CHAPTER 3

METHOD
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The aim of the study was

- To develop a protocol for screening visual impairment in children aged 3 to 6 years.
- To validate the
  - Visual acuity charts (Lea symbol, HOTV and E charts)
  - Stereo acuity charts (Frisby, Randot preschool and Titmus stereo fly test)
  - Photo refractor (Plusoptix A09)

for screening visual impairment in 3 to 6 years old children.

3.1 Definitions

Visual Impairment (VI) referred to presenting visual acuity of <20/40 or 0.3 log MAR in the better eye.\textsuperscript{136}

Operational definition of VI: In the current study, any presenting visual acuity <20/40 or 0.3 log MAR in the study eye was considered to be visually impairment as the study units were eyes.

Refractive error was defined as hyperopia $\geq$ 2.00 D, myopia $\leq$ -0.50 D, astigmatism $\geq$ 0.75 D.\textsuperscript{21}

Strabismus was defined as asymmetric alignment or abnormal cover tests results in addition to stereopsis <120 sec of arc.\textsuperscript{21}

The definition of significant refractive error as per the VIP study was hyperopia $>$ 3.25 D, myopia $>$ 2.00 D, astigmatism $>$ 1.5 D, anisometropia if interocular difference $>$ 1 D for hyperopia, $>$ 3.00 D for myopia or $>$ 1.5 D for astigmatism.\textsuperscript{57}
Bilateral amblyopia was defined as best-corrected visual acuity (VA) in each eye worse than 20/40 after best correction and unilateral amblyopia was defined as ≥2 lines difference in best-corrected interocular VA.\textsuperscript{59}

The criteria for detecting refractive amblyopic risk factors with Plusoptix A09 was considered to be Hyperopia > 1.88 D, Myopia > -3.00 D and Astigmatism > 1.50 D. For cycloplegic refraction, American Academy of Pediatric Ophthalmology and Strabismus (AAPOS) criteria was adopted. Hyperopia >3.50 D, Myopia > -3.00 D and Astigmatism >1.50 D\textsuperscript{54}

3.2 Study design: Cross sectional

3.3 Study Participants: 3 to 6 years old children

3.4 Study Setting: Outpatient department of Ophthalmology (OPD)

3.5 Sampling method: Purposive sampling

3.6 Sample Size: 123 eyes in each group (visually impaired/ normal).

The screening tests had to be validated, and visual acuity measurement was the most commonly used test across nations. Hence, the sample size calculation was determined using the formula \(4pq/d^2 /\text{prevalence}\) where “p” was the sensitivity of visual acuity chart and “d” was the precision level. Any validated tool must have at least 70% sensitivity. Anticipating 70% sensitivity\textsuperscript{39,40} for the visual acuity charts to pick up visual impairment with 5% precision and taking 6% as the prevalence of visual impairment\textsuperscript{7,18} in the age group of 3 to 6 years, the minimum sample size needed for the study was determined to be 123 visually impaired (VI) and 123 normal eyes. Expecting 20% non-co-operation rate, the total number of eyes targeted in each group was 146.
3.7 **Inclusion criteria:** 3 to 6 year old children visiting OPD

3.8 **Exclusion criteria:**
- Children who were not co-operative
- Parental consent if not obtained
- Children diagnosed with developmental delay

3.9 **Development of a screening protocol for visual impairment.**

A systemic search of research articles was conducted. The search was conducted in search engines and data bases such as Pubmed, Google Scholar, Embase, Scopus, Science direct, Hinari, Medline, Web of Science, CINAHL and Global Health to find out pertinent articles published in English language. The literature search was done using key words including preverbal children, preschool children, toddlers, vision screening, preschool, amblyopia, visual deficit, visual impairment, prevalence, refractive error, vision, charts, stereo acuity and photo refractor. All manuscripts considered relevant to the subject were scrutinised. In the end, we narrowed down to 26 articles published between 2003-2016. Their titles and abstracts were assessed and the full texts were downloaded and reviewed.

The protocol development was based on an extensive literature review.

Assessment of unaided vision is the first step towards detection of any ocular abnormality. Visual acuity cut offs for referring pre-school age group has not been uniform globally. This might be partly owing to different charts employed across countries and visual and cognitive abilities in the developmental stage of preschool children. Hence, there is a dire need for formulating age and chart specific referral criteria. AAP and AAPOS recommended vision assessment of children by 3 years of age as they remain doubtful to complain about their visual problems and their visual
deficit may result in amblyopia, leading to permanent visual impairment. The AAP, AAPOS, and AAO had advocated the referral of 3 to 5 year children to eye-care practitioners if the visual acuity was < 20/40 (6/12) or if the interocular difference was two line or more. The recommendation by Alley in her review was to refer any child who was untestable after 2 attempts, demonstration of any ocular anomaly or visual acuity less than 20/40 in either eye or 2 line difference in the visual acuity. A vision screening one time at least between 3 to 5 years was mandated by USPSTF.

HOTV was reported as the most frequently used vision chart in the United States. Lai et al reported the extensive use of C and E charts across Asian countries like China, Japan, and Taiwan, where English was not the native language and directional optotypes have high testability. Until now, there is no recognized gold-standard vision test for preschool children. Normative visual acuity levels in younger children must be determined to establish the referral criteria for vision screening precisely, successfully monitor and manage eye disorders. This normative VA should be defined based on vision test and the age of the child. Furthermore, population-specific norms need to be determined as ethnicity and socio economic status may influence the visual acuity measurement as reported in literature. There was no unanimity outlining normal vision in preschool children as reported by Chui et al. Kulp et al and Ciner et al emphasized that a child who was untestable to vision test could be twice as likely of having a visual deficit compared to who responded for preschool screening.

Anstice et al recommended Lea symbol, HOTV, Tumbling E for vision assessment of preschoolers compared to other commercially available charts. Allen cards and Wright figures lacked standardization, Patti pictures scored poorly for vision
assessment and Kay pictures demonstrated overestimation of visual acuity in amblyopia. The charts at shorter working distance (3 meter) were reported to improve the cooperation and concentration in a child.\textsuperscript{98} Moreover, Lea, HOTV and E charts have equal chance of guessing since all of them have only four different optotypes.\textsuperscript{32}

In a study by Diana et al, good agreement and test retest reliability were observed for Frisby and Titmus stereo tests in preschoolers.\textsuperscript{38} De La Cruz et al found that Titmus stereo fly test could be administered in 3 to 12 year old children. Randot preschool was used as the gold standard in their study.\textsuperscript{143} Ancona et al observed the repeatability to be legitimately good between Frisby, Titmus stereofly and Randot test.\textsuperscript{144} Afsari and co workers reported randot preschool test to be the most reliable one in detecting ocular problems compared to Lang II and stereo smile test. Randot preschool showed a higher AUC for the overall detection of visual disorders compared to others.\textsuperscript{47}

Birch et al reported the mean normal stereo acuity values at 3 years to be 100 sec, 5 years to be 60 sec and 7 years to be 40 sec of arc in Randot preschool test. According to the authors, normative data would help in defining the screening criteria and assessing the binocular vision status following treatment.\textsuperscript{145} The median stereo acuity observed for Frisby test in 5 to 10 year old was 25 arc sec according to Bohr et al.\textsuperscript{146} According to Ciner et al, the median stereo acuity observed for severe, moderate and mild vision deficits were 480, 120 and 120 sec of arc whereas for normal children aged 3 to 5 years it was found to be 60 sec of arc. The preschool children who failed stereo test were 5.75 times more likely to have an ocular abnormality as per the authors.\textsuperscript{99}

The U.S. Preventive Services Task Force had recommended photo screening modalities for identifying ARF in children aged 3 to 5 years.\textsuperscript{22} Silbert et al and Yan et al reported high sensitivity and specificity for Plusoptix A09 and recommended it for
community eye care of children.\textsuperscript{52,53,54} According to Silbert and co-works, 98% negative predictive value was observed for ocular anomalies including significant refractive errors if a normal Plusoptix result combined with normal ocular motility/alignment tests and visual acuity was obtained for children above 3 years. The authors suggested that the shortened eye examination with Plusoptix photo screener might preclude dilatation in selected children.\textsuperscript{147} Langreze et al. recommended the use of combination of tests rather than a single test as PPV of any single test used in VIP study was low.\textsuperscript{26} Further research was warranted on the combinations of vision screening tests for preschool screenings by Donahue et al.\textsuperscript{22}

In the current study, the screening tests used for the protocol were Lea symbol, HOTV and E charts were for visual acuity measurement, Frisby, Randot preschool and Titmus stereo fly test for assessing stereo acuity and Plusoptix A09 for refractive error screening.

\textbf{3.10 Study Instruments:}

- Torch light
- Log MAR Visual acuity charts (Lea, HOTV and E)
- Stereo acuity charts for near (Frisby, Randot preschool and Titmus stereo fly)
- Photo refractor(Plusoptix A09)
- Streak retinoscope (Welch Allyn)
- Prism bar (Luneau)
- Slit lamp Bio microscope (Topcon SL 3C)
- Direct ophthalmoscope(Welch Allyn)
3.11 Procedure

The permission for conducting the study was obtained from the Institutional Research Committee, School of Allied Health Sciences and Institutional Ethics Committee, Kasturba Hospital, Manipal. (IEC/312) Subsequently, the permission was obtained from the Head of the Department for carrying out the study in the Outpatient Department of Ophthalmology, Kasturba Hospital.

Consent from the parents

Parents or guardians of the children visiting the OPD, Ophthalmology was approached for enrollment. Around 308 children were approached and only 128 fulfilled the inclusion criteria. The sample recruitment flow chart is shown in Figure 3.1.

Once the participants satisfied the inclusion criteria, they were recruited for the study. The objectives, examination protocol and need for the study were explained. The Informed consent was obtained from the parents and verbal assent from the children. (Annexure-1).
3 to 6 year old children approached in the OPD
308 subjects

Assessed for eligibility
288 subjects

Declined (20 subjects)
- Parental reluctance in dilating their child’s eyes

Excluded (160 subjects)
Not eligible (120 subjects)
- Developmental delay: (60)
- Age group above 6: (50)
- Age less than 3 years: (10)

Not eligible (120 subjects)
- Developmental delay: (60)
- Age group above 6: (50)
- Age less than 3 years: (10)

Eligible but not enrolled (40 subjects)
- Already on dilating drops: (20)
- Symptomatic due to infections/trauma: (20)

Total children enrolled
(128 subjects)
n = 256 eyes

Data available for analysis
n = 254 eyes
128 normal and 126 VI eyes

Figure 3.1: Sample Recruitment flow chart
Validation of the protocol with the screened participants

A brief history was obtained from the parents/guardian. Torch light examination was performed before commencing the screening tests. A single investigator did all the enrollment, performed all the tests up to squint assessments. Dry refraction was done and acceptance attempted only for children who were co-operative. The order of presentation of the visual and stereo acuity charts was generated using a random number table to

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**Figure 3.2: Procedure - flow chart**

The flow chart which depicted the procedure is shown in Figure 3.2.
reduce the observer bias. Comprehensive eye examination was taken as the gold standard for final diagnosis.

Visual acuity measurement

Distance visual acuity examination was performed at 3 meters or 10 feet. The charts employed were Lea symbol chart, HOTV chart and E chart. All were log MAR charts designed for 3 meter distance to maintain uniformity and comparability. Each chart had 5 optotypes (symbols/letters) in each line and all the lines had same optotypes arranged in random sequence. Lea symbol chart had pictures of square, house, circle and apple. HOTV had letters H, T, O and V. E chart had orientations of letter E in 4 directions like right, left, up and down. All charts had only 4 different optotypes and were positioned at the eye level of children while measuring visual acuity.

The subject had to match each optotype to that in the lap/flash card or recognize verbally. For Tumbling E, the participant was trained to point in any of the four different orientations or use the lap card. For Lea symbol chart, other names for the pictures were acceptable if the child was consistently using them. A pretest was done and the child’s ability to identify the symbols/letters was checked binocularly by bringing the chart at a close by distance. Once the child could recognize all the optotypes, monocular testing was performed. A butterfly pattern occluder was used to interest the child and to ensure proper occlusion of the fellow eye before taking vision. Right eye was tested first followed by left eye in all children. Precaution was taken not to cover the surrounding optotypes when assessing visual acuity with the charts. Praises were showered on the child for the accurate responses. Four out of 5 optotypes had to be correctly identified to proceed to the next smallest optotype. The visual acuity was noted down as the smallest optotype size which the child recognized. It was recorded in log MAR/metric/feet
equivalent. The visual acuity range was from 1.0 to 0.0 log MAR (3/30 to 3/3 or 20/200 to 20/20). Testing distance was maintained throughout the procedure. The child was not allowed to move closer to the chart to identify the symbols/letters. All visual acuity measurement were done in normal room illumination.

Monocular visual acuity was recorded. An eye with visual acuity $\geq$ 20/40 or 0.3 log MAR in was taken as the normal eye. Near vision was recorded with N notation chart in all cases where the child responded. If the child was hesitant with N chart, lea symbol near vision chart was used. Otherwise, it was mentioned as no response.
Figure 3.4. HOTV Chart

Figure 3.5. E Chart
**Stereo acuity measurement**

The measurements were recorded in seconds of arc (sec of arc). Two repetitive correct responses at a given disparity level were considered for better accuracy. It was a binocular measurement.

- **Frisby stereo test**: Stereopsis was measured with Frisby using 6mm, 3mm and 1.5 mm thickness plates at 40 cm which corresponds to 340”, 170” and 85” disparity respectively. Each subject was asked to speak verbally or point out any of the square that had the target popping out. Altering the distance of the plates was done to record the maximum stereo acuity and the values obtained were documented. The measurements ranged from 600 to 15 sec of arc.

![Figure 3.6. Frisby stereotest](image)

- **Randot preschool stereo test**: The participant was instructed to wear the polaroid glass and the chart was kept at a distance of 40 cm. Non stereo pretest figure was first tested to ensure if the child could recognize the figures. The child had to match the pictures seen in right hand side of the booklet to that on left hand side. If the
subject could identify 2 figures for 1 stereo acuity level, he/she was directed to the next stereogram of decreased stereo acuity. The child was given an option of matching or spelling it out. The stereo acuity values were noted down based on the child’s response. The ranges of measurements was from 800 to 40 sec of arc.

![Randot Preschool stereotest](image)

**Figure 3.7. Randot Preschool stereotest**

- Titmus stereo fly test: In Titmus Fly test, the participant had to wear the polaroid glass. The booklet was held at 40 cm distance and the child was asked to clasp the wings of the fly with his/her hands which was equivalent to 3000 seconds of arc. Three rows of animals were then shown and the subject had to point out one animal in each row which was popping out and the range was from 400 to 100 sec of arc. Then stereo acuity levels with graded circles were measured which ranged from 800 to 40 sec of arc. The participant was asked to touch circle or push down whichever seemed to hover up. The stereo acuity values were recorded based on child’s response.
Figure 3.8. Titmus stereofly test

**Measurement with Plusoptix A09**

Plusoptix A09 was positioned at a distance of 1.20 meter (3.3 feet) away from the child at the eye level. Fixation target of the instrument was a smiley face which lighted automatically and a warble sound was produced on pressing the button. This enhanced to draw the attention of the child when the readings were taken. The instrument was moved forward until green circles were observed around the pupil and another warble sound was heard. The binocular measurements were taken automatically at this distance (1metre) and displayed on the monitor. “Measurements completed” was shown on the left side of the screen. The readings were checked twice. It was ensured that the child’s attention was not drawn towards the monitor. If the screen showed as “measurement aborted” the testing distance was rechecked, the room illumination reduced and the pupil brightness was tested. If binocular measurements were not obtained again, the investigator recorded measurements uniocularly. The readings displayed on the monitor were spherical, cylindrical or spherocylindrical refractive error values in diopters (D), Inter pupillary
distance in millimeters (mm) and pupil diameters in mm. All the readings were noted down.

![Plusoptix A09](image)

*Figure 3.9. Plusoptix A09*

**Squint Assessment tests**

The tests like extra ocular motility (EOM), smooth pursuits, Hirschberg test and cover tests were performed. If the child had squint, Krimskey test was done to measure the deviation for near and distance. It was documented in prism diopters.

**Anterior segment examination**

A Slit Lamp Bio microscope was used to assess the health of anterior segment structures of the eye.

**Cycloplegic refraction and posterior segment evaluation**

The homide 2% drops (homatropine hydro bromide) were administered in each eye, one drop each after every 10 minutes (2 times) to ensure maximum cycloplegic effect. One more drop was instilled after 30 minutes if pupil size was less than 6mm or pupillary light reflex was present. Cycloplegic refraction was performed after noting the
pupillary light reaction and the net value estimated by an experienced optometrist. Retinal evaluation was done after cycloplegic refraction. Cycloplegic refraction was considered as the gold standard for the refractive measurements.

Glass prescription was given in all possible cases. The child was called for Post Mydriatic Test (PMT) after 1 week if deemed necessary to finalize the spectacle prescription. The further management for 53 eyes with amblyopia, 29 eyes with anterior segment anomalies and 1 eye with posterior segment abnormality was done by ophthalmologists specialized in the field of pediatric eye care and follow up care advised. The ocular findings, diagnosis and management of each eye were recorded from the case files.

All the measurements and findings were entered in the protocol developed (Annexure 2) and the sensitivity and specificity of the protocol checked.

3.12 Data Analysis

All the data was entered and tabulated in the Statistical Package for the Social Sciences (SPSS) version 15. For tools giving continuous measures as outcomes, Receiver Operating Curve analysis to identify the optimal cut off to discriminate between normal and abnormal was plotted. Sensitivity, Specificity, PPV and NPV of different screening tests used for detecting visual impairment were estimated. Intraclass Correlation Coefficient between the screening techniques was determined. Kappa statistics was used to find out the agreement between the different screening tests combinations employed. Chi-square test was performed to find the association between visual impairment screenings with age, gender and residing area of the participants. A p value less than 0.05 was considered to be statistically significant.