



**Influence of Extended Soft Contact Lens Wear
on the Comparative Measurement of
Central Corneal Thickness
(Reprint)**

By

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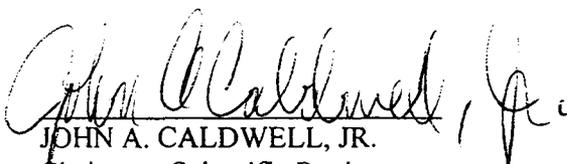
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Influence of extended soft contact lens wear on the comparative measurement of central corneal thickness

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ABSTRACT. The clinical performance of a portable ultrasound pachometer was compared with a digital, 'optical' pachometer attachment of a contact specular microscope. The two separate methods were used to assess central corneal thickness (CCT) in 214 extended-wear soft contact lens subjects over a cumulative 33 month period. The two test methods did not correlate well ($r = 0.56$). Mean ultrasound CCT was $0.542 \text{ mm} \pm 0.004 \text{ SEM}$; mean CSM 'optical' attachment CCT was $0.562 \text{ mm} \pm 0.004 \text{ SEM}$ (significantly different by t-test; $p < 0.05$). A two-way anova (each CCT method by immediate duration of extended lens wear, and by duration in study) revealed an apparent underestimation of central corneal thickness by the ultrasound pachometer. While this presumed ultrasound bias or error can be explained by concurrent morphological and physiological changes associated with long-term contact lens wear, other methodological errors could have influenced the results. Pending additional study, physiologically stressed corneas might be better evaluated by some method of corneal thickness measurement other than ultrasound.

Key words: central corneal thickness - ultrasound pachometer - digital pachometer - contact lenses.

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The clinical model commonly used to gauge compromised corneal function is corneal edema or swelling. Due to the extreme hydrophilic nature of the corneal stroma, edema infers a generalized increase in the hydration level of the tissue. Original clinical estimates of edema were based upon gross morphological observation via slit-lamp examination (i.e., documentation of striae), but more recently have been based upon actual in vivo corneal thickness measurements, or pachometry.

There are 3 basic, commonly available pachometry methods. Traditional optical pachometry involves use of a slit-lamp mounted-doubling device, requiring a subjective judgment in either 'edge-to-edge' or 'peak-to-peak' alignment of the doubled section. In contrast, the more recently available, ultrasound technique can provide an objective measurement. Lastly, a commercially available contact specular microscope (CSM) system includes a digital, 'optical' pachometer attachment yoked to the microscope's mo-

torized focusing mechanism. The digital readout may lead one to consider this as an objective measurement, but it is based on optical clarity of the endothelium, and therefore uses a subjective endpoint.

Previous clinical comparisons of biomicroscope-based, traditional optical vs ultrasound methods have been conflicting. Giasson & Forthomme (1992) found both clinical compatibility, and a close statistical correlation between these two methods, with a tendency towards over-estimation of corneal thickness by ultrasound methodology via oblique probe alignment. Alternatively, Patel & Stephenson recently (1994) documented a statistically significant difference between the same two methods. Their disparity was theorized to be a result of slit-lamp optic section light distribution or scatter yielding an end-point or thickness over-estimation via the slit-lamp, optical method. A similar disparity has been shown with surgically stressed corneas, but was attributed to ultrasound underestimation of corneal thickness (Nissen et al. 1991). There are no published data on the contact specular microscope (CSM) 'optical' pachometer attachment.

The purpose of this study was to assess central corneal thickness via both ultrasound, and CSM 'optical' attachment pachometry as a function of extended contact lens wear experience. Pachometry was performed on 214 volunteer subjects taking part in a longitudinal protocol designed to

examine the practical usefulness of contact lens wear by Army aircrew. The data gathering phase of this multicenter study ran from November 1988 to the end of September 1991. All subjects were enrolled in the protocol for at least 18 months. These two separate methods of pachometry were chosen in a effort to resolve the apparently conflicting data found in the literature.

Methods

The ultrasound method (Teknar Ophthalmic) uses a hand-held sensor with an ultrasound-emitting cone set by the manufacturer at a speed of 1630 meters per second. When the end of the cone is placed perpendicularly onto the apex of the cornea (± 5 degrees), the emitted sound waves are reflected back from surfaces where there is a change in refractive index (Dunn et al. 1969). In this case, theoretically, that occurs at the posterior corneal border where the endothelium borders the aqueous. The time taken for an emitted wave to traverse the cornea and reflect back to the cone is used to calculate the tissue thickness as a function of the preset ultrasound speed. Variability in ultrasound tissue thickness measurement can be induced by oblique probe alignment, interpatient variation in ultrasound velocity, point of sound reflection, and changes in tissue hydration (Salz et al. 1983; Gordon et al. 1990).

The CSM-mounted, 'optical' pachometer was a manufacturer-provided attachment to a Keeler-Konan specular microscope system. This system uses a cone-shaped objective assembly to flatten a specific area at the corneal apex in a process similar to that used in applanation tonometry. Initially, the 'optical' system is zeroed by focusing the microscope onto the surface of the cone. Once a clear image of the cone's surface is obtained, the cone is moved forward to applanate the central cornea. The system is then internally focused toward the subject until a clear image of the endothelium is obtained. Since this type of specular microscope images the posterior surface of the endothelium (Sherrard & Ng 1990), the optical focusing distance from cone surface to the endothelium

would represent the corneal thickness on contact applanation.

Initial or baseline CCT measurements were obtained prior to any contact lens use. Follow-up exams documented visual acuity, and anterior segment health prior to lens removal. Immediately after lens removal two drops of tetracaine were applied to each eye; the ultrasound CCT measurement was obtained within two minutes post-application of the anesthetic. Next, the contact specular microscope 'optical' measurement of CCT was obtained. This took an additional 3 to 4 minutes per eye (endothelial photos were taken at this time). The sequence was always the same; ultrasound OD and OS, then CSM 'optical' OD and OS.

The 214 volunteer subjects were Army aircrew personnel, primarily AH-64 Apache helicopter pilots and Special Operations aircrew members. There were only 2 female subjects because of assignment limitations that existed at the time of the study. Subjects were fitted either with a 58% water content disposable extended wear soft contact lens (etafilcon), or with a standard 38% water content extended wear soft lens (polymacon) used on a disposable basis. Peak refractive error was approximately -1.00 diopter, with a range from $+2.75$ to -6.00 diopters; a final government technical report documents the specific refractive error distribu-

tion pattern and subject demographics (Lattimore 1992).

Maximum allowable wearing time was 7 days/6 nights. Subjects were permitted to use lens comfort and sharpness of vision to adjust their lens replacement schedule to a shorter wearing period, if indicated. After the initial fitting exam, follow-up exams were done 24 hours post-fitting, 7 days post-fitting, and quarterly thereafter. Every attempt was made to conduct repeat exams at the same time of day as the original fitting. The majority fell within ± 1 hour, thus minimizing a diurnal variation effect, but not eliminating its influence. Also, prior to this study Army regulations forbade pilots from wearing contact lenses; thus, it was assumed that none of the subjects had any previous contact lens wearing experience.

Initial and follow-up exams were accomplished at five locations (Fort Rucker, AL; Fort Campbell, KY; Fort Hood, TX; Frankfurt, Germany; and Nurnberg, Germany). Three identical equipment sets were used (1 set @ Ft. Hood, 1 set moved between Ft. Rucker and Ft. Campbell, and 1 set used in Germany). Data were gathered by three different operators. Equipment was zeroed, and tested on a standard, prior to each subject examination. Equipment was electronically calibrated from zero to 1.0 mm prior to initial installation and at the conclusion of the study. No electronic measure-

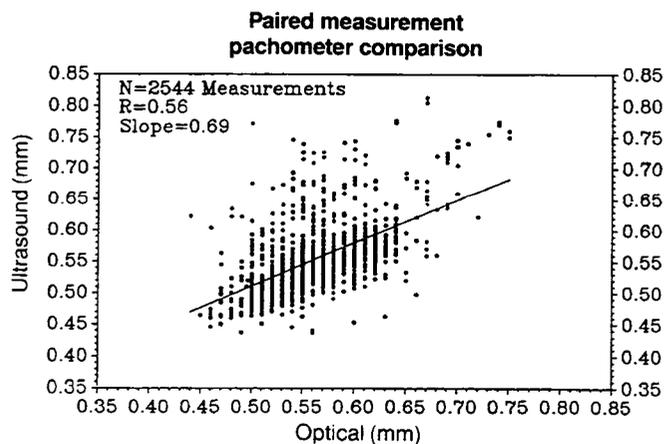


Fig. 1. Scatter plot of all pachometry measurements without consideration for examination sequence or conditions. The two methods correlated only very poorly for these extended soft lens wearers.

ment error was detected at these two times. However, both systems could be subject to transient electronic drift during each use. Data-gathering occurred from 1 November 1988 until 30 September 1991; the total number of subjects reached a zenith in the spring of 1990, yielding 18 months of data for all 214 participants, or 2,544 paired measurements.

Results and Discussion

Fig. 1 is a simple correlative plot of all ultrasound measurements as a function of all CSM 'optical' readings. There was a considerable degree of data spread on both axes with only a mild positive correlation ($R = 0.56$). Grouped data from the two methods were significantly different by t-test ($p < 0.05$). This methodological difference was not influenced by lens type/brand ($p = 0.32$), nor by lens power ($p = 0.16$). The methodological difference was consistent when comparing right eyes to right eyes, and when comparing left eyes to left eyes. Mean ultrasound thickness was $0.542 \text{ mm} \pm 0.004 \text{ SEM}$; mean contact 'optical' thickness was $0.562 \text{ mm} \pm 0.004 \text{ SEM}$.

The use of multiple equipment sets, in multiple locations, operated by several different individuals, with \pm one hour diurnal variation control (from follow-up to follow-up) can easily ex-

plain the data spread seen in Fig. 1. However, given the reasonable assumption that those general errors would equally affect both systems of measurement (i.e., would not cause one system to yield dramatically different results), and given the fact that all measurements were taken within just a few minutes of each other, alternative interpretations for the central tendency differences must be considered.

It has been shown that application of 2 drops of topical anesthetic has a transient effect on corneal hydration, causing a 8 to 9 minute increase in corneal thickness as measured by a traditional, optical pachometer slit-lamp attachment (Herse 1993). Since the pachometry measurements were obtained well within Herse's 8 to 9 minute window of induced swelling, a topical anesthesia influence may be a key component of the data spread documented in Fig. 1. Additionally, because of the fixed measurement sequence, the CSM 'optical' method would be less influenced by any anesthesia-induced transient than the ultrasound method.

A 2-Way analysis of variance (ANOVA) of central corneal thickness by method and number of days extended lens wear revealed some surprising differences (Fig. 2). Initial and 24-hour exams obtained essentially like measurements ($p = 0.38$), although the ultrasound technique demonstrated thicker measurements on the initial exam. However, after greater

than two days' extended lens wear, the ultrasound central corneal thickness measurements were progressively and significantly thinner than the CSM 'optical' measurements ($p < 0.001$). Additionally, while the 'optical' system documented corneal swelling associated with short-term extended lens wear, the ultrasound system failed to document that well-established occurrence.

Further comparative analysis using a 2-Way ANOVA of central corneal thickness by measurement method and long-term lens wear experience revealed a similar pattern of ultrasound under-determination of CCT ($p < 0.0001$; Fig. 3). On first look, these data apparently fail to show any long-term edema via either system. It should be remembered, however, that the quarterly follow-up exams were comprised of a mixture of immediate lens wear durations, ranging from 1 to 7 days of extended wear. Therefore, the flat regression of the grouped CMS 'optical' data in Fig. 3 is not unexpected. However, the apparent ultrasound underestimation was surprising.

The longitudinal underestimation of corneal thickness by ultrasound pachometry, as a function of short-term contact lens wear and long-term experience, could be tied to a compound effect of extended contact lens wear on relative corneal hydration as a result of two factors: loss of cellular tissue, and abnormal fluid accumulation. Studies on animal models have shown that

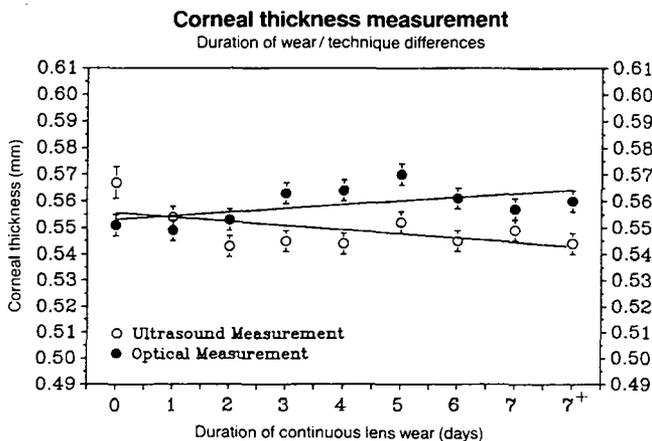


Fig. 2. The CSM 'optical' system clearly documents short-term corneal edema secondary to immediate extended lens wear experience. Yet the ultrasound system appears to indicate a decrease in central corneal thickness under the same conditions.

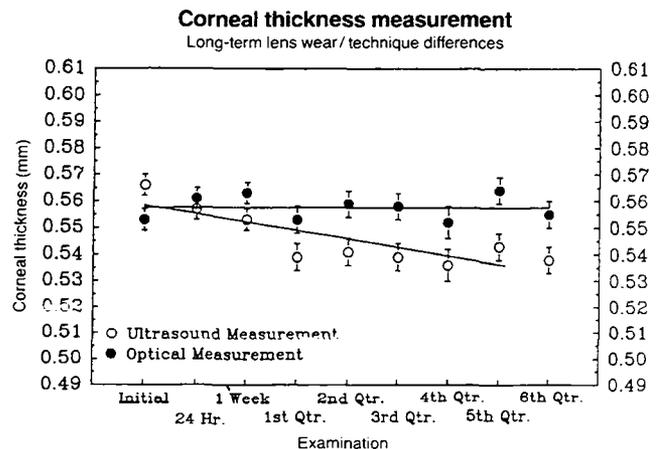


Fig. 3. The long-term monitoring of corneal thickness over the course of the study again shows an under-estimation of central corneal thickness by the ultrasound system.

there are a number of morphological corneal changes associated with hydrogel lens wear. These changes include: epithelial thinning, stromal keratocytic tissue depletion, and increased fluid accumulation, both intra- and extra-cellularly (Bergmanson & Chu 1982; Bergmanson et al. 1985; Bergmanson 1989). It may be reasonable to surmise that, as the corneal tissue mass or bulk dissipates, concurrent with a metabolically-induced extracellular edema, the tissue's overall density or ultrasonic index will decrease. The ultrasound signal would thereby be permitted to travel faster, resulting in an apparent under-calculation of tissue thickness. This can be seen in Figs. 2 and 3. The methodological differences would additionally be enhanced by Herse's anesthesia-induced edema transient, making ultrasound pachometry of questionable value in physiologically stressed corneas.

Based on these data, the ultrasound method of documenting central corneal thickness in extended wear contact lens subjects appears to be an inadequate means of documenting actual corneal thickness. As such, its clinical utility in contact lens practice is debatable unless a means of correcting for the proposed bias or error is made available. The contact 'optical' method appears to be less influenced by these sources of error, and is therefore recommended for use in contact lens and post-surgical practice pending additional study of this troubling phenomenon.

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