Sanjaa-Uyen-Tumur ophthalmometer: An introduction of the objective ophthalmometer

Uyen Bold*, S. Tumur, Otgonchimeg Kh, E. Sanjaa

Abstract:

PURPOSE: The purpose is to present the objective of the Sanjaa-Uyen-Tumur (SUT) ophthalmometer and compare its measurements with the standard Hertel exophthalmometer.

METHODS: Eyeball position of 88 healthy eyes of the patients was measured using both the SUT ophthalmometer and Hertel exophthalmometer. Both methods were performed in one session by the same experienced ophthalmologist. Data were analyzed using Bland–Altman method.

RESULTS: Mean age of the participants was 41.11 ± 14.08, further, 59% (26) were male and 41% (18) were female, respectively. The mean difference was 0.1420455 and the standard deviation of the difference was 0.9221067, 95% confidence interval, respectively. Based on the Bland–Altman analysis, lower limit of agreement in our study was from −2.284538 to −1.614211 and upper limit of agreement was from 1.33012 to 2.000447. According to the results of our studies, there is no relationship between the difference and the level of measurement in either plot.

CONCLUSION: This SUT ophthalmometer can be used same as the Hertel exophthalmometer in ophthalmology practice as can be accurate, affordable, and objective.

Keywords: Enophthalmos, exophthalmometer, exophthalmos, objective method, Sanjaa-Uyen-Tumur ophthalmometer

Introduction

Orbital wall fractures and orbital disorders may affect the eyeball position. The Hertel exophthalmometer has been commonly used in the testing of eyeball positions and treatment results of the patients, who can communicate and be focused during the test. The main principle of the test is the subjective method, in which the tools measure the distance between the lateral orbital rim and the apex of the cornea. The first exophthalmometer was introduced by Cohn in 1865.[1,2] The most popular Hertel design was first presented in 1905 and has been still beneficial in the diagnosis of orbital disorders.[3] In 1934, Russian researcher C. A. Spektor published an article on the objective exophthalmometer designed by himself; however, there had been no evidence of using it in practice.[4] Exophthalmometer was further improved by Luedde in 1938, by Dutch in 1939 under the name of proptometer, exophthalmometer for direct measurements by Gormaz in 1945 and Watson in 1967, respectively.[5-7] The following persons pursued the idea of Hertel design and updated its some details, i.e., Davanger in 1970, Naugle and Couvillon in 1992, and Yeatts et al. in the same year as well, further, Kratky and Hurwitz in 1994, respectively.[8-11] Even though those designs had been a good idea at that time, they had not put into ophthalmology practice. In 2004, Ameri and Fenton stated three main disadvantages of Hertel design, which are as follows: (1) the resting of the footplate on the lateral...
orbital rim, (2) the possible rotation of instrument at the horizontal axis, and (3) parallax errors.\textsuperscript{[12]} Further, for the purpose of eliminating disadvantages of Hertel instruments and improving outcome of the diagnosis and treatment results, Stijn W et al. introduced a new Parallax-free exophthalmometer. It is based on Hertel design, in which the mirrors were replaced with the 45 right-angled prism moving back and forward.\textsuperscript{[8]} Even though Hertel design has the above-mentioned disadvantages, it has been still beneficial and popular instrument in practice.

In this article, we present the Sanjaa-Uyen-Tumur (SUT) ophthalmometer equipment developed to eliminate disadvantages of subjective tools, improve outcome of the diagnosis and surgery and determine specifically objective measurement of the eyeball position during the surgery.

**Methods**

We are presenting a new SUT ophthalmometer [Figure 1], which consists of a movable vertical stem (1) with fixing screwbolt (2), a fixed vertical stem (5) at the one end of a measuring ruler (3) and a measuring unit (4).

Both of the movable stem (1) and the fixed stem (5) are made of plastic material and the measuring ruler (3) is carrying the fixed stem (5) and the movable stem (1) sliding along the measuring ruler. The measuring ruler is made with metal and dimensions of the measuring ruler: length of 150 mm; width of 7 mm; and thickness of 2 mm.

The measuring unit consists of cylinder [1 at Figure 2], a bolt fixing worm gear [4 at Figure 2], a bolt fixing contact tip [6 at Figure 2], a contact tip [7 and 8 at Figure 2], a measuring panel with scale in millimeters [2 at Figure 2], and a measure pointer [3 at Figure 2].

The cylinder of the measuring unit slides along the measuring ruler, further, the screwbolt connected with wormgear, the worm gear fixed with the contact tip, the measuring panel with scale in millimeters and the measure pointer are located on the cylinder. The measure pointer is fixed with the screw-bolt fixing the contact tip.

**Working principle of the ophthalmometer**

Supporting length is regulated by sliding of the movable stem [1 at Figure 1] with fixing screw-bolt [2 at Figure 1]. Clockwise and counter clockwise rotations of the worm gear by the fixing screw-bolt [4 at Figure 2] moves the fixing contact tip screw-bolt [6 at Figure 2] up and down, respectively.

Eyeball position of 88 healthy eyes of the patients was measured using both the SUT ophthalmometer and standard Hertel exophthalmometer. Both methods were performed in one session by the same experienced ophthalmologists. Data were analyzed using Bland–Altman method. Exclusion criteria are thyroid disease-related ophthalmopathy, orbital tumor, and orbital wall fracture cases.

**Measurement techniques**

Put one drop of local anesthesia in both eyes of the patient and make the patient lie down on the bed face up. Ask the patient to focus at 5 cm colorful shape placed from 3 m distance on the ceiling. The examiner places two external jaws at orbital lateral rims firmly. Position contacting tip directed at the center of the cornea. Apply one drop of goniogel on the corneal surface. Position contacting tip at the starting point of the imperial scale on vertical axes and move down the contacting tip accurately up to the center of the cornea and if it contacts cornea properly, then the ring shape will appear on the surface of goniogel layer [Figure 3]. After these steps, numerical indicators displayed on the imperial scale board to be noted. Measurement will be repeated three times.

Baseline is the measurement of the normal eye and any indicator $\pm$ 2 mm should be noted as pathologic changes (enophthalmos and exophthalmos). Configuration of the horizontal axes of the SUT ophthalmometer should be done holding the main part of the equipment. Hold conjunctiva at 3 and 9 o’clock position with two forceps sat one level without pushing below or pulling above to check the recovery status of eyeball position using SUT during surgery.

Disadvantages of the SUT are that it is not possible to use during corneal inflammation; further, the examiner is required to be informed with the instructions of the SUT to get accurate measurements.

Limitation of the study has not been tested in both exophthalmos and enophthalmos conditions yet.

**Ethical statements**

Ethical approval No 19/01/04 for this study was obtained from the Institute of Medical Sciences of Mongolia. All the participants were informed and written consents in Mongolian language were obtained from all of them.

**Table 1: Descriptive statistic**

|      | Count | Mean±SD | 95% CI | sUCL | LCL   |
|------|-------|---------|--------|------|-------|
| SUT  | 88    | 15.1193±2.948791 | 14.49453 | 15.74411 |
| HE   | 88    | 15.26136±2.693092 | 14.69075 | 15.83197 |
| Difference | 88  | -0.142045±0.9221067 | -0.3374212 | 0.0533029 |

Correlation coefficient=0.950582. SD=Standard deviation, CI=Confidence interval, SUT=Sanjaa-Uyen-Tumur, LCL=Lower control limit, sUCL=Upper control limit, HE=Hertel exophthalmometer.
Results

We examined the axial position of eyeball in 88 healthy eyes of the patients using both the Hertel exophthalmometer and SUT ophthalmometer. The 59% (26) of the participants were male and 41% (18) were female, respectively. The mean age of participants was 41.11 ± 14.08.

The mean difference was 0.1420455 and the standard deviation of the difference was 0.9221067, 95% confidence interval, respectively [Table 1]. Based on the Bland–Altman analysis, lower limit of agreement in our study was from −2.284538 to −1.614211, upper limit of agreement was from 1.33012 to 2.000447 [Table 2].

Discussion

Exophthalmometry is a low-cost and simple method used commonly to diagnose orbital disease and follow-up treatment results. Although there are numerous designs that had been introduced, the Hertel exophthalmometer has been commonly used worldwide. In recent years, authors improved certain details of the Hertel exophthalmometer; they have not
been into common practice. Those designs determine eyeball position measurements subjectively; however, measurement variability may occur due to parallax error, intra- and inter-observer variations. Nowadays, eyeball positions can be measured using computer tomography and magnetic resonance imaging, however, they are time consuming and expensive, therefore, they are not available everywhere. Thus, we need an accurate, reliable and low-cost design, which can be used everywhere.

The ophthalmometer designed by us can give accurate, the objective measurement of eyeball positions in a simple and reliable way. Consequently, we discussed and made comparisons between the SUT and the most commonly used Hertel design, further, with two objective exophthalmometers, which were introduced in the history of exophthalmometer’s development.

In addition to the disadvantages of the Hertel ophthalmometer emphasized by other authors, we consider that it has been less used in pediatric practice, is unable to measure eyeball positions at the highest and the lowest values during surgery and is unable to autoclave sterilization. In contrast, we tried to eliminate disadvantages of the Hertel, thus, we designed the SUT ophthalmometer. It is possible to test 0–3 years’ children under general anesthesia (GA) using the SUT. The SUT can present accurate measurement of eyeball positions (enophthalmos and exophthalmos) because of the objective method due to contacting corneal apex. The main distinguishing point of the SUT is that it can be used in the measurement of eyeball positions during the reconstructive surgery as the SUT can be autoclave sterilized.

In 1934, C. A. Spektor first developed exophthalmometer. The main purpose of this equipment is to eliminate disadvantages of Hertel exophthalmometer as well as to get accurate and objective measurement, which has been innovation at that time. However, even though this equipment had been a good idea at that time, we suspect that the following reasons were behind for not introducing this equipment in the ophthalmology practice:
1. Measurement was to be made at corneal limbus
2. Not possible to define whether each of the three ends of the measurement tip to touch corneal limbus simultaneously
3. It is possible to damage cornea and sclera during the measurement
4. Errors may occur in the measurement.

In 1946, Gormaz had initiated exophthalmometer to make objective measurement subsequently. This equipment was an attempt to reduce disadvantages of C. A. Spektor’s idea, but unfortunately, it was not put into practice. We suspect that the following reasons were considered:
1. Even though the measurement tip was similar to modern contact lens (it was called as “cup”), it could not cover cornea firmly
2. Measurement cup was not suitable with physical nature of cornea of different patients
3. Not possible to make measurement in congenital abnormality of cornea (keratoglobus and keratoconus).

We conclude that measurement techniques of the above-mentioned equipment were not satisfactory as eyeball position should be measured accurately in millimeters in clinical practice. The general structure of the SUT is similar to those two equipment, but its measurement is more accurate because it is objective, detailed and the size of its contacting tip is appropriate. The difference of the SUT is as follows:
1. The names of the two exophthalmometers suggest that they were developed to measure only exophthalmos cases, however, the name of the SUT
refers to the measurement of both enophthalmos and exophthalmos
2. The contacting tip of the SUT is made of smooth surface, synthetic polymer with 2-mm diameter
3. There will be no cornea damage during the measurement, and contact of cornea and tip will be clearly visualized
4. It is easy to handle.

Conclusion

We present the SUT ophthalmometer, which can solve the general disadvantages of the subjective design. Our SUT ophthalmometer can be used same as the Hertel exophthalmometer in ophthalmology practice and it can be affordable and objective. Further, an independent study should be performed to prove our findings.

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Conflicts of interest
The authors declare that there are no conflicts of interests of this paper.

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