old) whose dentition was classified in A1 of Eichner's classification were recruited to this study from a clinic of Geriatric Dentistry in Osaka Dental University Hospital between April 2018 and December 2020. In addition, 18 young healthy dentulous controls (YC group: 8 men and 10 women, mean age ± SD: 29 ± 4 years old) also participated in this study. Exclusion criteria for all the participants were diabetes, orofacial pain such as trigeminal neuralgia and neuroplastic pain, temporomandibular disorders with restriction of mouth opening and dementia. Prior to the experiment, informed consent was obtained from all the participants. This study was approved by the ethics committee in Osaka Dental University (approval No. 110968) and conducted in accordance with the Helsinki Declaration II.

2.2 | Study design

This study was performed as an observational study to investigate sensory response to mechanical stimulation to alveolar mucosa. Each participant was asked to sit on a dental chair comfortably in semi-Fowlar's position in a quiet room and examined by the same female examiner (AS). All of the parameters, the same fixed points on the alveolar mucosa on each jaw, were used (Figure 1). On either left

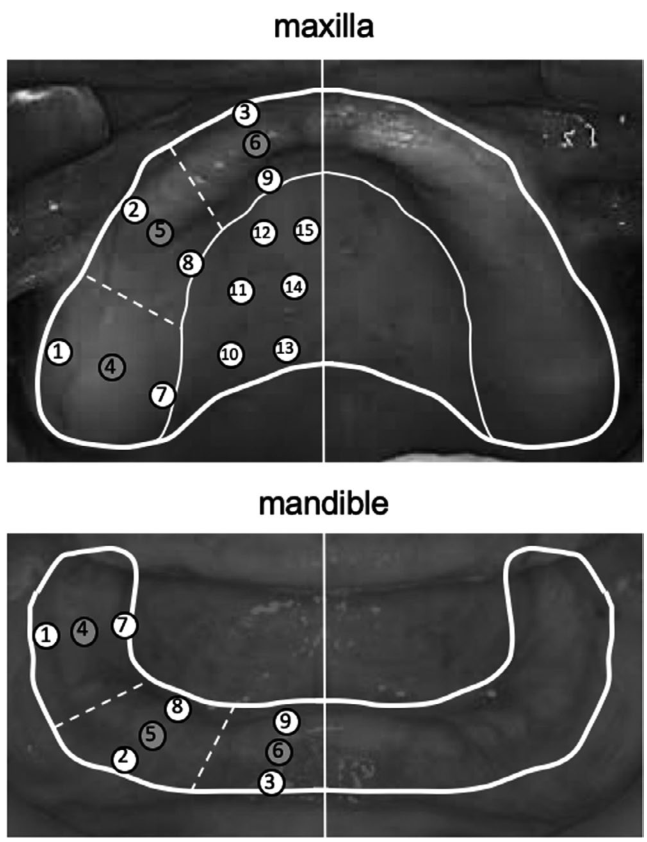

FIGURE 1 Test points for the sensory assessment (TDT, PT and MPS). White circles indicate the test points for all participants. Grey circles indicate additional test points included for entropy analysis in ED group

or right side of the maxilla or mandible, the area of the alveolar ridge was divided into three mesiodistally. The three points on the midline of each area pointing in the buccolingual direction are chosen for the measurements in ED group. Furthermore, the alveolar mucosa of the palate was also divided into three, following the lines dividing the alveolar ridge as mentioned above. Each area on the palate was then divided in two mesiolaterally, and the midpoints on each area were also chosen for the measurements. The number of the test points in ED was 24, whereas that in EC and YC was 18, because 6 points where teeth exist were omitted. The measurement on these 6 points was only used to calculate entropy scores only. The order of the test points was randomised. The randomisation was performed by the use of a table of random number.

2.3 | Sensory assessment

Outcome parameters for sensory assessment in this study were tactile detection threshold (TDT), mechanical pain threshold (PT) and mechanical pain sensitivity (MPS).

TDT was measured by a standardised set of von Frey filaments (OptiHair √2; Marstock Nervtest Ltd.,), ranging from 0.125 to 512 mN.[15,16] On each test point, von Frey filaments were applied perpendicularly for 2 s. To calculate TDT for each point, the method of limit was used.[17,18] Starting from the application of the 0.25 mN filament, the stimulus intensity increased in a step-by-step manner. Each participant was asked to raise the hand when the tactile stimuli were perceived. Then, the stimulus intensity decreased until the participant could not perceive the tactile sensation. After this process was performed three times, the geometric mean of the minimal upper threshold and the maximal lower threshold was defined as TDT.

The measurement of PT was started from the tactile stimuli of TDT on each test point. Each participant was asked to raise the hand when they perceive pain on the application of tactile stimuli with the filament. The first stimuli the participants felt pain was defined as PT.

MPS was measured with a 2 s application of 1 kg palpation[19] with an index finger of the examiner. The load was calibrated with a 1 kg palpometer (Palpeter ®, Sunstar Suisse SA, Swiss)[20] on each test point. Each participant was asked to score perceived sensory intensity with a 0–50–100 Numeric Rating Scale (NRS) that 0 indicates no sensation at all, 50 indicates a just barely painful sensation, and 100 indicates the most painful sensation imaginable.[14] MPS was defined as the mean of NRS scores with 3 measurements.

Entropy scores were calculated for PT, TDT and NRS scores for MPS of the test points on the maxilla or mandible, respectively, following a calculation method previously described.[11]

2.4 | Statistical analyses

Statistical analyses were performed using Prism 8 for macOS (Version 8.4.3; GraphPad Software,). A two-way analysis of variance (ANOVA) was used to analyse PT, TDT and NRS scores for MPS. The factors in the ANOVA were test points (maxilla: 12 levels and mandible: 6 levels) and groups (3 levels). For the analysis of entropy scores, a one-way ANOVA whose factor was groups (3 levels) was performed. Furthermore, post hoc Tukey's honestly significant difference test with corrections for multiple comparisons was performed, when appropriate. All data are presented as mean ± SEM. The significant level was set at $p < .05$. A sample-size calculation performed by G-power analysis before the study showed that with 8 participants per group we would be able to detect a difference in means (effect size =0.83) with a power of more than 80% at a significance level of 5%. The normality of the data was tested with D'Agostino & Pearson test in Prism 8.

3 | RESULTS

3.1 | Sensory assessment

The results of TDT, PT and MPS are shown in Figure 2. The ANOVA for TDT of both the maxilla showed a significant effect of groups (maxilla: $p < .001$, $F = 15.89$, mandible: $p < .001$, $F = 12.28$), but not points (maxilla: $p = .168$, $F = 1.401$, mandible: $p = .052$, $F = 2.221$) nor interaction between the two (maxilla: $p = .864$, $F = .864$, mandible: $p = .985$, $F = .281$). A post hoc test showed that TDT of both the maxilla and the mandible in EC group was significantly higher than that in YC (maxilla: $p = .018$, mandible: $p = .013$). Moreover, TDT of both the maxilla and the mandibular in ED group was significantly lower than that in EC group (maxilla: $p < .001$, mandible: $p < .001$).

The ANOVA for PT of both the maxilla and mandible showed a significant effect of groups (maxilla: $p < .001$, $F = 16.89$, mandible: $p < .001$, $F = 13.38$) and points (maxilla: $p = .001$, $F = 2.967$, mandible: $p = .014$, $F = 2.894$), but not the interaction (maxilla: $p = .851$, $F = .691$, mandible: $p = .548$, $F = .885$). A post hoc test showed that PT of both maxilla and the mandible in EC group was significantly higher than that in YC (maxilla: $p = .001$, mandible: $p = .009$). Similar to TDTs, PTs of both the maxilla and the mandibular in ED group was significantly lower than that of EC group (maxilla: $p < .001$, mandible: $p < .001$). Moreover, on the maxilla, PT on #9 (the palatal side of the incisor region) was significantly higher than that of #2 (the buccal side of the premolar regions) ($p = .027$), #3 (the buccal side of the incisor regions) ($p = .042$) and #13 (the mid-distal region of the palate) ($p = .046$). On the mandible, PT on #7 (the lingual side of the molar region) was significantly higher than that on #3 (the buccal side of incisor region) ($p = .009$).

The ANOVA for NRS scores of MPS on the both maxilla and mandible showed a significant effect of group (maxilla: $p = .009$, $F = 4.758$, mandible: $p < .002$, $F = 6.401$), but not test points (maxilla: $p = .450$, $F = .995$, mandible: $p = .776$, $F = .500$) and the interaction (maxilla: $p = .980$, $F = .477$, mandible: $p = .981$, $F = .299$). The post hoc test showed that the NRS score of MPS on both the maxilla and the mandibular in ED group was significantly higher than that in EC group (maxilla: $p = .028$, mandibular: $p = .001$).

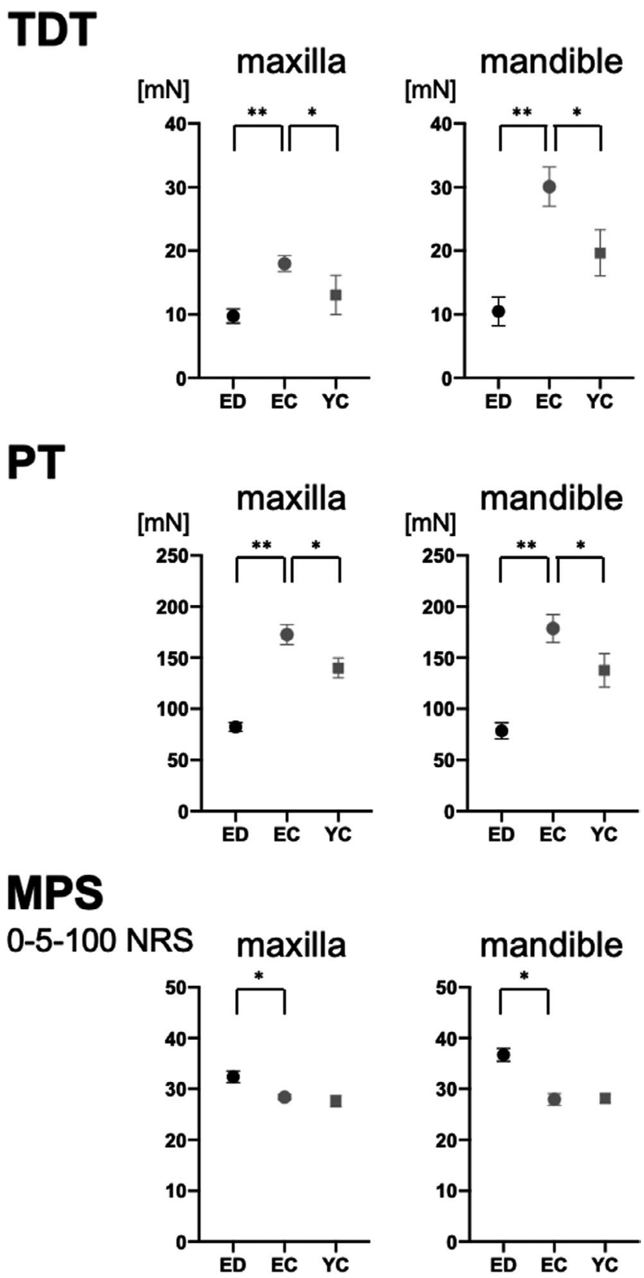

FIGURE 2 Comparison of TDT, PT and NRS on MPS. The data indicate mean ± SEM. $N = 18$. * indicates $p < .05$. ** indicates $p < .001$

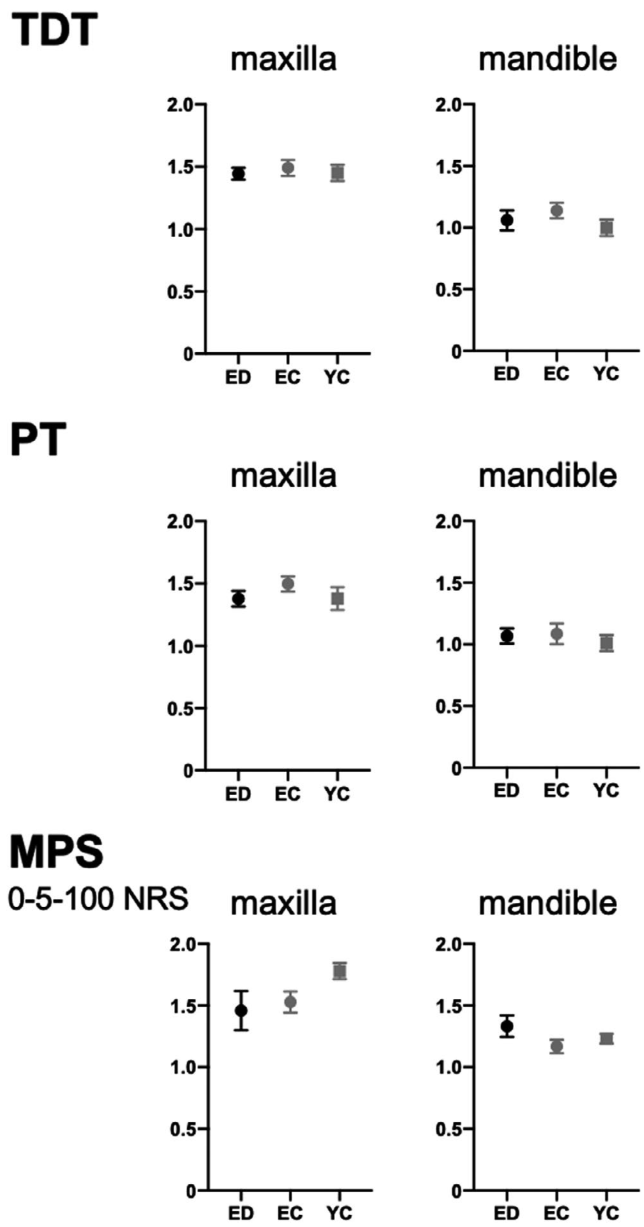

FIGURE 3 Comparison of entropy scores on TDT, PT and NRS on MPS. The data indicate mean ± SEM. $N = 18$. There was no significant difference between the groups in TDT, PT and MPS

3.2 | Entropy analysis

The results of TDT, PT and MPS are shown in Figure 3. The one-way ANOVA for entropy scores of PT, TDT and NRS scores for MPS showed no significant difference between groups, as well as points, on both maxilla and mandible (Table 1).

4 | DISCUSSION

In this study, we provide evidence that sensory function, such as tactile sensation and pain, on the alveolar mucosa changes both due to ageing and loss of teeth. However, distribution of the sensation is not affected by such factors.

Mechanical sensation is known to become insensitive due to ageing.[21] In this study, the comparison of TDT and PT between EC and YC groups showed a tendency consistent with this phenomenon. A decrease in sensation as a function of age might be explained by the fact that the number of mechanical receptor cells located in the skin and the mucosa that detect mechanical pressure, such as Merkel cells and Meissner's corpuscles, decreases drastically according to age.[22,23] The higher TDT and PT in EC group, compared with YC group, observed in this study could be caused by this physiological change accompanied with ageing. Interestingly, a systematic review

TABLE 1 Results of ANOVA for Entropy scores

		Groups	
		p values	*F* values
TDT	Maxilla	.836	0.180
	Mandible	.350	1.073
PT	Maxilla	.421	0.879
	Mandible	.730	0.317
MPS	Maxilla	.118	2.232
	Mandible	.193	1.698

and meta-analysis by Lautenbacher et al[24] showed a significant difference in PT depending on body sites of stimulation. In agreement with this study, increased PT in the head area was shown in older individuals. This is important information dentists should acknowledge when treating elderly patients, because increased pain sensation during and after treatment can significantly impact oral health and patients QOL.

The comparison of ED and EC groups, which was performed to understand the effect of tooth loss in the elderly, resulted in significant differences between the groups in all the pain-related parameters measured. This result is consistent with a past study that showed lower mechanical and pain sensitivity could be caused by chronic inflammation of the oral mucosa due to pressure from dentures covering the alveolar mucosa that receive bite force.[25] In addition, from a perspective of pain signalling, it is possible that the continuous mechanical stimulation caused by denture wearing can cause long-term sensitisation of the nociceptors in the alveolar mucosa.

Different from PT measured with von Frey filaments, NRS on MPS measured with a 2-sec application of 1-kg palpation had a significant difference only between ED and EC. PT measurements in this study aimed to test sensory function where A-delta afferent fibres are involved, whereas MPS measurements aimed to test sensory function where C-fibres are involved.[26] The results of NRS on MPS were consistent with those of PT that showed that the sensitivity of the alveolar mucosa in ED was significantly higher than that in EC. The increased MPS and PT in ED suggest that both A-delta afferent fibres and C-fibres are likely mechanically sensitised due to denture wearing. In addition, in the epithelium of the oral mucosa in denture wearers, keratinisation can be reduced.[27] This might cause direct stimulation of C-fibres that react to pressure pain and resulted in higher pain sensitivity than non-denture wearers.

Taken together, these results suggest that mechanical sensation decreases as a function of ageing. This agrees with a loss of somatosensory innervation in the oral mucosa.[17] However, in ageing edentulous individuals with removable dentures, this effect is significantly reversed. This suggests that the continuous mechanical stimulation of the alveolar mucosa by a denture can be a strong modulator of mechanical pain signalling, which is likely a major cause for the soreness that many removable denture wearers experience.

Another focus of this study was to understand basic characteristics of entropy scores of pain-related outcome parameters in edentulous elderly individuals by comparing with age-matched dentate elderly individuals. A uniform entropy score on the outcome parameters related to sensory response to different mechanical stimuli was found in both edentulous and dentate groups. Entropy analysis has been applied to clarify the diversity of sensory response to mechanical stimuli in experimental models of orofacial pain such as TMD myalgia.[11] Since the edentulous patients who participated in this study were pain-free in the alveolar mucosa, the diversity of PPT probably could not be wide enough to be detected, compared with the pain conditions that showed a significant difference in entropy scores of masticatory muscles in past studies.[11–14]

4.1 | Methodological limitations

This study was the first attempt to elucidate a better understanding on mechanical sensitivity on the alveolar mucosa in edentulous individuals from a novel perspective of entropy. Since perception of pain denture wearers perceive should be well understood to avoid causing soreness of the alveolar mucosa, this study focused on change in mechanical sensitivity in the alveolar mucosa. However, there are many other factors to be considered. One of the possible factors that could affect mechanical sensitivity in the alveolar mucosa is xerostomia. Prevalence of xerostomia is higher in the elderly,[28] and it was found that presence of oral dryness can alter pain pressure threshold on the alveolar mucosa in removable denture wearers.[29] Although none of the participants in this study had the symptom of xerostomia, considering the fact that saliva flow decreases as a natural physiological change,[30] it might be a possible factor that affects difference in PT between EC and YC groups shown in this study. Nevertheless, the findings in this study can provide important information to understand basic characteristics on change in mechanical sensitivity according to teeth loss and ageing, which should be considered when prosthodontic treatment with removable dentures is provided for the elderly edentulous patients.

5 | CONCLUSION

Within the limitation of this study, we demonstrate that both ageing and tooth loss are significant factors in altering tactile and pain perception in the oral mucosa. Moreover, diversity of pain-related parameters is not affected by such factors, which indicates that oral sensory function is fundamental to maintain oral health, and, thus, cannot be disturbed easily. In other words, there is a possibility that sensory function is impaired if an entropy score of pain-related parameters is abnormal. This suggests that it might be beneficial to assess sensory function of the alveolar mucosa in edentulous patients clinically prior to denture fabrication for selecting proper design or materials of dentures.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this study.

AUTHOR CONTRIBUTION

ZL participated in collecting data and approved the final manuscript. AS conceived the study, planned and participated in data collection, and drafted the manuscript. TK and TI carried out the analysis of the data and approved the final manuscript. AK planned the data collection, performed the statistical analysis and approved the final manuscript. KT participated in the design of the study and approved the final manuscript. All authors provided critical feedback and approved the final manuscript.

DATA AVAILABILITY STATEMENT

The data included in the manuscript will be shared by the authors upon reasonable request.

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