

Orthokeratology practice in children in a university clinic in Hong Kong*

Clin Exp Optom 2008

DOI:10.1111/j.1444-0938.2008.00259.x

Ben Chan BSc (Hons) Optom

Pauline Cho PhD, FAAO

Sin Wan Cheung MPhil, FAAO

School of Optometry, The Hong Kong Polytechnic University, Hong Kong SAR, China

E-mail: soben@polyu.edu.hk

Purposes: The aim of this study was to analyse clinical data of children undergoing orthokeratology (ortho-k) and to investigate patients'/parents' perspective on ortho-k via telephone interviews.

Methods: Clinical records of children undergoing ortho-k from a university optometry clinic were reviewed and the effects of ortho-k on refraction, vision and cornea were investigated. A telephone interview was conducted to solicit patients'/parents' perspective of the treatment.

Results: One hundred and eight files were reviewed. Median age of the children was nine years (range six to 15); mean (\pm SD) pre-treatment refractive sphere was -3.56 ± 1.49 D and the median refractive cylinder was -0.50 D (range zero to -4.25 D). Significant refractive spherical reduction (58 per cent), improvement in unaided vision and corneal topographical changes were noted after only one night of wear. No significant change in astigmatism was found. Corneal staining was the most commonly observed complication with ortho-k and more than 80 per cent of patients were advised to apply ocular lubricants to loosen the lens before lens removal. Ortho-k was mainly undertaken for myopic control and about 90 per cent of the respondents reported good/very good unaided vision after ortho-k and ranked the treatment as satisfactory or very good. Lens binding and ocular discharge were the most frequently reported problems during the treatment.

Conclusion: Under close monitoring, overnight ortho-k is effective and safe for reducing low to moderate myopia and the treatment is well accepted by the children.

Submitted: 27 February 2007

Revised: 4 November 2007

Accepted for publication: 7 November 2007

Key words: corneal staining, corneal topographical changes, myopic reduction, ocular lubricants, orthokeratology, unaided vision

The effectiveness of overnight orthokeratology (ortho-k) in flattening the cornea and temporarily reducing myopia has been widely documented.¹⁻⁶ A significant

myopic reduction is noted even after a short period of lens wear,⁴⁻⁹ with more than 75 per cent of myopia being reduced within the first week^{4,5,7} in adult subjects. Walline and co-workers¹⁰ reported similar results in children wearing ortho-k lenses. The majority of ortho-k wearers in Hong Kong are children.¹ Therefore, it is necessary to investigate the efficacy of ortho-k

for myopic reduction and vision correction in children.

Overnight ortho-k was introduced in Hong Kong in 1997. In Hong Kong, the prevalence of myopia is high, from 11 per cent among seven-year-olds, up to 57 per cent among 12-year-olds and over 70 per cent among 17-year-olds.^{11,12} Most ortho-k wearers in this region are children

*Presented at the 2nd Asia Cornea and Contact Lens Conference, Hong Kong, China, 14-15 April 2005

Age range (median) (years)	6–15 (9)
Gender (male/female)	37/71
Mean \pm SD pre-treatment refractive sphere (range) (D)	-3.56 \pm 1.49 (-0.75 to -8.75)
Pre-treatment refractive cylinder range (median) (D)	0 to -4.25 (-0.50)

Table 1. Patient demographics (n = 108)

aiming at myopic control.¹³ Although a recent non-randomised clinical study has shown that ortho-k is effective in slowing the rate of myopic progression,¹⁴ there is a need to conduct a randomised study to confirm this finding. Understanding the clinical profile of children undergoing ortho-k will also be helpful to practitioners in better advising their patients/parents before starting the treatment.

The Optometry Clinic of The Hong Kong Polytechnic University has been providing ortho-k service since 1997. Our clinic employs full-time practitioners and in the late 1990s, two experienced ortho-k practitioners joined our clinic. All practitioners working in our clinic are independent and our clinic does not impose any constraints on the type of lenses fitted or the care systems used for their patients. The primary aim of this study was to conduct a retrospective review of the files of children undergoing overnight ortho-k in our clinic. Through a telephone interview, we also investigated the attitudes of patients and parents and satisfaction towards ortho-k, and identified the most commonly encountered problems during the treatment.

METHODS

The files of all children (younger than 16 years of age) undergoing ortho-k and fitted between April 2000 and November 2003 were reviewed. Only patients who had a pair of lenses used for at least six months and were still on ortho-k during the surveyed period were included in this study. One hundred and eight patients met these inclusion criteria. Demographical and clinical data were retrieved from their clinical files during the six-month treatment period. These included data

before the treatment, after the first night of lens wear and at approximately one week, two weeks, one month, three months and six months after wearing the lenses. Only information from the right eye was used for analysis. At each visit, a non-cycloplegic subjective refraction was performed, with the 'plus one blur test' to ensure relaxed accommodation. Corneal topographical data, including the flattest and steepest simulated keratometry readings, Q (asphericity, $Q = -e^2$) at 9.8 mm chord (flat meridian) and apical radius of curvature (Ro) were collected from the Medmont E300 corneal topographer (version 3.90, Medmont Pty. Ltd., Camberwell, Australia). Corneal staining with sodium fluorescein was recorded based on Efron's scale.¹⁵ Information on the brands of lenses used, the recommended lens care system and the number of lenses required to achieve the optimum ortho-k effect was also collected.

In addition, a telephone interview using a structured list of questions was conducted to obtain information on why the patients/parents chose ortho-k, how they knew about ortho-k, their most commonly encountered problem(s) with the procedure and their overall satisfaction with the treatment. The general questions in the questionnaire were to be answered by parents, while questions involving visual performance and satisfaction with the treatment were addressed to the children.

Treatment of data

As this was a retrospective study where data were collected from clinic files, most of the results were presented in numbers and percentages. Some data may be missing due to omissions in the patient's record at some visits. Data were analysed to determine the effect of overnight

ortho-k on refractive, visual and corneal changes. The relationships between changes in consecutive visits were also determined.

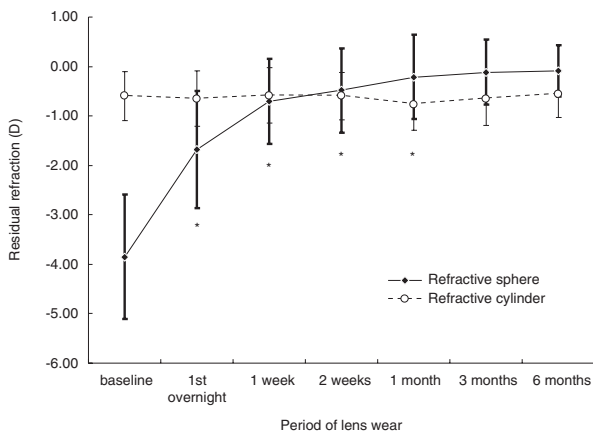
The distribution of refractive sphere, unaided vision and topographical parameters were not significantly different from normal (Kolmogorov-Smirnov D tests, $p > 0.05$), so parametric tests were used for statistical analyses. Repeated measures analysis of variance (ANOVA) was used to test for changes over the six-month treatment period; paired t tests with Bonferroni correction were used to test for differences between any two consecutive visits. For refractive sphere and topographical parameters (six comparisons), p-values less than 0.008 (0.05/6) and for unaided vision (five comparisons) p-values less than 0.01 (0.05/5) were considered as significant. The distributions of the data for the baseline and six-month refractive cylinder and six-month residual refractive sphere were significantly different from normal (Kolmogorov-Smirnov D tests, $p < 0.05$). For these and ordinal variables (for example, corneal staining), Friedman test and Spearman's correlation coefficients were used for analysis.

RESULTS

Table 1 presents the demographical data of 108 children whose files were reviewed. At the time of lens fitting, the median age of the wearers was nine years (range six to 15 years) and most of them were female (66 per cent).

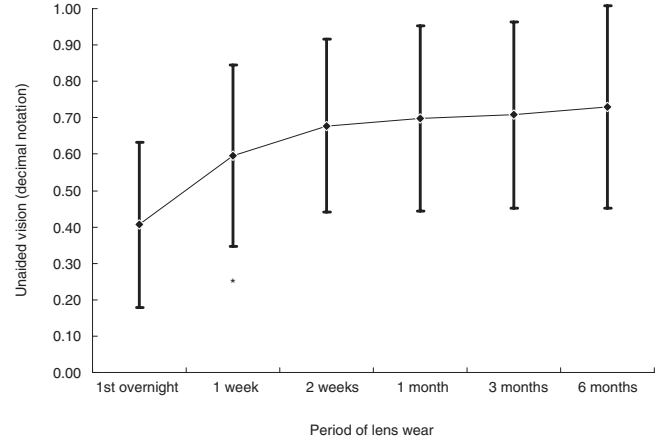
Refraction and unaided vision

The mean (\pm SD) pre-treatment refractive sphere was -3.56 ± 1.49 D and the median refractive cylinder was -0.50 D (range zero to -4.25 D). Only 27 patients had subjective refraction recorded at every visit. Changes in refractive sphere and cylinder during the six-month treatment period are shown in Figure 1. The refractive sphere after ortho-k treatment was significantly reduced when compared to the baseline data (repeated measures ANOVA, $F(6, 21) = 60.32$, $p < 0.001$) and the amount of reduction increased with the time of treatment. The largest refrac-



* $p < 0.001$ (the residual spherical refraction is significantly different compared with previous visit)

Figure 1. Residual subjective refractive errors at different visits during six months of lens wear (each error bar indicates one standard deviation) (n = 27)



* $p < 0.001$ (the unaided vision is significantly different compared with previous visit)

Figure 2. Unaided vision at different visits during six months of lens wear (each error bar indicates one standard deviation) (n = 29)

tive spherical reduction (58 per cent) was observed after the first night of lens wear and appeared to stabilise by the first month of wear (98 per cent) (paired t tests, $p < 0.008$). No further change was observed over subsequent visits (paired t tests, $p > 0.008$). The mean (\pm SD) myopia reduced from -3.88 ± 1.27 D (baseline) to -0.26 ± 0.83 D (one month). At the six-month visit, the mean residual refractive sphere was -0.09 ± 0.53 D. No significant reduction in refractive cylinder was found over the six-month treatment period (Friedman $X^2 = 8.24$, $p = 0.221$) (Figure 1).

For all patients with subjective refraction recorded at the six-month visit ($n = 108$), the residual refractive sphere and cylinder were significantly associated with the pre-treatment refractive sphere and cylinder, respectively (refractive sphere: Spearman $r = 0.39$, $p < 0.001$; refractive cylinder: Spearman $r = 0.44$, $p < 0.001$).

For patients with unaided vision recorded at all visits ($n = 29$), the mean unaided vision after the first night of lens wear was 0.41 ± 0.23 decimal (0.40 logMAR or Snellen 6/15) and continued to improve (repeated measures ANOVA, $F(5, 24) = 13.57$, $p < 0.001$) until after two weeks of lens wear (paired t test, $p < 0.01$).

No further improvement was observed ($p > 0.01$) thereafter, that is, among subsequent visits. The mean unaided vision for this group of patients at the two-week and six-month visits were 0.68 ± 0.24 decimal (0.18 logMAR or Snellen 6/9) and 0.73 ± 0.28 decimal (0.12 logMAR or Snellen 6/7.5), respectively (Figure 2).

For all patients who had unaided vision recorded at the six-month visit ($n = 103$), 58 per cent had unaided vision of 0.80 decimal (0.10 logMAR or Snellen 6/7.5) or better and for four per cent of the patients it was worse than 0.20 decimal (0.70 logMAR or Snellen 6/30), which was mainly due to the significant residual refractive error and lens decentration. The mean unaided vision at the six-month visit was significantly correlated to the residual refractive sphere (Spearman $r = 0.55$, $p < 0.001$) and cylinder (Spearman $r = 0.48$, $p < 0.001$). The mean UVA was also correlated to the pre-treatment refractive sphere and refractive cylinder, respectively (refractive sphere: Spearman $r = 0.53$, $p < 0.001$; refractive cylinder: Spearman $r = 0.28$, $p = 0.004$).

After six months of ortho-k treatment, 21 of the 108 patients (19 per cent), with mean residual refractive sphere of -1.64 ± 1.43 D required the aid of spectacles to obtain acceptable clear distance

vision during the daytime. On average, these patients also had significantly higher pre-treatment refractive sphere and cylinder than patients who did not require visual aids during the daytime (Table 2). Some patients with lower pre-treatment myopia (-3.50 D) also had significant residual refractive errors and required the aid of spectacles after the procedure.

Corneal responses

Table 3 summarises the corneal topographical changes over the six-month lens wear ($n = 73$). There were significant flattening in the simulated keratometry reading and Ro and significant change in Q after commencing ortho-k treatment (repeated measures ANOVA: flattest simulated keratometry reading: $F(6, 67) = 72.08$, $p < 0.001$; steepest simulated keratometry reading: $F(6, 67) = 57.89$, $p < 0.001$; Ro: $F(6, 67) = 184.34$, $p < 0.001$; Q: $F(6, 67) = 88.98$, $p < 0.001$). Maximum changes in corneal parameters were observed after the first night of lens wear, with stabilisation within two weeks of lens wear (paired t test, $p < 0.008$).

After the first overnight lens wear, corneal staining was observed in 41 per cent of patients (44 out of 108) and 74 per cent of staining recorded was within the central three millimetres of the cornea.

	Visual aid required (n = 21) mean ± SD	Visual aid not required (n = 87) mean ± SD	p-value Unpaired-t-test
Baseline refractive sphere (D)	-5.18 ± 1.30 (range -3.50 to -8.75)	-3.16 ± 1.26 (range -0.75 to -6.25)	<0.001
Baseline K _f (mm)	7.79 ± 0.15	7.81 ± 0.28	>0.05
Baseline K _s (mm)	7.48 ± 0.14	7.58 ± 0.24	>0.05
Baseline Ro (mm)	7.71 ± 0.40	7.73 ± 0.22	>0.05
Baseline Q	-0.43 ± 0.15	-0.43 ± 0.13	>0.05
Residual refractive sphere at 6 month (D)	-1.64 ± 1.43	-0.08 ± 0.48	<0.001
	Median (range)	Median (range)	Mann-Whitney U test
Baseline refractive cylinder (D)	-1.00 (0.00 to -4.25)	-0.50 (0.00 to -2.25)	<0.001

K_f = Flattest simulated keratometry reading; K_s = Steepest simulated keratometry reading; Ro = Apical radius of curvature; Q = Asphericity value

Table 2. Ocular parameters of patients with or without need of visual aid during the daytime after orthokeratology

	Baseline	First overnight	1 week	2 weeks	1 month	3 months	6 months
K _f (mm)	43.38 ± 1.52	42.18 ± 1.35	42.01 ± 1.42	41.72 ± 1.47	41.71 ± 1.61	41.55 ± 1.56	41.61 ± 1.55
K _s (mm)	44.79 ± 1.65	43.80 ± 1.58	43.40 ± 1.63	43.11 ± 1.67	43.10 ± 1.71	43.09 ± 1.68	43.14 ± 1.67
Ro (mm)	7.70 ± 0.26	8.06 ± 0.37	8.12 ± 0.29	8.14 ± 0.32	8.19 ± 0.33	8.20 ± 0.32	8.20 ± 0.35
Q	-0.42 ± 0.13	0.18 ± 0.22	0.14 ± 0.12	0.11 ± 0.13	0.09 ± 0.14	0.08 ± 0.15	0.07 ± 0.17

K_f = Flattest simulated keratometry reading; K_s = Steepest simulated keratometry reading; Ro = Apical radius of curvature; Q = Asphericity value

Table 3. Summary of corneal changes (mean ± SD) at different visits over 6 months of ortho-k lens wear (n = 73)

The incidence of corneal staining decreased over the course of treatment from 41 per cent after the first overnight lens wear to 25 per cent at the six-month visit. Most staining (84 per cent) at all visits was graded as mild (Grade 1 or less); 13 per cent were graded as Grade 2 and only three per cent were graded as Grade 3 or Grade 4. Patients who had Grade 2 or higher level of staining in the central cornea were advised to cease lens wear until the condition subsided. Figures 3 and 4 summarise the levels and locations of staining recorded over the six-month treatment period. None of the patients had corneal staining at every visit. The frequency of staining was significantly associated with pre-treatment spherical refractive error (Spearman $r = -0.25, p = 0.01$), though the association was not very strong.

Lens designs and care regimen used

DreimLens (Taiwan Macro Vision Group, Taiwan) was the most commonly used lens design (80 per cent), followed by the eLens (E&E Optics Asia Ltd, Hong Kong) (14 per cent). Only 1.4 per cent of patients used a custom-made lens design. The lens material used for all patients was Boston XO (Polymer Technology Corporation, Rochester, NY, USA).

Most patients (76 per cent) were advised to use a separate daily cleaner and disinfecting solution. Boston Advance Cleaner and Boston Advance Conditioning Solution (Polymer Technology Corporation, Rochester, NY, USA) were the most commonly recommended care solutions. The remaining patients (24 per cent) were prescribed multipurpose solution: 22.8

per cent used Unique pH (Alcon Laboratories Inc, Fort Worth, TX, USA) and one per cent used Boston Simplus (Polymer Technology Corporation, Rochester, NY, USA). All patients were instructed to use non-preserved saline for rinsing the lenses after cleaning.

More than 80 per cent of patients (89 out of 108) were advised to use ocular lubricants before lens removal in the morning, and about 58 per cent were advised to use a single-dose formulation. The most commonly recommended single-dose ocular lubricant was Tear Naturale Free (Alcon Laboratories Inc, Fort Worth, TX, USA).

Almost all reviewed patients (97 per cent) used a suction holder to aid lens removal. Only three per cent of patients removed lenses with their fingers.

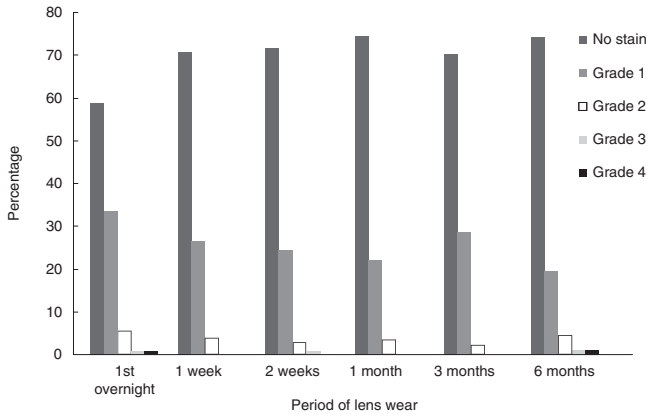


Figure 3. Corneal staining recorded at different visits during six months of lens wear (first overnight, $n = 107$; 1 week, $n = 102$; 2 weeks, $n = 106$; 1 month, $n = 86$; 3 months, $n = 91$; 6 months, $n = 108$)

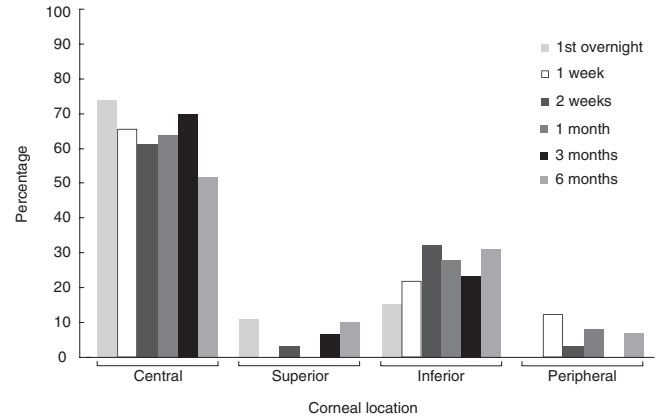


Figure 4. Corneal staining at different locations during six months of lens wear (first overnight, $n = 107$; 1 week, $n = 102$; 2 weeks, $n = 106$; 1 month, $n = 86$; 3 months, $n = 91$; 6 months, $n = 108$)

Number of lenses

For patients with myopia greater than 4.00 D ($n = 40$), a 'stepwise' fitting protocol (see Discussion) was applied, so the number of lenses used was dependent on the amount of pre-treatment myopia. For patients with myopia equal to or lower than 4.00 D ($n = 68$), the first pair of lenses prescribed aimed for full correction. The majority of these patients (73.5 per cent) achieved optimum ortho-k effect using only one pair of lenses. All of these patients had good lens centration, as shown in their topographical maps, and the mean myopic reduction was within 0.25 D of the target. About 16 per cent of the patients required two pairs of lenses and 7.4 per cent required three pairs of lenses to achieve the optimum ortho-k effect. Two patients (three per cent) were unable to achieve satisfactory result with vision even after four pairs of lenses. The number of lenses required by patients with higher myopia (greater than 4.00 D) to achieve optimum myopic reduction was significantly associated with the baseline refractive sphere (Spearman $r = -0.33$, $p = 0.005$) but was not associated with refractive cylinder, corneal curvature, Ro and Q (Spearman $-0.07 < r < 0.01$, $p > 0.05$).

Telephone survey

Ninety-four patients agreed to a telephone interview. The primary reason for undergoing ortho-k was myopic control (87 per cent). More than 50 per cent heard about ortho-k from their friends and relatives who had children undergoing the treatment. About 30 per cent learned about the treatment from their optometrists, 12 per cent from newspapers and one per cent from public seminars.

Almost 90 per cent of those interviewed reported good or very good post-ortho-k unaided distance vision. Fifty-seven per cent of the patients reported that the quality of unaided vision could be maintained until the end of the day and the rest reported noticeable deterioration of distance vision about 12 hours (median) after lens removal (range: four to 16 hours).

The most frequently reported non-visual problems were lens binding (44 per cent) and ocular discharge in the morning (40 per cent), followed by tearing (21 per cent), redness (18 per cent) and discomfort (12 per cent).

Of the respondents, 89 per cent (84/94) ranked the treatment as good or very good, 8.5 per cent (8/94) ranked the treatment as acceptable and two per cent

ranked the treatment as poor. The last two had discontinued lens wear (after more than six months) due to discomfort and unacceptable post-ortho-k vision even after modifications to lens fittings.

DISCUSSION

Demographics

This retrospective study collected an extensive body of data of children who started ortho-k treatment in a university clinic during the first three years of this century. In agreement with our previous study,¹³ most wearers (more than 90 per cent) were children, probably reflecting the prevalence and severity of myopia in Chinese children. Our patients included children with high myopia (6.00 D or greater) and astigmatism (1.50 D or greater), although conventional clinical wisdom would suggest that such patients are likely to be relatively unsuccessful in ortho-k, in terms of leaving significant amounts of refractive error and poor unaided vision after the treatment. The parents of these patients requested ortho-k for myopic control, even though they were informed of the necessity of wearing spectacles to correct residual

refractive errors to achieve satisfactory distance vision after the procedure.

Refraction and unaided vision

The greatest change in refractive sphere was observed after the first night of lens wear. Similar results have been reported.^{4-7,9} Our results also indicate that although there was a continued reduction in refractive sphere until after one month of lens wear, visual improvement reached optimum level after two weeks of lens wear. At six months, the average unaided vision of our patients improved to the maximum level of 0.74 decimal (equivalent to 0.13 logMAR or Snellen 6/8), however, this finding is relatively poorer than the average 0.02 logMAR or better reported in most studies.⁴⁻⁷ Among our patients, 42 had pre-treatment refractive sphere of more than 4.00 D and 11 patients had pre-treatment refractive cylinder of more than 1.50 D. If we excluded these patients, unaided vision was improved to a mean of 0.88 decimal (equivalent to 0.06 logMAR or Snellen 6/7). Consistent with previous reports,^{3,4,7,16} unaided vision after ortho-k is significantly correlated with the amount of pre-treatment and residual refractive errors, including spherical and cylindrical errors. These subjects were advised to use spectacles to achieve good distance vision after the procedure.

Ortho-k has been reported to be ineffective in reducing refractive cylindrical power.^{3-6,16} The present survey agrees with these reports. No significant refractive cylindrical change was noted during the six-month ortho-k treatment, however, some researchers have reported changes in with-the-rule corneal astigmatism in their ortho-k subjects.¹⁷⁻¹⁹

Corneal responses

Consistent with previous studies,^{2,6-8,20} we found that on average, the corneal shape changed from prolate to oblate over a 9.8 mm corneal chord after a single night of lens wear. Therefore, it is not surprising to find significant correlations between corneal shape changes, including simulated keratometry readings, apical radius of curvatures and refractive

changes. Several authors have reported similar clinical findings in overnight ortho-k.^{4,7,14,20}

The safety of overnight ortho-k for myopic reduction is still a controversial issue despite the development of hyperoxygen permeable lens materials and innovative lens designs, which allow greater myopic reduction and more predictable results.^{7,20} Safety is a major concern, as there have been several reports of serious corneal complications associated with ortho-k and most of these cases involved children.²¹⁻²⁴ Corneal staining is a common complication in any type of contact lens wear and the incidence of staining is increased in ortho-k lens wear.²⁵ Corneal staining in ortho-k may be due to thinning of the central corneal epithelium, improper lens fitting, corneal hypoxia, hyper-sensitivity to contact lens solution, mechanical abrasion due to the build-up of deposits on the back surface of the lens, lens binding and incorrect removal of a bound lens on waking. Our results show that almost one half of the patients (41 per cent) exhibited corneal staining after the first night of ortho-k lens wear. The incidence of staining decreased to 25 per cent at the six-month visit. Although the incidence of corneal staining decreased with the period of lens wear, most of the staining (74 per cent) was in the central cornea. Central (as opposed to peripheral) corneal staining is of greater concern as the disruption of central corneal integrity is more likely to lead to sight-threatening complications, if accompanied by improper use and care of lenses and accessories. Hence in ortho-k practice, the level of central corneal staining that is regarded as clinically significant should be more stringent. In the present study, most staining (84 per cent) were graded as clinically insignificant (that is, lower than Grade 2) and no clinical action was taken for these patients. Patients who had Grade 2 or higher level of staining in the central three millimetres of the cornea were advised to cease lens wear until the condition subsided and none of them required medical treatment. A few studies have also reported the incidence

of corneal staining after the commencement of overnight ortho-k treatment.^{3,10} Rah and co-workers³ found that the majority of their subjects did not exhibit significant corneal staining at the morning visits. Walline and co-workers¹⁰ reported that more than one half of their children exhibited corneal staining in the morning immediately after lens removal. As the severity of the staining was not clinically significant, they did not recommend discontinuation of lens wear. We also noted that the incidence of corneal staining tended to be higher when aiming for a higher target.

Lens designs and care regimens used

DreimLens was the most frequently used brand of lenses in our clinic in the early 2000s, as it was the first lens design introduced into Hong Kong for overnight ortho-k therapy. The trend has changed with time as many different lens designs have since been introduced into this region.

The majority of patients were instructed by their optometrists to use a separate lens care system, that is, daily cleaner with rubbing of lenses, saline for rinsing and disinfecting solution for storing the lenses, instead of a bottle of multi-purpose solution for cleaning, rinsing and disinfecting. Single bottle systems are less complex and more convenient to use, and are believed to facilitate compliance. In terms of efficacy, a single bottle solution serving the functions of cleaning, rinsing and disinfecting is essentially a compromise solution and some multipurpose solutions can cause irritation when they are in contact with the eye. Ortho-k involves sleeping with high Dk lenses and hence, it is desirable to have the lenses as clean as possible and any chance of solution sensitivity should be avoided. In our clinic, we recommend rubbing the lenses with a daily cleaner and rinsing the lenses with normal saline after cleaning and before insertion. Several disinfecting solutions are available for rigid gas permeable lenses and the majority of these solutions are compatible with ortho-k lenses.

It should be noted that the brands of lenses and solutions used do not necessarily reflect the effectiveness of these brands over others. The preference for lenses or disinfecting solutions to prescribe to the patients depends on the individual practitioner and/or the availability in the stock of a particular brand in our clinic. Our results on the preferred solutions to be prescribed to patients only highlighted the importance placed by ortho-k practitioners in our clinic on the use of daily cleaner and normal saline in the care of ortho-k lenses.

The use of an ocular lubricant is optional in overnight ortho-k treatment, as dryness is not a problem during sleep, however, due to the high incidence of lens binding associated with overnight ortho-k, more than 80 per cent of patients were advised to apply an ocular lubricant to aid lens removal in the morning. Patients were instructed to apply an ocular lubricant to mobilise the lens before removal, thereby ensuring safety. Most patients were advised to use single dosage formulations, to avoid possible problems of hypersensitivity to the preservatives present in multi-dosage formulations, and to minimise contamination, however, only about 50 per cent of the patients used single dosage ocular lubricants.

The majority of patients/parents were taught to use a suction holder to aid lens removal. This procedure is much easier to learn than using fingers, especially for patients/parents who have no previous experience in rigid lens wear. A recent study²⁶ has shown a high contamination rate of suction holders in ortho-k lens wearers. Dependency on suction holders for removal of ortho-k lenses is not to be encouraged as patients/parents may not know how to remove the lenses properly if they lose the suction holder. There is a danger of serious corneal damage when a suction holder is used to remove a lens that is not on the cornea. Also, lens binding is common in overnight ortho-k and forcefully removing a bound lens can cause severe injuries to the cornea and the situation may be exacerbated if a suction holder is used to aid removal. To reduce the risk of microbial infection in

ortho-k lens wear and to increase safety during removal, our clinic has commenced teaching parents/patients to remove ortho-k lenses with their fingers. A suction holder is given for emergency use only. In cases where a suction holder is necessary, daily cleaning, proper storage, weekly disinfection and regular replacement of the suction holder should be emphasised.

Number of lenses used

Many of our patients (73.5 per cent) with pre-treatment myopia equal to or lower than 4.00 D (n = 68) required only one pair of lenses to achieve the optimum ortho-k effect. In our clinic, for patients with myopia greater than 4.00 D, a 'stepwise' fitting protocol is used, that is, the first pair of lenses target a myopic reduction of 4.00 D, and provided the corneal health and lens centration are good, the target of reduction is increased progressively (usually in 1.00 D steps) until either the desired refractive change is achieved (usually within one month) or the cornea does not respond to further changes. Therefore, the greater the amount of myopia, the more lenses are required to achieve optimum myopic reduction. Our clinicians believe that a stepwise protocol for higher myopic reduction is prudent, as it is less aggressive and allows monitoring of the cornea with a lower target lens before attempting a higher target.

Telephone interview

Generally, myopic control is the main reason for parents enrolling their children for ortho-k treatment at our clinic. Most of them learned of the treatment from other parents, friends or relatives whose children had received the treatment. Some were recommended from their optometrists.

Most of the interviewed patients reported good post-ortho-k unaided vision and no visual problems during waking hours. About one half of the patients reported a deterioration of post-ortho-k vision towards the end of day, mostly after about 12 hours (median) (range: four to 16 hours) of no lens wear. The regression of the effect of ortho-k has been studied

by Mountford²⁷ and Rah and co-workers.³ Mountford²⁷ conducted a 90-day retrospective study on 48 subjects and found that the regression of apical corneal power over approximately an eight-hour period was 0.50 to 0.75 D. Similarly, Rah and co-workers³ also reported an amount of 0.25 to 0.50 D daytime regression in spherical equivalent manifest refraction after one-month overnight ortho-k treatment. These two studies used adult subjects so it is uncertain whether the regression rate in children would be the same. Further work in Hong Kong is investigating the daytime regression of ortho-k effect in children.

More than 40 per cent of the respondents ranked lens binding as the most common non-visual problem they experienced. Lens binding associated with overnight ortho-k has been reported previously,^{6,28} and the suggested cause was the increase of tear viscosity during sleep with the lenses, resulting in a fluid adhesion force between the lens and the cornea. Therefore, the level of binding is patient-dependent^{29,30} and may not be resolved by improving the lens fit.²⁸ Improper removal of a bound lens can cause serious damage to the cornea, especially if a suction holder is used. Proper patient education on how to free a bound lens before removal is of vital importance not only at the visit before lens delivery but should be reinforced at each after-care visit.

About 90 per cent of the interviewed patients ranked the treatment as good or very good. Previous surveys using the National Eye Institute Refractive Error Quality of Life (NEI-RQL 42) instrument to evaluate the levels of patient satisfaction with overnight ortho-k showed that there were either no differences³¹ or better²⁵ quality-of-life indices in overnight ortho-k compared to 30-day continuous wear silicone hydrogel lenses or daily disposable hydrogel lenses, respectively. This indicates that overnight ortho-k is well accepted as a means for myopic correction.

SUMMARY

This study provides comprehensive information and a quick overview on the characteristics of the children undergoing ortho-k in a university clinic in Hong Kong during the first three years of this century. In general, most children were undergoing ortho-k for myopic control. Overnight ortho-k using modern reverse geometry lens designs is an effective non-surgical way for the reduction of low to moderate myopia and improvement in unaided vision. Spherical ortho-k lens designs are not effective for the reduction of astigmatism. Most ortho-k effects occur within the first week of lens wear with the greatest effect observed after the first night of wear. Refractive change in ortho-k is associated with corneal topographical changes. Apart from occasional corneal staining, we had no record of significant corneal complications in our patients. The majority required only one pair of lenses to achieve an optimum effect. Referral from friends was the major source of introduction to ortho-k. Most of the surveyed wearers reported their post-treatment unaided distance vision to be good or very good and none reported problems at near. Improved unaided vision after ortho-k lens wear was reported to be maintained over 12 hours after lens removal. For safety, patients should be advised and trained to use finger manipulation instead of a suction holder to remove their lenses. It is essential for all ortho-k practitioners to strongly emphasise proper removal of bound ortho-k lenses with the use of ocular lubricant at delivery of ortho-k lenses and to reinforce such instructions during further visits.

REFERENCES

1. Cho P, Cheung SW, Edwards MH, Fung J. An assessment of consecutively presenting orthokeratology patients in a Hong Kong based private practice. *Clin Exp Optom* 2003; 86: 331–338.
2. Maldonado-Codina C, Efron S, Morgan P, Hough T, Efron N. Empirical versus trial set fitting systems for accelerated orthokeratology. *Eye Contact Lens* 2005; 31: 137–147.
3. Rah MJ, Jackson JM, Jones LA, Marsden HJ, Bailey MD, Barr JT. Overnight orthokeratology: preliminary results of the Lenses and Overnight Orthokeratology (LOOK) study. *Optom Vis Sci* 2002; 79: 598–605.
4. Soni PS, Nguyen TT, Bonanno JA. Overnight orthokeratology: visual and corneal changes. *Eye Contact Lens* 2003; 29: 137–145.
5. Sorbara L, Fonn D, Simpson T, Lu F, Kort R. Reduction of myopia from corneal refractive therapy. *Optom Vis Sci* 2005; 82: 512–518.
6. Tahhan N, Du Toit R, Papas E, Chung H, La Hood D, Holden BA. Comparison of reverse-geometry lens designs for overnight orthokeratology. *Optom Vis Sci* 2003; 80: 796–804.
7. Nichols JJ, Marsich MM, Nguyen M, Barr JT, Bullimore MA. Overnight orthokeratology. *Optom Vis Sci* 2000; 77: 252–259.
8. Sridharan R, Swarbrick H. Corneal response to short-term orthokeratology lens wear. *Optom Vis Sci* 2003; 80: 200–206.
9. Swarbrick HA, Wong G, O'Leary DJ. Corneal response to orthokeratology. *Optom Vis Sci* 1998; 75: 791–799.
10. Walline JJ, Rah MJ, Jones LA. The Children's Overnight Orthokeratology Investigation (COOKI) pilot study. *Optom Vis Sci* 2004; 81: 407–413.
11. Edwards MH, Lam CS. The epidemiology of myopia in Hong Kong. *Ann Acad Med Singapore* 2004; 33: 34–38.
12. Lam CS, Goh WS. The incidence of refractive errors among school children in Hong Kong and its relationship with the optical components. *Clin Exp Optom* 1991; 74: 97–103.
13. Cho P, Cheung SW, Edwards MH. Practice of orthokeratology by a group of contact lens practitioners in Hong Kong. Part 1. General overview. *Clin Exp Optom* 2002; 85: 365–371.
14. Cho P, Cheung SW, Edwards M. Longitudinal Orthokeratology Research In Children (LORIC) in Hong Kong: a pilot study on refractive changes and myopic control. *Curr Eye Res* 2005; 30: 71–80.
15. Efron N. Grading scales for contact lens complications. *Ophthalmic Physiol Opt* 1998; 18: 182–186.
16. Cheung SW, Cho P. Subjective and objective assessments of the effect of orthokeratology: a cross-sectional study. *Curr Eye Res* 2004; 28: 121–127.
17. Lu F, Jiang J, Qu J, Jin W, Mao X, Shen Y. Clinical study of orthokeratology in young myopic adolescents. *ICLC* 1999; 26: 113–116.
18. Mountford J, Pesudovs K. An analysis of the astigmatic changes induced by accelerated orthokeratology. *Clin Exp Optom* 2002; 85: 284–293.
19. Hiraoka T, Furuya A, Matsumoto Y, Okamoto F, Sakata N, Hiratsuka K, Kakita T, Oshika T. Quantitative evaluation of regular and irregular corneal astigmatism in patients having overnight orthokeratology. *J Cataract Refract Surg* 2004; 30: 1425–1429.
20. Mountford J. An analysis of the changes in corneal shape and refractive error induced by accelerated orthokeratology. *ICLC* 1997; 24: 128–144.
21. Young AL, Leung AT, Cheng LL, Law RW, Wong AK, Lam DS. Orthokeratology lens-related corneal ulcers in children: a case series. *Ophthalmology* 2004; 111: 590–595.
22. Tseng CH, Fong CF, Chen WL, Hou YC, Wang JJ, Hu FR. Overnight orthokeratology-associated microbial keratitis. *Cornea* 2005; 24: 778–782.
23. Hsiao CH, Lin HC, Chen YF, Ma DH, Yeh LK, Tan HY, Huang SC, Lin KK. Infectious keratitis related to overnight orthokeratology. *Cornea* 2005; 24: 783–788.
24. Sun X, Zhao H, Deng S, Zhang Y, Wang Z, Li R, Luo S, Jin X. Infectious keratitis related to orthokeratology. *Ophthalmic Physiol Opt* 2006; 26: 133–136.
25. Lipson MJ, Sugar A, Musch DC. Overnight corneal reshaping versus soft disposable contact lenses: vision-related quality-of-life differences from a randomized clinical trial. *Optom Vis Sci* 2005; 82: 886–891.
26. Boost MV, Cho P. Microbial flora of tears of orthokeratology patients, and microbial contamination of contact lenses and contact lens accessories. *Optom Vis Sci* 2005; 82: 451–458.
27. Mountford J. Retention and regression of orthokeratology with time. *ICLC* 1998; 25: 59–64.
28. Chui WS, Cho P. Recurrent lens binding and central island formations in a fast-responding orthokeratology lens wearer. *Optom Vis Sci* 2003; 80: 490–494.
29. Swarbrick HA, Holden BA. Rigid gas-permeable lens adherence: a patient-dependent phenomenon. *Optom Vis Sci* 1989; 66: 269–275.
30. Swarbrick HA, Holden BA. Rigid gas permeable lens binding: significance and contributing factors. *Am J Optom Physiol Opt* 1987; 64: 815–823.
31. Richey ER, Barr JT, Mitchell GL. The Comparison of Overnight Lens Modalities (COLM) study. *Eye Contact Lens* 2005; 31: 70–75.

Corresponding author:

Ben Chan

School of Optometry

The Hong Kong Polytechnic University

Hong Kong SAR

CHINA

E-mail: soben@polyu.edu.hk