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# Effects of cataract surgery on blinking.

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## ABSTRACT

**Purpose:** To assess the effects on the spontaneous blinking pattern and blinking kinematics of cataract surgery.

**Setting:** FISABIO Oftalmología Médica (FOM) eye hospital, Valencia, Spain.

**Design:** Observational, descriptive, clinical study.

**Methods:** Patients with senile cataract were evaluated before (visit 1), and 1 month (visit 2) and 3 months (visit 3) after undergoing phacoemulsification cataract surgery. The blinking of patients was recorded for 90 seconds using an eye-tracking device. Blinks were analyzed by means of image analysis to obtain a non-invasive detailed description of blinking including blink rate, number of complete and incomplete blinks, percentage of incomplete blinks and kinematic parameters, including amplitude, closing, contact, opening and total durations and closing and opening speeds.

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**Results:** A total of 50 patients were included in this study. The blink rate was significantly smaller at visit 3 compared to baseline ($P$ = .03) and visit 2 ($P$ = .001). Likewise, the number of complete blinks was significantly smaller, and the percentage of incomplete blinks significantly higher 3 months postoperatively compared to baseline ($P$ = .02 and $P$ = .01, respectively), while no differences were observed 1 month after surgery ($P$ > .05). Conversely, no differences in the number of incomplete blinks or any kinematic parameter were observed between visits ($P$ = .12).

**Conclusions:** Cataract surgery significantly altered the blinking pattern 3 months postoperatively, although kinematic parameters remained unvaried. Clinicians should be aware of potential alterations in blinking after phacoemulsification cataract surgery and the implications this may have on the ocular surface of patients.

## INTRODUCTION

Cataract is the leading cause of blindness in the world and can only be resolved by surgery at present.[1] Cataract surgery is one of the most frequently performed medical interventions in industrialized nations.[2] Conventional phacoemulsification and intraocular lens (IOL) implantation are the most common cataract surgery procedures performed, with over 20 million interventions executed each year globally.[3]

Phacoemulsification is a mechanically assisted extracapsular technique of cataract extraction in which a corneal incision at the temporal site is made to allow the introduction of an ultrasound probe to emulsify the cataractous lens and replace it with an IOL.[4] Intrinsic factors of the procedure such as the toxic effects of preservatives used during and after the surgery, repeated intra-operative ocular surface drying or phototoxicity effects of the operating microscope light might damage the ocular surface to different extents.[5] Most importantly, full-thickness incisional wounds performed

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during cataract surgery can disrupt radial stromal nerves at the corneal periphery, resulting in a loss of corneal sensitivity which may additionally affect the tear production reflex (a.k.a. lacrimal functional reflex) and further disrupt the tear film.[6,7] One of the main factors responsible for normal spontaneous blinks is the imminent break-up of the tear film which is sensed by the cornea.[8] Consequently, alterations in the sensitivity of the cornea and the ocular surface can significantly impact the blinking pattern of patients.

Blinks occur as a result of a complex and coordinated interaction of different skeletal muscles acting antagonistically (the levator palpebrae superioris and the orbicularis oculi) throughout the process of blinking, with each stage depending on different muscle actions and interactions.[9] Blinking is essential for maintaining ocular surface integrity, tear film stability and clarity of vision, while it keeps the eye surface humid and hydrated, favors the drainage of tears, helps in the expression of lipids from the meibomian glands and spreads tear lipids through the precorneal film.[10-13] Therefore, while blinking is highly influenced by the status of the ocular surface, it is also essential to maintain its homeostasis.

Nevertheless, despite the relevance and direct relationship with the ocular surface, no study to date has assessed the effects of cataract surgery on blinking. Recently, high-speed video cameras, implemented with image processing algorithms, have been used to precisely and non-invasively gather and analyze blink kinematic parameters in natural viewing conditions, allowing a full and in-deep description of the blinking process.[14,15]

Accordingly, the present study aimed, for the first time, to assess the effects of cataract surgery on the spontaneous blinking pattern and blinking kinematics of patients

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using for the purpose a newly developed technique for the non-invasive characterization of blinking.

## METHODS

### *Patients*

The present study followed the tenets of the Declaration of Helsinki and and the approval from the ethical committee of FISABIO eye hospital was obtained. All the patients received verbal and written explanations about the nature of the study and signed the informed consent.

An observational descriptive clinical study was conducted at the FISABIO Oftalmología Médica (FOM) eye hospital (Valencia, Spain), from April to November 2021. Fifty eyes of 50 patients meeting the inclusion and exclusion criteria and ranging in age from 61 to 87 years (72 ± 8) were evaluated before and after undergoing cataract surgery. Patients attending the eye hospital for cataract surgery were invited to participate in the study. All consenting patients with senile (age-related) cataract admitted for surgery were potentially eligible. After an initial anamnesis, including questions about eye discomfort and dry eye-related symptomatology, patients underwent a complete eye examination, including, but not limited to, comprehensive slit-lamp biomicroscopy and ocular surface staining and fundoscopic and binocular examination. Exclusion criteria were ocular history of injury or eye surgery in the last 6 months, anterior segment pathology, including dry eye disease (DED), current use of topical medication or daily use of artificial tears and eyelid abnormalities. Likewise, patients were not recruited into the study if they needed combined surgical procedures, if their age was < 50 or > 90 years or had any known neurologic disorder or took any temporary medication that could affect blinking.

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### *Measurements and procedure*

The spontaneous blinking of patients was assessed before (visit 1 – baseline) and 1 month (30 days) (visit 2) and 3 months (90 days) (visit 3) after undergoing cataract surgery. Patients were recruited in their visit before the surgery. During the invitation to participate patients were only informed that non-invasive measurements of their eyes would be taken before and after surgery. In case interest in participating was expressed, the nature of the study was fully explained and one of the authors checked whether or not each volunteer met the inclusion/exclusion criteria before initiating the experiment. For the measurements, patients were instructed to look at a Maltese cross, arranged at eye level and displayed on a liquid crystal display (LCD) screen at 50 cm in front of them, for 120 seconds (sec), until the examiner told them to stop.

The eye movements of patients were recorded during the last 90 s (allowing a 30 s stabilization) using an infrared video-based eye tracker (Cambridge Research Systems Ltd) working at a sample rate of 250 frames per sec (fps). Patients were not actively told that their blink movements were being recorded to prevent them from blinking consciously. A 90-sec recording was chosen based on previous research of similar nature and as a compromise between sampling time and volume of information.[14] The High-Speed Visual Eye-Tracker (HSVET) consists of a high-speed infrared camera, with a resolution of 320 per 240 pixels, a visible/infrared dichroic beamsplitter and a chin rest. Due to the configuration of the device, the image of the eye is reflected on the infrared mirror without interfering with the observer's line of sight, simulating natural viewing conditions.[14] Patients carried out the tasks with their heads resting on the HSVET chin rest. The height of the chin rest, as well as that of the chair, was carefully adjusted to the height and natural position of the patients to ensure their comfort.

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Recordings were performed on the right eye in all patients. Each measurement generated a sequence of 22500 images of the right eye of the patients that was stored onto an external hard drive and subsequently studied by means of image analysis, to obtain a non-invasive detailed description of the eye blink movement. The image processing-based method used for the automatic analysis of blinking has been previously described in the literature.[14] Blinks were assessed in terms of the spontaneous blink rate (i.e., total number of blinks in one minute), number of complete and incomplete blinks, percentage of incomplete blinks, blink amplitude, opening and closing blink speeds and opening, closing, contact and total blink durations. A complete blink was defined as that in which the position of the superior eyelid reached the median height level of the inferior eyelid.[14]

***Experimental conditions***

All measurements were taken in the same laboratory, in the mornings, from 9 to 11 am, under the same, constant environmental conditions (temperature and humidity). Patients were asked not to use eye drops – including artificial tear substitutes – and not to drink any beverage containing caffeine 1 and 24 hours before the measurements, respectively.[16] Fifteen minutes previous to the visit of the patients, the laboratory was acclimatized, and the experimental conditions were set up. To minimize the effects of outdoor conditions on the way to the laboratory, a 10-minute acclimatization period was left between the entry of the patients into the room and the measurements. The whole experiment was carried out under constant artificial illumination. Room illuminance was maintained at approximately 220 ± 7 lux on the plane of the eyes of the patients and was provided by indirect lighting to avoid any glare sources. Chroma Meter CL-200 lux meter (Konica Minolta, Ramsey, NJ) was used to measure photometric values. Room

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temperature and humidity were monitored and remained stable at 23.8 ± 1.6 °C and 44.3 ± 4.5 %, respectively.

***Cataract surgery***

Before surgery, all patients underwent examination of blood pressure, intraocular pressure, urine sugar, keratometry and optical biometry or ultrasound A-scan. Phenylephrine and tropicamide eye drops were used for dilating the pupil. Surgery was performed under topical or peribulbar injection anesthesia, based on patient cooperation. All cataract surgeries were performed by the same experienced surgeon, who used a standardized phacoemulsification technique with manual capsulorhexis and IOL implantation. A 2.2 mm temporal clear corneal incision was made for phacoemulsification. The phacoemulsification time was 1 to 2 minutes. A monofocal intraocular lens for distance correction was inserted in the capsular bag in all cases. No intraoperative complication happened. Patients instilled 0.3 % ofloxacin ophthalmic solution (Exocin® 3 mg/ml, Allergan, Irvine, CA, USA) eye drops 4 times daily for 1 week, and 1 % prednisolone acetate (Pred Forte®, Allergan, Irvine, CA, USA) eye drops 4 times daily for 1 month postoperatively.

***Statistical analysis***

The results were evaluated using SPSS software v.26 (IBM Corp., Armonk, NY). The normality of data was assessed using the Kolmogorov–Smirnov test. When normality could be assumed, a repeated-measures ANOVA was used to examine the statistical significance of the blink variables for the 3 visits. The Mauchly test was used to evaluate the assumption of sphericity. If sphericity could not be assumed, the Greenhouse-Geisser correction was applied. Whenever the repeated-measures ANOVA pointed to a statistical significance, post-hoc pairwise comparisons were carried out using Bonferroni correction. The non-parametric Friedman test for repeated measures

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with Dunn-Bonferroni post-hoc analysis was used when parametric test assumptions were not fulfilled.

Finally, two-way mixed ANOVA were used to examine the interaction between sex and the changes on blinking with cataract surgery. Blinking parameters were selected as dependent variables and sex (Female / Male) and visits (visits 1, 2 and 3) as between-subjects and within-subjects variables, respectively. The normality of data was assessed using the Shapiro-Wilk test. The Levene test was used to evaluate the assumption of homogeneity of variance while the Mauchly test was used to evaluate the assumption of sphericity. P-values of $< .05$ were considered statistically significant.

Sample size was calculated based on the results of the first 10 patients using the G-power tool.[17] The significance level was 5 %, with an allowance of 0.05 alpha error and a study power of 80 %. The estimated sample size was that of 46 patients. Fifty individuals were finally included for analysis. The statistical power was calculated post-hoc, being this superior to 0.8 (effect size = 0.5).

## RESULTS

Sixty-seven Caucasian patients were initially recruited out of which 50 (22 men and 28 women) ranging in age from 61 to 87 years ($72 \pm 8$) met the inclusion/exclusion criteria and completed all study visits. Table 1 presents the intra-average values of the blinking kinematic variables assessed in the present study before undergoing cataract surgery (visit 1 – baseline) and 1 month (visit 2) and 3 months (visit 3) after the intervention. The table also displays the statistical results of the comparison.

Figure 1 shows boxplots of the blink rate (a), number of complete blinks (b), number of incomplete blinks (c) and percentage of incomplete blinks (d) obtained before and after the surgical intervention. Statistically significant differences between

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visits were observed in the blink rate ($P$ = .004), number of complete blinks ($P$ = .04) and percentage of incomplete blinks ($P$ = .02). Post-hoc comparisons revealed a significantly lower blink rate at visit 3 compared to visits 1 and 2 ($P$ = .03 and $P$ = .001, respectively), along with a significantly lower number of complete blinks ($P$ = .02) and a higher percentage of incomplete blinks ($P$ = .01) at visit 3 compared to baseline. Conversely, no difference in the number of incomplete blinks was observed between visits ($P$ = .12).

Figure 2 shows boxplots of the duration of each of the phases of blinking for the 3 study visits. No differences were observed in the duration of any of the blink phases between visits ($P \geq .18$). Finally, Figure 3 displays the boxplots of the blinking amplitude (a) and the blinking closing (b) and opening (c) speeds. No differences either were observed in any kinematic variable between visits ($P \geq .37$).

Finally, the two-way mixed ANOVA did not reveal an influence of sex on the effects of cataract surgery on blinking parameters (blink rate, $P$ = .65; number of complete blinks, $P$ = .39; number of incomplete blinks, $P$ = .35; percentage of incomplete blinks, $P$ = .46; amplitude, $P$ = .88; closing duration, $P$ = .19; contact duration, $P$ = .25; opening duration, $P$ = .17; total duration, $P$ = .37; closing speed, $P$ = .24; opening speed, $P$ = .08).

## DISCUSSION

Damage to corneal nerves in cataract surgery is well documented.[6,7,18] The incisional wounds in cataract surgery can disrupt radial stromal nerves, mainly at the corneal periphery,[7] ultimately resulting in depleted sensitivity not only at the site of incision but also in areas far from the incision site,[7] which may take several months to return to normal, even with modern micro-incisional techniques.[6,18] There is strong

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evidence for significant interactions between corneal sensitivity and blink frequency.[8] Impaired corneal innervation can inhibit the protective blink reflex,[19] which may explain the decrease in the blink rate exhibited in the present study 3 months postoperatively. Taking the above into consideration, cataract surgery likely induced a low-blink complication attributable to a decrease in corneal sensitivity secondary to corneal denervation. This is especially relevant as it puts the cornea at an increased risk of desiccation due to diminished trophic support provided by corneal nerves.[19]

According to previous investigations on phacoemulsification cataract surgery, reduced corneal sensitivity may persist for more than 3 months after the intervention.[6,18] Kim et al.[18] observed a progressive recovery of corneal sensitivity to almost preoperative levels in the months following phacoemulsification cataract surgery using the Cochet-Bonnet testing method, however, subbasal nerve density did not completely recover to the preoperative level by 3 months. The authors suggested that, considering the limitations of the Cochet-Bonnet testing method and its potential lack of sensitivity to detect complete neural recovery, 3 months of care would not be enough for recovery of corneal sensation. Khanal et al.[6] found that central corneal sensitivity did not return to normal levels within 3 months of the surgery using a non-contact air jet corneal aesthesiometer and speculated that blink rate would be reduced as a result. Given the strong association between corneal sensitivity and blinking previously elucidated, the reduced blink rate observed in the present study 3 months after phacoemulsification cataract surgery may return to normal levels in the following months, once sensitivity is fully restored and neural recovery of the cornea has occurred.

In parallel, cataract surgery has been acknowledged as a consistent risk factor for DED,[5] with a clear association between the intervention and both the development of iatrogenic DED and exacerbation of preexisting DED.[20-22] Numerous intra and

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postoperative factors in phacoemulsification cataract surgery, such as repeated intra-operative ocular surface drying, phototoxicity effects of the operating microscope light or the toxic effects of eye drop preservatives during the postoperative period can disturb the tear film milieu in the short-term.[5] Also, direct surgical trauma due to incisional damage is likely to cause ocular surface inflammation and oxidative stress and upset tear film homeostasis.[23] The surgical trauma inherent in cataract surgery is associated with the production of inflammatory cytokines, oxygen-free radicals and prostaglandins, among others, leading to inflammation and contributing to tear film instability in the early postoperative period.[23-25] In addition, since corneal sensation is partially responsible for tear secretion, an impairment in corneal sensitivity associated with incisional nerve injury may prolong ocular surface dryness as long as the sensory loss is compromised.[5,] Significant tear film and ocular surface abnormalities have been observed in the weeks following surgery, returning to baseline levels approximately 1 – 3 months postoperatively.[20,21,26-28]

Ocular surface conditions represent an important trigger for the initiation of a blink.[29,30] Itokawa et al.[30] found that the frequency of blinks in patients after cataract surgery was associated with tear stability and that it increased when the tear film became unstable. Accordingly, the short-term induced dryness and tear film abnormalities associated with cataract surgery may have stimulated the ocular surface and subsequently motivated reflex blinking, preventing a reduction in the blink rate due to a loss in corneal sensitivity during the first weeks after surgery. This may explain why no differences in the blink rate were observed 1 month after the intervention compared to baseline, despite a reduction 3 months postoperatively. Nevertheless, specific research on the matter is needed to drive conclusions.

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Furthermore, cataract surgery changed the proportion of complete/incomplete blinks in comparison to before surgery, by reducing the number of complete blinks and increasing the percentage of incomplete blinks. Partial blinking is one of the main characteristics of spontaneous blinking in DED patients. Therefore, the changes in complete/incomplete blinking exhibited in the present study after surgery could be compatible with ocular surface dryness secondary to the surgical procedure. Likewise, the loss of corneal sensitivity associated with denervation is suspected to contribute to the development of reduced blink completeness,[31] although Collins et al.[8] observed no change in the relative proportion of complete/incomplete blink types following anaesthetic administration.

Partial blinking alters the distribution of mucin over the ocular surface, causes poor maintenance of lipid layer integrity and reduces tear film thickness in the inferior cornea, which is, therefore, more prone to tear evaporation and break-up problems.[32] Additionally, blinking abnormalities affect the drainage of tears, leading to low tear clearance from the ocular surface, and the accumulation of inflammatory mediators in the conjunctival sac.[33] Consequently, the increased proportion of incomplete blinks 3 months after cataract surgery added to a decreased blink rate may pose a threat to the ocular surface after the first months postoperatively. Additionally, abnormal blinking may alter meibomian gland secretion, leading to chronic changes in the gland.[34] Cataract surgery has been associated with alterations in the function of the meibomian glands,[35] which may be explained by the findings of the present study.

Despite the changes in the number and relative proportion of blink types found in the present study after cataract surgery, no differences were observed in blinking kinematics between visits. Marqués-Fernández et al.[36] detected a mild and transient ptosis of the upper eyelid in the early postoperative period after phacoemulsification

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cataract surgery. In the present study, despite a decrease in the number of complete blinks after surgery, blink amplitude remained unvaried, though contact duration slightly reduced 3 months after the intervention. Judging from these results, blinks may still travel a similar distance after cataract surgery, although both eyelids may ultimately fail to make contact, leading to incomplete blinks. Nevertheless, further studies of similar nature are needed to confirm these findings.

The present study had some limitations to consider. The results had limitations attributable to the image processing technique used, which have already been described in detail elsewhere.[14] Although patients were not actively told that their blink movements were being recorded, some patients may have been more aware of their blinking when being under examination conditions. Likewise, patients with greater ocular discomfort might have been more inclined to participate, which could have introduced selection bias in our data. Nevertheless, patients with any eye disease were excluded as per exclusion criteria and references to the nature of the study were avoided during the invitation to participate. Tear film and corneal sensitivity measurements were not taken, which might have helped explain some findings. Nevertheless, the present study aimed to assess and report potential changes in blinking as a result of phacoemulsification cataract surgery and establishes the basis for future works. Furthermore, a control group was not included. This choice was made to prevent a considerable increase in statistical noise due to the high variability of ocular surface parameters, especially in older individuals, which would have led to an increased probability of type II errors. Also, including a control group would have generated an unmanageable volume of data, limited by the image processing method. Finally, due to the lack of studies that have assessed blinking after cataract surgery, results could not be contrasted with the literature.

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In conclusion, phacoemulsification cataract surgery led to significant changes in blinking 3 months postoperatively, although no differences were observed 1 month after the intervention. Blink rate decreased, associated with a decrease in the number of complete blinks, and the percentage of incomplete blinks increased, consequently growing the risk for tear film abnormalities and ocular surface desiccation after cataract surgery. Conversely, blinking kinematics did not significantly change because of the surgery. We should be aware of potential alterations in blinking after phacoemulsification cataract surgery and consider solutions to counteract the impact on the ocular surface of patients. Further studies are needed to confirm these findings in larger samples. Likewise, studies assessing blinking for longer periods are needed to evaluate whether changes are maintained after 3 months of the intervention.

## VALUE STATEMENT

### What was known

- Phacoemulsification cataract surgery results in a loss of corneal sensitivity due to incisional wounds performed during the intervention. Also, intra and postoperative factors in phacoemulsification cataract surgery can disturb the tear film milieu in the short-term.
- Blinking is highly influenced by corneal sensitivity and the status of the ocular surface.
- Changes in upper eyelid position have been observed in the early postoperative period. Nevertheless, the effects of cataract surgery on blinking remain unstudied.

### What this paper adds

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- Phacoemulsification cataract surgery significantly altered the blinking pattern of patients three months postoperatively, despite no changes one month after the intervention.
- The blink rate and the number of complete blinks decreased, while the percentage of incomplete blinks increased after surgery.
- No change in blinking kinematics was observed during the study period.

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**FIGURE LEGENDS**

**Figure 1.** Boxplots of (A) blink rate, (B) number of complete blinks, (C) number of incomplete blinks and (D) percentage of incomplete blinks obtained before (visit 1), and 1 month (visit 2) and 3 months (visit 3) after phacoemulsification cataract surgery. * Indicates statistical significance.

**Figure 2.** Boxplots of the duration of each of the phases of blinking obtained before (visit 1), and 1 month (visit 2) and 3 months (visit 3) after phacoemulsification cataract

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surgery. (A) closing duration, (B) contact duration, (C) opening duration and (D) total duration. * Indicates statistical significance.

**Figure 3.** Boxplots of (A) the blinking amplitude and (B) the closing and (C) opening speeds obtained before (visit 1), and 1 month (visit 2) and 3 months (visit 3) after phacoemulsification cataract surgery. * Indicates statistical significance.

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**Table 1:** Intra-average values of the blinking kinematic variables obtained before (visit 1) and 1 month (visit 2) and 3 months (visit 3) after cataract surgery and statistical results of the comparison. Data are presented as mean ± SD or median (IQR).

| Variable | Visit 1 (pre-operative) | Visit 2 (1-month post-operative) | Visit 3 (3-months post-operative) | *P*-value | Statistically significant post-hoc differences (*P*-value) |
|---|---|---|---|---|---|
| **Blink Rate [*Total Number of Blinks*] (blinks/min)** | 20 [*30*] (13 – 29) | 23 [*34*] (11 – 38) | 15 [*23*] (7 – 25) | $P = .004^{‡}$ | Visit 1 – Visit 3 ($P = .03$)<br>Visit 2 – Visit 3 ($P = .001$) |
| **Number of Complete Blinks** | 10 (2 – 24) | 7 (1 – 14) | 5 (1 – 13) | $P = .04^{‡}$ | Visit 1 – Visit 3 ($P = .02$) |
| **Number of Incomplete Blinks** | 13 (6 – 20) | 15 (8 – 37) | 13 (6 – 28) | $P = .12^{‡}$ | — |
| **Percentage of Incomplete Blinks (%)** | 61 (15 – 94) | 71 (44 – 96) | 78 (42 – 94) | $P = .02^{‡}$ | Visit 1 – Visit 3 ($P = .01$) |
| **Amplitude (mm)** | 4.9 ± 1.7 | 4.8 ± 1.7 | 4.8 ± 1.5 | $P = .87^{†}$ | — |
| **Closing Duration (ms)** | 42.6 (31.5 – 49.1) | 38.0 (29.9 – 45.8) | 42.1 (33.2 – 50.8) | $P = .18^{‡}$ | — |
| **Contact Duration (ms)** | 74.6 (48.7 – 96.9) | 68.7 (54.0 – 92.3) | 60.7 (47.6 – 90.9) | $P = .90^{‡}$ | — |
| **Opening Duration (ms)** | 143.0 (86.5 – 185.7) | 123.1 (77.99 – 180.4) | 155.2 (96.5 – 210.5) | $P = .66^{‡}$ | — |
| **Total Duration (ms)** | 275.0 ± 104.9 | 251.7 ± 100.4 | 277.9 ± 107.7 | $P = .30^{†}$ | — |

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| | | | | | |
|---|---|---|---|---|---|
| **Closing Speed (mm/s)** | 128.9 ± 47.5 | 132.7 ± 44.0 | 121.8 ± 36.1 | *P* = .37† | — |
| **Opening Speed (mm/s)** | 41.2 (27.5 – 65.0) | 51.4 (31.3 – 61.0) | 38.8 (29.3 – 55.3) | *P* = .61‡ | — |

mm = millimetres; ms = milliseconds. Asterisks denote statistically significant values (*P* < .05). † Repeated-measures ANOVA. ‡ Friedman.

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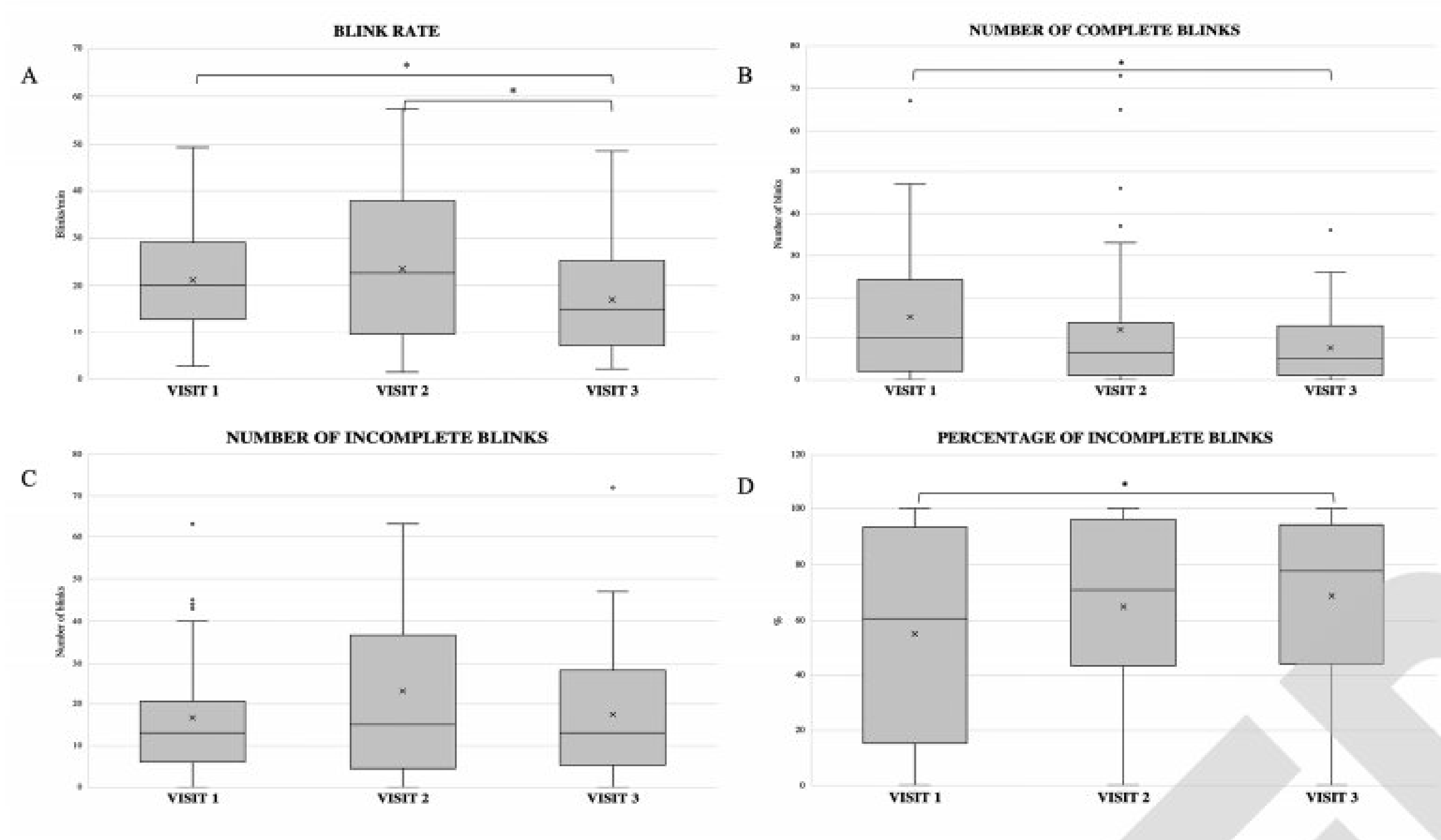


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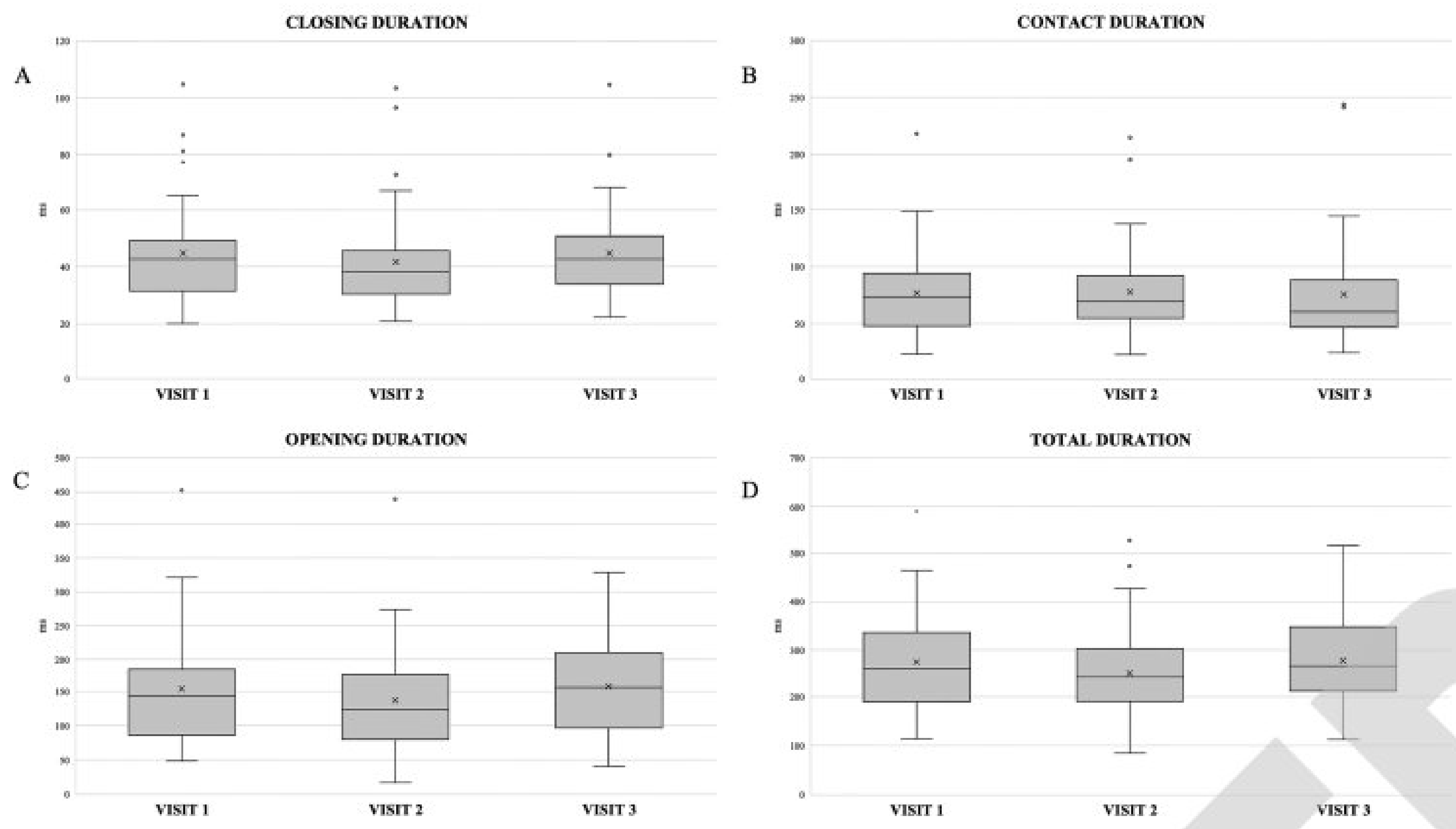


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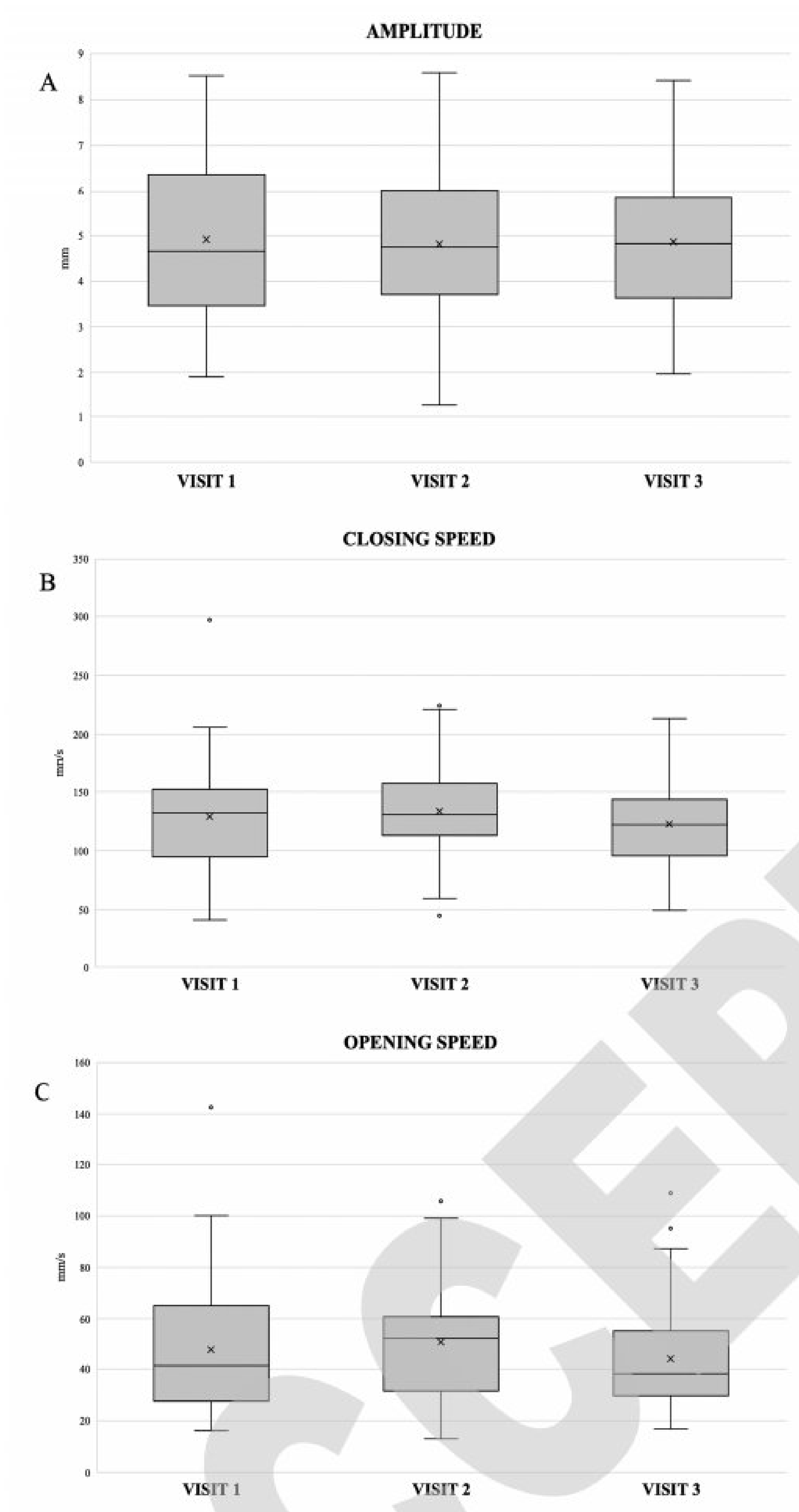


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