INTRODUCTION

Corneal wounds may result in significant visual and optical defects. Scar formation within the cornea leads to irregularities produced by variable tractional forces on the corneal surface and visual loss possibly caused by regular and irregular astigmatism.\(^1\) Corneal topographic considerations must now be included early in the management of corneal scars after trauma and also at the final visual rehabilitation phase.\(^2\) The visual acuity test cannot specify optical defects such as ghost images and halo induced by corneal aberrations. Rigid gas permeable contact lenses create a new optical surface in front of the injured cornea and optically eliminate surface irregularities.\(^3\) We describe our experience using rigid gas permeable contact lenses in children with corneal scars as a method for visual rehabilitation and prevention of early developed amblyopia.

PATIENTS AND METHODS

The institutional ethics committee at Tanta University Hospital reviewed and approved this
study. A written informed consent was obtained from each participant.

Fifteen children (5 females and 10 males) with a history of penetrating ocular trauma with corneal scars or irregular corneal incision after cataract extraction and IOL implantation were included. Their ages ranged from 5.7 to 14 years (mean ± standard deviation: 9.4 ± 2.9 years). They attended the outpatient clinic of pediatric ophthalmology at Tanta University Hospital. They all had best corrected visual acuity (BCVA) of worse than 20/20. The children all wore spherical rigid gas permeable contact lenses (ROSE K2 Irregular Cornea IC; Menicon Co. Ltd., Nagoya, Japan) for 6 months.

Visual acuity was measured using the Snellen Landolt C chart. Uncorrected and best corrected visual acuity with spectacles and rigid gas permeable contact lenses were obtained in decimal format and underwent statistical analysis.

A detailed ophthalmologic examination was performed, including slit-lamp examination of the corneal scar and its extent from the visual axis and examination of the eyelids and the ocular adnexa. The tear meniscus was also examined to evaluate the tear break-up time by Schirmer test. The error of refraction and astigmatism were evaluated clinically.

Visual outcomes were assessed at the end of 6 months of follow-up. The Titmus test was used for assessment of stereopsis in children with improved visual acuity of 20/40 or better while wearing the contact lens.

The corneal and topographic profile including the optical defects and corneal aberrations was evaluated using the Sirius topographer (CSO, Firenze, Italy). It provides aberrometric analysis and offers a complete overview of the corneal contribution to vision in a standard summary with different maps.

Corneal aberrations were Zernike polynomials for second (astigmatism and defocus), third (coma and trefoil), and fourth (quatrefoil, astigmatism II, and spherical aberrations) order aberrations. Root mean square, limits of agreement, and higher order aberrations were also detected. The simulated vision functions (spot diagram, point spread function, modulation transfer function, and image convolution) were evaluated. All data were compared before and after rigid gas permeable contact lenses.

We excluded from our study children with narrow palpebral fissure, traumatic eyelid deformity, dry eye, frequent falling, missing contact lenses, and those with less motivated parents.

The regimen for rigid gas permeable contact lens use was: (1) contact lens wearing on a daily basis of part-time per day according to the protocol for amblyotherapy and occlusion of the other eye; (2) avoiding wearing of rigid gas permeable contact lenses outdoors; (3) frequent instillation of tear substitutes; and (4) increasing the learning curve of the parents by frequent training courses for rigid gas permeable contact lens wear, care, and hygiene.

Statistical Analysis

All statistical analysis was performed with SPSS statistical software (version 23; SPSS, Inc., Chicago, IL). Continuous variables were presented as mean ± standard deviation. The difference between average variables was analyzed using the Wilcoxon test for nonparametric data and the paired t test for parametric data. A two-sided P value of less than .05 was considered to be statistically significant.

RESULTS

All children wore spherical hard contact lenses for 6 months. The average time between suture removal and rigid gas permeable contact lens wear was 4.1 ± 0.58 months. The mean BCVA was 0.4 ± 0.18 for spectacles and 0.7 ± 0.16 for rigid gas permeable contact lenses.

There was a significant improvement in the contact lens BCVA after 6 months (P = .001). There was an improvement of two or more lines of Snellen visual acuity after wearing rigid gas permeable contact lenses compared to the spectacle BCVA (Table 1 and Figure 1).

In our study, the higher order aberrations (P = .008), limits of agreement, root mean square, and point spread function (P = .001) were significantly improved after wearing rigid gas permeable contact lenses compared to before (Table 2).

The corneal aberrations for the second and third order aberrations all improved, but the fourth order spherical aberration values decreased toward zero and negative values without a significant difference compared to before wearing the lenses (P = .20).

Figures A-C (available in the online version of this article) show representative cases.
DISCUSSION

New advances in hard contact lens manufacturing that solved the problem of hypoxia made it possible for them to be used in children for rehabilitation after traumatic corneal laceration.\(^5\)

Rigid gas permeable lenses or corneal transplantation are options for irregular astigmatism. However, due to the inherent complications of corneal transplantation, that option is less desirable, especially in low socioeconomic countries.\(^6-8\) In our study, rigid gas permeable contact lenses were fitted to children in an even younger age group. Most children were older than 6 years (13 cases) and only two children were younger than 6 years. The keys to successful use of rigid gas permeable contact lenses were parent cooperation, the continuous training courses for the parents guided by the American Academy of Ophthalmology course 2007, and our special regimen of rigid gas permeable contact lens use.\(^9\)

Boghani et al.\(^10\) showed a success rate of 50% in children younger than 10 years and the cases of failure were due to less motivated, uncooperative parents and corneal irritation. Kanpolat and Ciftçi\(^11\) recorded a success rate of 90% in children older than 10 years. The principle of correction of corneal irregularities by rigid gas permeable contact lenses has been explained by several authors. Rigid gas permeable lenses improve visual acuity by masking irregular astigmatism from these corneal opacities through the creation of a tear lens by using the precorneal tear layer.\(^12,13\) In this study, the keratometric astigmatism and visual acuity after wearing rigid gas permeable contact lenses were significantly improved. Also, stereopsis was regained in 90% of cases with BCVA of better than 20/40 after 6 months of wearing rigid gas permeable contact lenses with the occlusive therapy.

Many studies also reported evidence of proper visual rehabilitation by using rigid gas permeable contact lenses in children.\(^6\)

Vision is a complex process and the perception of a visual stimulus is affected by many anatomical factors, such as corneal surface, curvature, clearness of the optical media, and the axial length of the eye. Visual acuity tests were subjective and inadequate for the clinical diagnosis of eyes with abnormal vision as cases with corneal scars. It does not disclose all of the visual defects.\(^14\)

Corneal topography is an objective tool that is effective in the clinical diagnosis of cases with BCVA worse than 20/20. In this study, it could detect disturbances in the point spread function (image quality with the appearance of picture halos or blur) induced by the corneal scars. There was a significant improvement in the point spread function after wearing rigid gas permeable contact lenses. This was reflected in the improvement of the retinal image quality that could provide some clues to how well a person can see.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Median</th>
<th>Range</th>
<th>IQR</th>
<th>(p^a,b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCVA Spectacle</td>
<td>0.4</td>
<td>0.7</td>
<td>0.3 (0.292 to 0.495)</td>
<td>.001</td>
</tr>
<tr>
<td>Spectacle</td>
<td>0.7</td>
<td>0.6</td>
<td>0.2 (0.62 to 0.8)</td>
<td>.001</td>
</tr>
<tr>
<td>Keratometric astigmatism Before</td>
<td>4.56</td>
<td>7.36</td>
<td>5.75 (3.67 to 6.56)</td>
<td>.001</td>
</tr>
<tr>
<td>RGPCL Before</td>
<td>1.06</td>
<td>0.98</td>
<td>0.41 (0.79 to 1.13)</td>
<td>.001</td>
</tr>
</tbody>
</table>

RGPCL = rigid gas permeable contact lens; IQR = interquartile range; BCVA = best corrected visual acuity

\(^a\)Wilcoxon signed-rank test.

\(^b\)\(P < .05\) is significant.

Figure 1. Comparison of best corrected visual acuity (BCVA) with spectacles and rigid gas permeable contact lenses (RGPCLs).
The different corneal aberrations were evaluated before and after wearing rigid gas permeable contact lenses. There was a significant improvement in lower order aberrations, second order aberrations, and root mean square. Dorronsoro et al.\(^{15}\) reported that root mean square decreased from 1.36 to 0.46 m for patients with higher dominance (second order and higher). This improvement was coincident with the improvement in our study, decreasing from 1.5 to 0.59.

The spherical aberrations in our study did not differ significantly after wearing rigid gas permeable contact lenses, but the value of spherical aberrations moved toward zero and the negative values. The explanation was that there was a compensation of the spherical aberration induced by the contact lens and the tear lens meniscus between the back surface of the contact lens and the anterior corneal surface.\(^{15}\)

The optical performance of rigid gas permeable contact lenses has been demonstrated to be effective in the visual rehabilitation of children with traumatic corneal lacerations and prevention of amblyopia. The study regimen of rigid gas permeable contact lenses use was effective in wearing lenses for 6 months of follow-up. Corneal topography was an objective tool for detecting optical disorders compared to visual acuity tests.

### REFERENCES


### TABLE 2

<table>
<thead>
<tr>
<th>Aberration</th>
<th>Median</th>
<th>Range</th>
<th>IQR</th>
<th>(p^{ab})</th>
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</thead>
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<tr>
<td>Lower order</td>
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<td></td>
<td></td>
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<tr>
<td>Before</td>
<td>1.14</td>
<td>2.11</td>
<td>1.39 (0.91 to 1.68)</td>
<td>.001</td>
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<tr>
<td>After</td>
<td>0.34</td>
<td>0.81</td>
<td>0.22 (0.24 to 0.44)</td>
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<tr>
<td>Higher order</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Before</td>
<td>0.67</td>
<td>1.14</td>
<td>0.37 (0.51 to 0.84)</td>
<td>.008</td>
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<tr>
<td>After</td>
<td>0.39</td>
<td>0.67</td>
<td>0.37 (0.32 to 0.56)</td>
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<tr>
<td>Root mean square</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>1.45</td>
<td>1.80</td>
<td>1 (1.23 to 1.85)</td>
<td>.001</td>
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<tr>
<td>After</td>
<td>0.52</td>
<td>0.67</td>
<td>0.31 (0.46 to 0.71)</td>
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<tr>
<td>Point spread function</td>
<td></td>
<td></td>
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<td>.001</td>
</tr>
<tr>
<td>Before</td>
<td>0.08</td>
<td>0.10</td>
<td>0.06 (0.07 to 0.11)</td>
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<tr>
<td>After</td>
<td>0.18</td>
<td>0.15</td>
<td>0.07 (0.15 to 0.20)</td>
<td></td>
</tr>
</tbody>
</table>

RGPCL = rigid gas permeable contact lens; IQR = interquartile range

\(^{a}\)Wilcoxon signed-rank test.

\(^{b}\)\(p < .05\) is significant.
Figure A. Case 1. (A) Slit-lamp photograph of a 10-year-old boy with a central scar. (B) Wearing a rigid gas permeable contact lens. (C and D) Summary photograph plates of Zernike polynomials before and after lens wearing. (E and F) Summary photograph plates of point spread function, root mean square, higher order aberrations, and limits of agreement before and after lens wearing.
Figure B. Case 5. (A) Slit-lamp photograph of a 6-year-old girl with a paracentral scar. (B) Wearing a rigid gas permeable contact lens. (C and D) Summary photograph plates of Zernike polynomials before and after lens wearing. (E and F) Summary photograph plates of point spread function, root mean square, higher order aberrations, and limits of agreement before and after lens wearing.
Figure C. Case 6. (A) Slit-lamp photograph of a 9-year-old boy with a peripheral scar. (B) Wearing a rigid gas permeable contact lens. (C and D) Summary photograph plates of Zernike polynomials before and after lens wearing. (E and F) Summary photograph plates of point spread function, root mean square, higher order aberrations, and limits of agreement before and after lens wearing.