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Research Article

Evaluation of Corneal Biomechanical Properties by Corvis ST in Saudi Females with Dry Eye Disorder

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Abstract

Aim: This study compared corneal biomechanics in patients with Dry Eye Disorder (DED) and age-matched control subjects using the Corvis ST. Furthermore, the current study correlated the parameters of DED with alterations in the corneal biomechanical properties.

Methods: Sixty eyes participated in this prospective case-control study. They were divided into 2 groups: Dry eye (n = 40 eyes) and control eye (n = 20 eyes) groups. The age range was 20-39 years. Each subject underwent a comprehensive ophthalmologic examination. In addition, the Non-Invasive Tear Break-Up Time (NIBUT) and Tear Meniscus Height (TMH) were measured using the OCULUS Keratograph non-invasive ocular surface analyzer. All participants completed an Ocular Surface Disease Index (OSDI) questionnaire to evaluate the dry eye symptoms before conducting the study. The corneal biomechanical parameters and central corneal thickness were measured for all eyes using Corvis ST with an automatic release mode.

Results: This study found a significant difference in only one parameter (A1 Length) between the 2 groups. The dry eye group had a significantly higher A1 length (2.31 ± 0.32 mm) compared to the control group (2.10 ± 0.34 mm) (Mann-Whitney U=274.50, P=0.049). However, this study demonstrated no correlation between the parameters of DED (NIBUT, TMH and OSDI) and the corneal biomechanical properties.

Conclusion: This study found that the dry eye group exhibited a significantly higher A1 length compared with the control group, suggesting a potential trend toward altered corneal deformation behavior in dry eye disease. However, this study did not confirm any significant correlation between DED parameters and corneal biomechanics.

Keywords: Dry Eye Disorder; Corneal Biomechanics; Corvis ST

Introduction

The TFOS DEWS II has amended the definition of dry eye to “Dry eye is a multifactorial disease of the ocular surface characterized by a loss of homeostasis of the tear film and accompanied by ocular symptoms, in which tear film instability and hyperosmolarity, ocular surface inflammation and damage and neurosensory abnormalities play etiological roles” [1]. Alsahly, et al., estimated the prevalence of Dry Eye Disorder (DED) in the Saudi Arabian population to be 64.04% [2]. Almujalli, et al., estimated the prevalence of DED in Riyadh to be 46.6% in females [3]. They found that age, LASIK refractive surgery, skin disease surrounding the eye and thyroid eye disease are the most relevant risk factors. The consistent elevation of inflammatory cytokines and chemokines in ocular inflammation associated with DED could lead to stromal changes and weakening of the corneal tissue. Therefore, the impact of DED on corneal biomechanics is expected. Considering the high prevalence of DED, its potential influence on corneal biomechanics needs to be clarified [4].

A few studies investigated the corneal biomechanics in DED. Long, et al., evaluated corneal biomechanical characteristics in dry eye patients and healthy participants using Corvis ST [4]. They demonstrated a significant difference only in the Highest Concavity time (HC-time) between the two groups. A shorter HC time may be due to a more compliant cornea reaching the highest concavity. Satitpitakul, et al., reported a significant correlation between conjunctival staining scores with second applanation velocity, corneal staining scores with second applanation length, Schirmer test with first applanation time and first applanation velocity [5]. Only the two previous studies have investigated the relationship between the DED and the alternation in corneal biomechanics assessed by Corvis ST.

Borrego-Sanz, et al., compared corneal biomechanical properties between patients with dry eyes secondary to Sjögren's syndrome and healthy participants using an Ocular Response Analyzer (ORA) [6]. They found a significant difference in the mean of Corneal Hysteresis (CH) values between Sjögren's syndrome dry and healthy eyes ($P = 0.003$). The mean of CH values in Sjögren's syndrome dry eyes (10.1 mmHg) is significantly less than that of healthy eyes (11.18 mmHg). However, Firat and Doganay detected no significant difference in CH and CRF between dry eyes and control eyes using ORA [7].

Previous studies have evaluated corneal biomechanics in DED using Corvis ST or ORA; however, most have investigated small populations, did not explore the Saudi population or only examined selected corneal biomechanical parameters. The association between DED severity and corneal biomechanics necessitates further investigations for illustration and documentation. In addition, to our knowledge, the current study is the first one to investigate this correlation in Saudi Arabia.

This study compared the corneal biomechanics in DED patients with age-matched control subjects using Corvis ST in Saudi Arabia, a population that has not been previously studied. Furthermore, it correlated the parameters of DED with alterations in the corneal biomechanical properties. This approach allows us to extend and localize previous findings, providing new insights into how DED may affect corneal biomechanics in this demographic.

Methodology

Study Design

This prospective, non-randomized, cross-sectional, case-control, observational and quantitative study adhered to the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board, King Saud University, Riyadh, Saudi Arabia (Research Project No. 22/0114/IRB). After explaining all the study procedures, written informed consent was obtained from all participants.

Subjects and Methods

The study included 60 eyes (only the right eyes) of 60 healthy Saudi females. The study included only the right eyes to avoid inter-eye correlation and ensure statistical independence. The age range was 20-39 years. They were recruited from the female section of the College of Applied Medical Sciences at King Saud University, Riyadh, Saudi Arabia. The study included healthy participants with a best-corrected visual acuity of 20/20 or better and an Intraocular Pressure (IOP) of 21 mmHg or less. The study excluded participants with ocular hypertension, glaucoma, keratoconus, corneal edema, contact lens use, diabetes, systemic autoimmune disease, superficial punctate keratitis, recurrent pterygium, corneal opacity or irregularity and ocular surgery. Each subject underwent a comprehensive ophthalmologic examination, including visual acuity measurement, manifest refraction, biomicroscopic examination, IOP measurement with an air puff tonometer and funduscopy.

DED in this study followed internationally accepted symptom-plus-sign criteria in accordance with TFOS DEWS II recommendations [1]. Symptoms were evaluated using the Ocular Surface Disease Index (OSDI). All participants completed the OSDI questionnaire to evaluate their dry eye symptoms before the study began. Subjects were asked to answer questions about the symptoms of dry eye that they had experienced during a 1-week recall period. The OSDI questions comprise three distinct subscales: ocular symptoms, vision-related functions and environmental irritant considerations. Each response was verified on a 4-point scale that extended from zero (indicating no problems) to four (indicating a significant problem). Answers to all questions were linked to create a combination OSDI score ranging from 0 to 100, with higher OSDI scores representing more severe symptoms and lower vision-related quality of life. Scores ≥ 13 were recognized as a marker of dry eye. Objective signs were assessed using the OCULUS Keratograph non-invasive ocular surface analyzer (OCULUS, Wetzlar, Germany). A Non-Invasive Tear Break-Up Time (NIBUT) <10 seconds was considered indicative of tear film instability. Additionally, tear meniscus height (TMH) was measured using the Keratograph, applying a threshold of < 0.20 mm. These references have been incorporated to justify the selected cut-off values and to ensure alignment with international DED diagnostic frameworks. The eyes were classified into 2 groups:

- Group 1 (the dry eye group) included eyes with <10 seconds NIBUT and/or TMH with a baseline value ≤ 0.20 mm and OSDI scores ≥13
- Group 2 (the control group) included eyes with ≥10 seconds NIBUT and/or TMH with a baseline value > 0.20 mm and OSDI scores <13

The corneal biomechanical parameters and Central Corneal Thickness (CCT) were measured for all eyes using Corvis ST with an automatic release mode. A high-speed Scheimpflug camera recorded the process of corneal deformation by applying an air impulse within 8.5 mm of the corneal apex, which could record 4330 frames per second.

CST measurements were carried out three times and the averages of the CST parameters were calculated. CST measurements were considered reliable based on the “OK” quality index displayed on the CST device monitor [8]. The measurements were done on the same day between 8:00 and 11:00 to eliminate the potential diurnal variability. CST measures the biomechanical response of the cornea at the moment of the first and second applanations (A1/2) time, A1/2 length, A1/2 velocity, peak distance, highest concavity deformation amplitude, highest concavity time and radius [9]. The practitioner performing the measurements was masked to the participants’ dry eye status during data collection to minimize bias. Each eye was measured twice by the same examiner using the Corvis ST and the device’s built-in quality score was used to select the higher-quality image for analysis.

Statistical Analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS v.28). First, descriptive statistics were used to describe the basic features of the data in the study, including frequencies, percentages, mean and standard deviation, presented as mean ± SD. Second. The Shapiro-Wilk test was used to test the normal distribution. Additionally, the independent samples T-test was applied to test the difference between the two groups (control and case). In addition, the Mann-Whitney U test was used to compare the observational parameters of the two groups depending on data normality. Pearson's bivariate correlation analysis was used according to data normality to assess the relationship between corneal biomechanical parameters and the potentially related characteristics, such as age, IOP, CCT and dry eye parameters. Spearman's bivariate correlation analysis was used as a non-parametric measure of rank correlation. P-values <0.05 were considered statistically significant.

Results

Sixty eyes participated in this study. They were divided into 2 groups: the dry eye and control eye groups. The mean age of the dry eye group (n = 40 eyes) (66.6%) was 25.30 ± 6.34 years (20-39 years), while that of the control group (n = 20 eyes) was 22.95 ± 4.35 years (20-34 years). The mean Spherical Equivalent (SE) of the dry eye group was -1.05 ± 2.37 D (-7.25 to 3.75 D) compared to -0.42 ± 2.12 D (-6.25 to 3.25 D) in the control group. There were no significant differences between the ages and SE of the two groups. The mean NIBUT of the dry eye group was 5.62 ± 2.51 sec (1.2-9.5 sec) compared to 17.38 ± 4.81 (11.4-25.8 sec) in the control group. In addition, the mean TMH of the dry eye group was 0.17 ± 0.02 mm (0.13-0.20 mm) compared to 0.23 ± 0.02 mm (0.21-0.27 mm) in the control group. Additionally, the mean OSDI of the dry eye group was 26.20 ± 8.71 (16-45) compared to 7.75 ± 4.77 (0-12) in the control group. This study reported significant differences in the mean NITBUT, TMH and OSDI between the two groups (P < 0.001). Table 1 shows the demographics and clinical data of the dry and control groups. In this study, there were no significant differences in IOP and CCT between the two groups (IOP: P = 0.436; CCT: P = 0.251). This study found a significant difference in only one parameter (A1 length) between the 2 groups. The dry eye group had a significantly higher A1 length (2.31 ± 0.32 mm) compared to the control group (2.10 ± 0.34 mm), (Mann-Whitney U=274.50, P = 0.049). The corneal biomechanical parameters, CCT and IOP values are shown in Table 2. Fig. 1 shows the distribution percentage differences between the dry eye and control groups for A1 length.

The bivariate correlation analysis in the dry eye group showed a highly significant positive moderate correlation between A1 length and CCT (*P* = 0.001). Fig. 2 shows the bivariate correlation analysis between A1 length and CCT in the dry eye group. Also, a significant positive moderate correlation was detected between A1 length and IOP (*P* = 0.011). Fig. 3 shows the bivariate correlation analysis between A1 length and IOP in the dry eye group. However, this study demonstrated no correlation between the parameters of DED (NIBUT, TMH and OSDI) and the corneal biomechanical properties.

Parameters	**Dry eye group (*n* = 40)**		**Control group (*n* = 20)**		**p-value**
	Mean	SD	Mean	SD	
Age (years)	25.30	6.346	22.95	4.359	0.106
SE (D)	-1.0534	2.37174	-0.4250	2.12214	0.289
NIBUT (seconds)	5.626	2.5131	17.385	4.8105	<.001**
TMH (mm)	0.1710	0.02262	0.2310	0.02532	<.001**
OSDI	26.20	8.718	7.75	4.778	<.001**

SE: Spherical Equivalent; NIBUT: Non-Invasive Tear Break Up Time; TMH: Tear Meniscus Height; OSDI: Ocular Surface Disease Index; P <0.05 and P <0.01 were considered statistically significant (*) and highly significant at (**), respectively.

Table 1: Demographics and clinical data of the dry eye and control groups.

Parameters	**Dry eye group (*n* = 40)**	**Control group (*n* = 20)**	***t*/*U* value**	**P value**
A1-time (ms)	6.9690±.38591	6.9620±.33908	-0.069[a]	0.945
A2-time (ms)	21.5762±.40076	21.5330±.97846	326.50[b]	0.249
A1-length (mm)	2.3110±.32958	2.1065±.34885	274.50[b]	**0.049***
A2-length (mm)	2.0088±.30938	1.9520±.32160	359.50[b]	0.525
A1-V (m/s)	0.1283±.01500	0.1310±.01997	372.50[b]	0.661
A2-V (m/s)	-0.2525±.02250	-0.2570±.03840	397.00[b]	0.962
HC-time (ms)	16.8768±.43271	17.0810±.41483	308.50[b]	0.145
PD (mm)	4.8542±.45187	4.9525±.26721	375.50[b]	0.701
HC radius (mm)	7.9675±.73419	8.1620±.79247	0.942[a]	0.350
DA (mm)	1.0570±.08265	1.0585±.08719	0.065[a]	0.948
IOP (mmHg)	16.90±2.113	16.52±2.099	350.50[b]	0.436
CCT (μm)	560.23±31.480	549.60±37.265	-1.159[a]	0.251

A1-v: A1-velocity; A2-v: A2-velocity; HC-time: highest concavity-time; PD: peak distance; HC radius: radius at highest concavity; DA: deformation amplitude; IOP: intraocular pressure; CCT: central corneal thickness; a: *t*-test value; b: Mann-Whitney *U* test value. *: Significant at level 0.05.

Table 2: Comparison of the mean values of the corneal biomechanical parameters, CCT and IOP between the dry eye and control groups (mean ± SD).

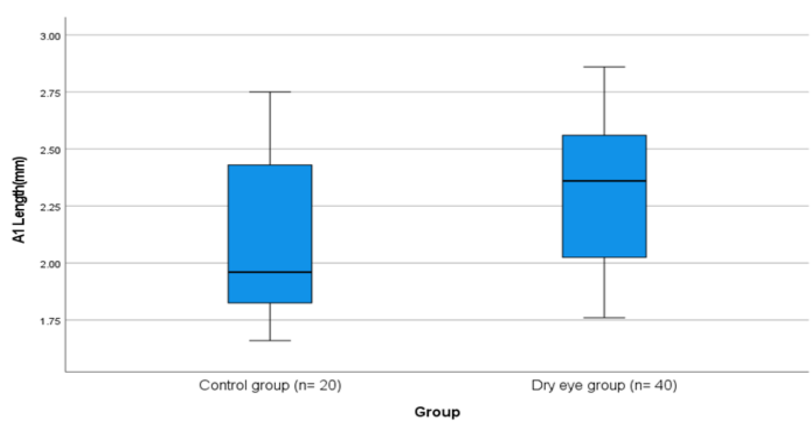

Figure 1: The box plot shows the distribution percentage difference between the dry eye and control groups for A1 length (mm).

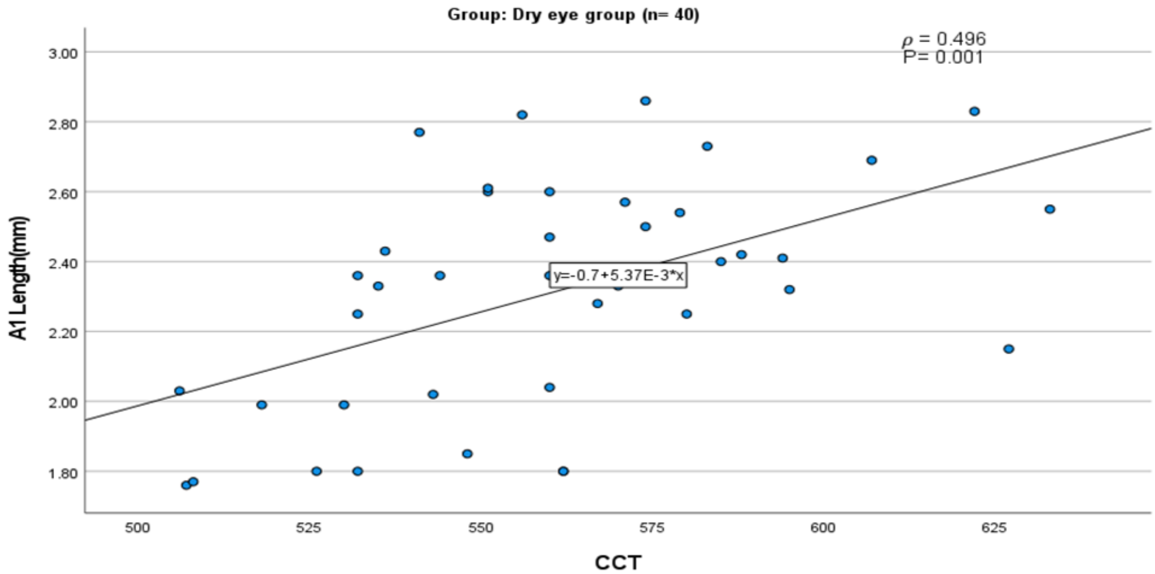

Figure 2: The scatter diagrams of the bivariate correlation analysis between A1 length (mm) and CCT (μm) in the dry eye group.

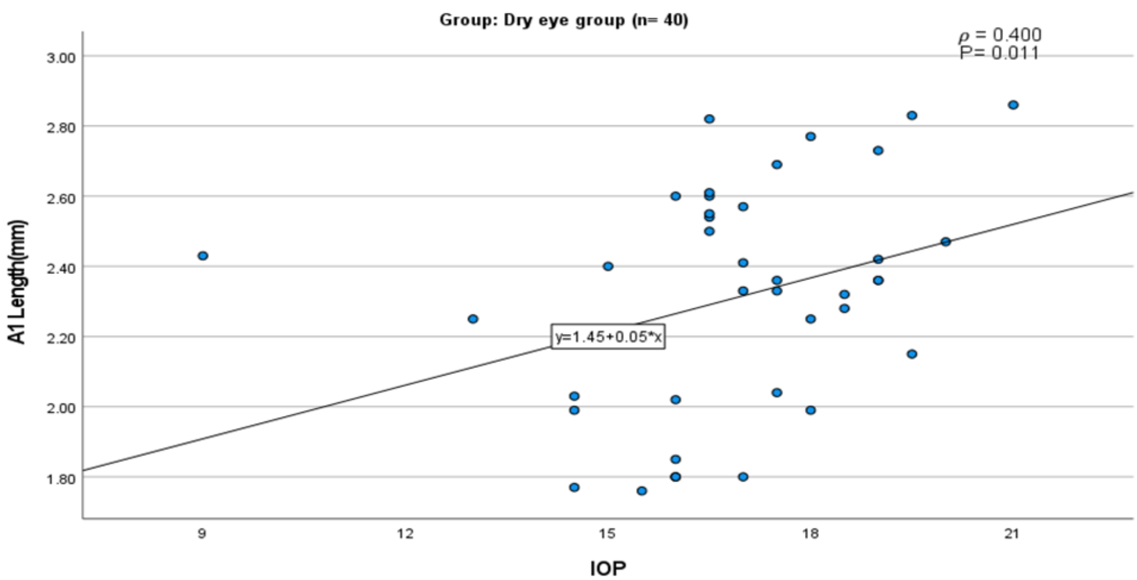

Figure 3: The scatter diagrams of the bivariate correlation analysis between A1-length (mm) and IOP (mmHg) in the dry eye group.

Discussion

This study evaluated the corneal biomechanical parameters in 40 eyes of dry eye patients compared to 20 eyes of the control group using Corvis ST. The mean age of the dry eye group was 25.30 ± 6.346 years (20-39 years). There was a statistical difference only in A1 length between the 2 groups. A1 length means the length of the flattened cornea at the first applanation. The dry eye group had significantly higher A1 length (2.31 ± 0.32 mm) than the control group (2.10 ± 0.34 mm). Long, et al., compared the corneal biomechanical parameters between 28 eyes of 28 patients with dry eye (dry eye group) and 26 normal subjects (control group) using Corvis ST [4]. They found that only the Highest Concavity time (HC-time) is significantly lower in the dry eye group than in the control group (P = 0.02). HC-time denotes the time from the start until the highest concavity is reached and reflects the time to maximum deformation. A more yielding cornea needs a shorter HC time to induce maximum concavity. The authors confirmed that the stroma controls the corneal biomechanical behavior; consequently, greater changes would be anticipated in severely dry eyes that show greater corneal stromal lesions.

On the other hand, Satitpitakul, et al., found no difference in corneal biomechanical parameters between participants with low and normal tear production (P > 0.05) using Corvis ST [5]. They examined 81 participants from the Comprehensive Geriatric Clinic, King Chulalongkorn Memorial Hospital, Bangkok, Thailand. Their mean age was 66 ± 3.4 years (60-77 years). They evaluated DED using the Schirmer test, OSDI questionnaire, Tear Film Break-Up Time (TBUT) and conjunctival and corneal staining.

Borrego-Sanz, et al., compared corneal biomechanical properties between 31 patients with dry eye secondary to Sjögren's syndrome and 44 healthy participants using ORA [4]. They found a significant difference in the mean of CH values between Sjögren's syndrome dry and healthy eyes (P = 0.003). The mean of CH values in Sjögren's syndrome dry eyes (10.1 mmHg) is significantly less than that of healthy eyes (11.18 mmHg). However, Firat and Doganay detected no significant difference in CH and CRF between dry eyes and control eyes using ORA [7]. They evaluated 70 eyes of 40 patients with dry eye (group 1) and 75 eyes of 40 normal subjects (group 2). The research used the clinical symptoms, biomicroscopical evaluation and Schirmer test to diagnose dry eye.

The current study demonstrated no correlation between the parameters of DED (NIBUT, TMH and OSDI) and the corneal biomechanical properties. This finding mismatched Satitpitakul, et al., study, which reported a significant association between eight corneal biomechanical parameters and symptoms or signs of DED [5]. They found a negative association between OSDI and the Highest Concavity radius (HC-radius) (P = 0.02). Also, they detected significant positive associations between the Schirmer test and first applanation time (A1-time) (P = 0.04) and corneal staining scores with second applanation length (A2 length) (P = 0.01). In addition, they reported significant negative associations between conjunctival staining scores with second applanation velocity (A2-velocity) (P = 0.04) and between the Schirmer test with first applanation velocity (A1-velocity) (P = 0.01). Moreover, participants with low tear production in their research showed a significant positive association between OSDI scores and Highest Concavity Peak Distance (HC-DA) (P = 0.04). Furthermore, conjunctival staining scores showed significant negative associations with second applanation length (A2 length) (P = 0.01) and second applanation velocity (A2 velocity) (P < 0.01), significant positive association with Highest concavity deformation amplitude (HC-PD) (P = 0.04). On the other hand, in the participants with normal tear production in their study, they reported that Schirmer test had a significant positive association with A1time (P = 0.02) and a significant negative association with HC-DA (P = 0.03). Also, they found a positive association between corneal staining scores and A2 length (P < 0.01). The authors concluded that there was a significant association between the increased severity of DED and less corneal stiffness in both low and normal tear production groups. Also, Long, et al., detected a fragile but significant negative association between HC-time and corneal staining score in the dry eye group [4]. The authors concluded that the ocular surface damage in dry eyes can lead to a more obedient cornea. Our study showed no significant difference in CCT and IOPcc values between the 2 groups. This finding matched Firat and Doganay [7]. This study had some limitations. First, the relatively small sample size due to a technical problem in Corvis ST forced us to stop the data collection. Second, all enrolled subjects were Saudi females; therefore, the results might not be totally applicable to males in Saudi Arabia and in other countries.

Conclusion

The current study is the first to investigate this correlation in Saudi Arabia. This study found that the dry eye group exhibited a significantly higher A1 length compared with the control group, suggesting a potential trend toward altered corneal deformation behavior in dry eye disease. However, this study did not confirm any significant correlation between DED parameters and corneal biomechanics. Evaluation of the association between DED and the alterations of corneal biomechanical properties will help to understand and verify the effect of the severity of DED on corneal biomechanics, as this might be helpful in clinical practice, especially for planning ophthalmological interventions, such as refractive surgery. Further studies using large sample sizes and further investigations, such as the TearLab Osmometer and epithelial mapping, are recommended to verify the impact of DED on corneal biomechanics.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Acknowledgement
The authors have no acknowledgments to declare.

Data Availability Statement
The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethical Statement
The project did not meet the definition of human subject research under the purview of the IRB according to federal regulations and therefore was exempt.

Informed Consent Statement
Informed consent was obtained from all participants included in the study.

Authors' Contributions
All authors contributed equally to this paper.

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