·综　　述·

角膜塑形术后治疗区偏位对视觉质量和近视控制效果的影响

李晶欣　综述　王凯　审校

北京大学人民医院眼科　北京大学人民医院眼视光中心　眼病与视光医学研究所　视网膜脉络膜疾病诊治研究北京市重点实验室　北京大学医学部眼视光学院，北京 100044

通信作者：王凯，Email：wang_kai@bjmu.edu.cn

【摘要】　近年来，青少年近视发病率逐年攀升，如何有效地控制近视发展成为公共卫生领域的研究热点。角膜塑形术以其安全性好、控制效果明确、对日常生活影响小的优点已广泛应用于近视防控领域。角膜塑形术将角膜塑形出相对平坦的中央治疗区和相对陡峭的周边离焦区。角膜塑形术后治疗区的偏位是临床中可观察到的常见现象，以向颞下方偏位最为常见。研究表明，角膜前表面的不对称性越大、基线近视度数越高、镜片直径越小，塑形术后治疗区偏位距离就越大。此外，治疗区的偏位与镜片的重力作用、Bell 现象、眼睑作用等因素也有关。较大的偏位距离会导致塑形术后的视觉质量下降，主要表现为重影、眩光等临床症状，可能是由于彗差的增加所引起。治疗区的偏位相对正位会达到较好的近视控制效果，这与瞳孔区内近视离焦明显增大有关。明显的治疗区偏位可以通过增加矢高、调整定位弧、加大镜片直径或改用环曲面镜片的方法来解决。本文就角膜塑形术后影响治疗区偏位的因素以及治疗区偏位对视觉质量和近视控制效果的影响进行综述，探讨解决治疗区偏位的方法，对临床配镜与换镜进行指导。

【关键词】　近视；治疗；角膜塑形术；治疗区偏位；影响因素；视觉质量

基金项目：国家自然科学基金项目（82171092）；首都卫生发展科研专项项目（2022-1G-4083）

DOI：10.3760/cma.j.cn115989-20211024-00581

Effect of the decentration of the treatment zone on visual quality and myopia control after overnight orthokeratology lens wear

Li Jingxin, Wang Kai

Department of Ophthalmology & Clinical Centre of Optometry, Peking University People´s Hospital, Eye Diseases and Optometry Institute, Beijing Key Laboratory of Diagnosis and Therapy of Retinal and Choroid Diseases, College of Optometry, Peking University Health Science Center, Beijing 100044, China

Corresponding author: Wang Kai, Email: wang_kai@bjmu.edu.cn

[Abstract]　In recent years, the incidence of myopia in adolescents has been increasing year by year, and how to effectively control the development of myopia has become a research hotspot in the field of public health. The orthokeratology lens has been widely used in myopia control because of its great safety, reliability, and little impact on daily life. The cornea after overnight orthokeratology lens wear can be divided into a relatively flat central treatment zone and a steep peripheral defocus zone. Decentration of the treatment zone is common in clinical practice and is mainly located in the inferior temporal quadrant. Studies have shown that the greater the asymmetry of the anterior corneal surface, the greater the degree of myopia at baseline, and the smaller the diameter of the lens, the greater the deviation of the treatment zone. In addition, decentration of the treatment zone is also related to the gravity of the lens, Bell phenomenon, eyelid, and so on. Large decentration of the treatment zone results in decreased visual quality, including clinical symptoms such as ghosting vision and glare, which may be caused by the increase in comatic aberration. Decentration of the treatment zone may have better myopia control, due to the increase of defocus in the pupil area. Obvious decentration of the treatment zone can be solved by increasing the sagittal height, adjusting the alignment curve, increasing the lens diameter and switching to toric lenses, etc. This article reviewed the factors that affect the decentration of the treatment zone after overnight orthokeratology wear, the influence of decentration on visual quality and myopia control, and the methods to help solve the problems caused by the decentration of the treatment zone, which can guide fitting and replacement of orthokeratology lenses.

[Key words]　Myopia; Therapy; Orthokeratologic procedures; Decentration of the treatment zone; Influencing factors; Visual quality

Fund program: National Natural Science Foundation of China (82171092); Capital's Funds for Health Improvement and Research (2022-1G-4083)

DOI: 10.3760/cma.j.cn115989-20211024-00581

据统计,2000 年有 14 亿人患有近视,预计到 2050 年这一数字将达到 48 亿[1],近视已成为世界第六大导致视力丧失的原因[2]。角膜塑形术具有可逆、安全、个性化设计等优点,是当前控制近视效果较明确的治疗方法,可以使眼轴增长速度减缓 33%~57%[3-5]。大部分研究表明角膜塑形术控制近视可能与周边角膜变陡、屈光度增加,相应地改变周边视网膜离焦状态有关[6-7]。几项研究均证明角膜塑形术可以将周边屈光度从远视离焦转变为近视离焦[8-10]。角膜塑形镜的设计通常分为四弧或五弧,包括最中央的基弧、反转弧、1 个或多个定位弧以及周边弧。对于近视矫正,基弧比角膜平 k 更平坦,以提供所需的屈光矫正总量以及约 0.75 D 的过矫量;反转弧提供抽吸作用,形成相对陡峭的周边离焦区;定位弧对于塑形镜的定位和镜片松紧影响最大;周边弧使镜片边缘翘起,以帮助泪液交换[6-7,11]。研究表明,角膜前表面不对称性、近视屈光度数、镜片的设计以及眼睑张力作用等诸多原因可能与治疗区偏位有关[12-19]。治疗区偏位与角膜塑形术后的并发症,如重影、复视、角膜上皮损伤等以及近视控制效果有密切关系[20-25]。本文就近视患者角膜塑形术后治疗区偏位的影响因素及治疗区偏位对视觉质量和近视控制效果的影响进行综述。

1 角膜塑形术后治疗区偏位的影响因素

角膜塑形术后治疗区偏位的概念来自于角膜准分子激光术后激光消融中心与入瞳中心的不一致[26-27]。Tsai 等[28]对角膜准分子激光术后切削中心的偏位进行分级,将激光消融中心距瞳孔中心<0.5 mm 定义为轻度偏位,0.5~1.0 mm 为中等偏位,>1.0 mm 为严重偏位,此分级也沿用到大部分角膜塑形术后治疗区偏位的研究中。

角膜塑形术后治疗区的偏位大多数发生在颞侧,可能与治疗前患者鼻侧、颞侧曲率不对称有关。人群中的角膜地形图以鼻侧较平坦、颞侧较陡峭多见,当因为镜片参数、眼睑张力、重力、睡眠姿势等原因导致镜片位置不稳定时,镜片容易被固定在更加弯曲的颞侧。部分患者偏位发生于颞下侧,可能与镜片的重力作用、Bell 现象、眼睑作用等有关[16-17,29]。

1.1 角膜前表面不对称性

角膜前表面不对称性越大,角膜塑形术后治疗区的偏位也越明显。Yang 等[12]首先在角膜地形图上对角膜塑形术后治疗区的偏位进行量化,发现镜片直径和角膜散光会影响偏位幅度的大小,较小的镜片直径和较大的角膜散光会造成更明显的镜片偏位。除了角膜散光外,之后的研究也发现其他反映角膜前表面不对称性的参数较大可能均与塑形术后治疗区偏位距离较大相关,包括表面非对称指数、角膜不对称向量、鼻-颞和上-下象限 Q 值差之和、8 mm 弦长区角膜前表面高度差等[13-15,29-30]。Chen 等[14]进一步研究发现,角膜不对称向量的平均角度与塑形术后治疗区偏位的平均角度一致。角膜前表面不对称的曲率增大,使角膜前表面局部弯曲,造成镜片定位的不稳定。由于眼睑和眼球的活动,镜片容易骑跨在弯曲的一侧,导致治疗区的偏位。这也与角膜塑形术后治疗区偏位最容易发生在角膜颞侧的原因一致[16-17]。

1.2 基线近视度数

基线近视度数越大,塑形术后治疗区偏位也越大。杨晓等[16]按不同基线近视度数(≤-3.0 D、-3.25~-5.0 D、>-5.0 D)将受试者分为 3 个组,发现角膜塑形术后 1 个月 3 个组受试者的治疗区偏位距离无明显差异,分别为(0.54±0.36)、(0.59±0.40)和(0.62±0.50)mm,但中低度近视组较高度近视组的治疗区偏位距离有增大的趋势。付心怡等[17]观察发现,角膜塑形术后 3 个月低度近视组(≤-3.0 D)治疗区偏位距离为(0.52±0.26)mm,明显小于中度近视组(-3.0~-6.0 D)的(0.57±0.29)mm。基线球镜度数对应的是角膜塑形镜矫正屈光不正的降幅,是角膜塑形镜的基本参数之一[18-19]。戴镜前的基线度数越高、降幅越大,为达到理想视力所需的角膜前表面形变越大,周边离焦环的陡峭程度越深,镜片定位不稳定,发生偏位的幅度越大。

1.3 其他影响因素

临床中也观察到由于镜片直径或配适松紧度不合适导致的镜片偏位。杨晓等[16]发现,相同 VST 设计、不同镜片直径组的治疗区偏位距离有明显差异,10.0 mm 直径组治疗区偏位距离明显大于 10.2~10.6 mm 直径组和 11.0 mm 直径组,分析可能与增加镜片直径可以增加镜片与角膜的接触面积,从而提高镜片定位的稳定性有关。而小镜片直径所对应的小角膜和通常与小角膜相关的角膜大曲率,会导致镜片塑形所需角膜形变量较大,治疗区定位不稳定。另外,眼睑张力和睡眠姿势作为无法量化的指标,也可能与镜片偏位相关[16-17]。

2 治疗区偏位对近视控制效果的影响

治疗区偏位导致本应与瞳孔呈同心圆环绕的周边近视离焦区进入瞳孔,瞳孔区正离焦明显增大,眼轴增长速度变缓。目前,治疗区偏位有利于增强近视控制效果在学界基本成为共识。吴纲跃等[31]观察角膜塑形术后 24 个月的 134 例近视受试者的右眼,将其分为轻度、中度、重度偏位组,3 个组眼轴增长分别为(0.45±0.34)、(0.32±0.28)和(0.23±0.29)mm,重度偏位组眼轴增长最少。Wang 等[20]选取 30 例一侧眼非偏位适配(偏位距离<0.5 mm)、另一侧眼偏位适配(偏位距离为 0.5~1.5 mm)的受试者,结果显示偏位眼的眼轴增长量为(0.20±0.24)mm,明显小于非偏位眼的(0.29±0.20)mm。Chen 等[32]发现,角膜塑形术治疗后 24 个月,110 例近视受试者眼轴增长与基线年龄、基线等效球镜度数和治疗区的偏位幅度相关,偏位幅度越大,眼轴增长越小。除了偏位幅度,偏位方向也与眼轴控制有关。郭丽等[33]研究认为,偏位幅度增大、偏位方向向

垂直方向偏移可以抑制近视进展，这可能与垂直方向周边视网膜较平坦、周边屈光度偏近视有关。视网膜越平坦、越多的近视离焦，可以使光线远远聚焦于视网膜前，抑制眼轴进一步拉长。

3　治疗区偏位对视觉质量的影响

角膜塑形术后最佳矫正视力下降的报道少见。在临床中，配戴角膜塑形镜后的视觉问题大多是由于近视矫正不足、较小或偏位的治疗区导致的重影、眩光、对比敏感度降低等[34-38]。治疗区偏位对视觉质量的影响体现在受试者自觉有视力下降、眩光、视物重影等主观症状[16]。吴娟等[30]研究发现，角膜塑形术后有重影主诉的眼治疗区偏位距离明显大于无重影主诉的眼。治疗区偏位导致周边陡峭区进入瞳孔，角膜中央塑形不规则，直接导致上述主观症状。治疗区偏位也会导致高阶像差、对比敏感度、截止频率等相关指标的变化[19,32,39-43]。Hiraoka 等[19]研究显示，配戴角膜塑形镜后 3 个月患者治疗区偏位幅度为(0.85±0.51)mm，治疗区偏位幅度与彗差增加量和球差增加量均呈正相关，与对比敏感度呈负相关。有研究显示治疗区偏位后彗差增加[39-40]，垂直偏位距离和水平偏位距离分别是影响垂直彗差增加量和水平彗差增加量的唯一因素。彗差的增加可能是角膜塑形术后治疗区偏位导致视觉质量下降的主要原因[40-41]。治疗区偏位导致角膜各个方向的屈光力不对称，对轴外光线成像影响大，从而导致彗差的明显改变。

4　解决治疗区偏位的方法

在临床中，常使用增加矢高、收紧定位弧或加大镜片直径的方法来解决明显的治疗区偏位。弧区和直径的相应调整能增加镜片与角膜的接触面积，加强镜片中心定位的稳定性[16]。Maseedupally 等[13]研究认为，较平的塑形镜基弧（与角膜前表面距离较近）通常与较大的镜片偏位有关，而较陡的基弧（与角膜前表面距离较远）通常与较小的镜片偏位有关，但对于高复曲面角膜（1.50~3.50 D），调整矢高并不能明显改变镜片偏位。

在环曲面设计问世之前，通常认为 1.75 D 及更大的角膜散光患者不适合使用角膜塑形镜，因为会导致严重的治疗区偏位和视觉质量下降[13,19]。双轴环曲面设计镜片基于角膜散光与角膜子午线上对称两点的角膜高度差异明显相关的原理，其具有复曲面的光学区，并且在各个平行弧区垂直的方向上具有不同的矢高，有利于镜片稳定性，改善塑形术后的治疗区偏位[44-46]。但双轴环曲面设计镜片矫正治疗区偏位的作用有限，仍然有少部分中至高度角膜散光（1.50~3.50 D）患者配戴环曲面设计镜片后，仍表现出明显的治疗区偏位（>1 mm）[46]。

自由曲面角膜塑形镜的出现使在更不规则的角膜形态上验配成为可能。自由曲面角膜塑形镜是一种多轴环曲面设计镜片，镜片能与角膜表面任意定位点相匹配，保证每一点的等效矢高。医师可以根据角膜地形图对角膜塑形镜的各轴区曲率、轴区大小进行个性化设计，达到镜片与角膜形态的高度吻合，有望带来更好的居中稳定性。

5　小结

角膜塑形术后，较大的角膜前表面不对称性、较高的基线近视度数、较小的镜片直径等原因与治疗区偏位明显相关。治疗区的偏位直接导致塑形形成的周边离焦环进入瞳孔区，有利于减缓近视进展，但会导致日间视觉质量下降，以彗差的增加为主。在设计镜片时，可通过增加矢高、加大镜片直径或采用环曲面设计来加强镜片中心定位的稳定性，解决过大的治疗区偏位，其中自由曲面角膜塑形镜有望实现复杂形态角膜的塑形镜验配，在未来的角膜塑形术中具有发展潜力。在临床决策中，需要综合考虑，与患者充分沟通以达到满意的治疗效果。

利益冲突　所有作者均声明不存在利益冲突

参考文献

[1] Holden BA, Fricke TR, Wilson DA, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050[J]. Ophthalmology, 2016, 123(5): 1036-1042. DOI: 10.1016/j.ophtha.2016.01.006.

[2] Morgan IG, He M, Rose KA. Epidemic of pathologic myopia: what can laboratory studies and epidemiology tell us? [J]. Retina, 2017, 37(5): 989-997. DOI: 10.1097/IAE.0000000000001272.

[3] He M, Du Y, Liu Q, et al. Effects of orthokeratology on the progression of low to moderate myopia in Chinese children [J/OL]. BMC Ophthalmol, 2016, 16: 126[2022-08-20]. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4964026/. DOI: 10.1186/s12886-016-0302-5.

[4] Sun Y, Xu F, Zhang T, et al. Orthokeratology to control myopia progression: a meta-analysis [J/OL]. PLoS One, 2015, 10(4): e0124535[2022-08-20]. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4391793/. DOI: 10.1371/journal.pone.0124535.

[5] Santodomingo-Rubido J, Villa-Collar C, Gilmartin B, et al. Long-term efficacy of orthokeratology contact lens wear in controlling the progression of childhood myopia[J]. Curr Eye Res, 2017, 42(5): 713-720. DOI: 10.1080/02713683.2016.1221979.

[6] Cho P, Tan Q. Myopia and orthokeratology for myopia control[J]. Clin Exp Optom, 2019, 102(4): 364-377. DOI: 10.1111/cxo.12839.

[7] Vincent SJ, Cho P, Chan KY, et al. CLEAR-orthokeratology[J]. Cont Lens Anterior Eye, 2021, 44(2): 240-269. DOI: 10.1016/j.clae.2021.02.003.

[8] Ticak A, Walline JJ. Peripheral optics with bifocal soft and corneal reshaping contact lenses[J]. Optom Vis Sci, 2013, 90(1): 3-8. DOI: 10.1097/OPX.0b013e3182781868.

[9] Queirós A, González-Méijome JM, Jorge J, et al. Peripheral refraction in myopic patients after orthokeratology[J]. Optom Vis Sci, 2010, 87(5): 323-329. DOI: 10.1097/OPX.0b013e3181d951f7.

[10] Kang P, Swarbrick H. Peripheral refraction in myopic children wearing orthokeratology and gas-permeable lenses[J]. Optom Vis Sci, 2011, 88(4): 476-482. DOI: 10.1097/OPX.0b013e31820f16fb.

[11] Caroline PJ. Contemporary orthokeratology[J]. Cont Lens Anterior Eye, 2001, 24(1): 41-46. DOI: 10.1016/s1367-0484(01)80008-4.

[12] Yang X, Zhong X, Gong X, et al. Topographical evaluation of the decentration of orthokeratology lenses[J]. Yan Ke Xue Bao, 2005, 21(3): 132-135, 195.

[13] Maseedupally VK, Gifford P, Lum E, et al. Treatment zone decentration during orthokeratology on eyes with corneal toricity[J]. Optom Vis Sci, 2016, 93(9): 1101-1111. DOI: 10.1097/OPX.0000000000000896.

[14] Chen Z, Xue F, Zhou J, et al. Prediction of orthokeratology lens decentration with corneal elevation[J]. Optom Vis Sci, 2017, 94(9): 903-907. DOI: 10.1097/OPX.0000000000001109.

[15] Li Z, Cui D, Long W, et al. Predictive role of paracentral corneal toricity using elevation data for treatment zone decentration during orthokeratology[J]. Curr Eye Res, 2018, 43(9): 1083-1089. DOI: 10.1080/02713683.2018.1481516.

[16] 杨晓，龚向明，戴祖优，等. 角膜塑型镜治疗后镜片偏离中心的角膜地形图分析[J]. 中华眼科杂志，2003，39(6)：335-338. DOI：10.3760/j:issn:0412-4081.2003.06.005.
Yang X, Gong XM, Dai ZY, et al. Topographical evaluation on decentration of orthokeratology lenses[J]. Chin J Ophthalmol, 2003, 39(6): 335-338. DOI: 10.3760/j:issn:0412-4081.2003.06.005.

[17] 付心怡，张晓峰，夏静，等. 配戴角膜塑形镜后光学区偏中心原因分析[J]. 中华眼视光学与视觉科学杂志，2016，18(2)：83-87，92. DOI：10.3760/cma.j.issn.1674-845X.2016.02.005.

Fu XY, Zhang XF, Xia J, et al. Analysis of the reasons for decentration after orthokeratology[J]. Chin J Optom Ophthalmol Vis Sci, 2016, 18(2): 83-87, 92. DOI: 10.3760/cma.j.issn.1674-845X.2016.02.005.

[18] 韦伟, 王晓睿, 孙西宇, 等. 影响角膜塑形镜偏中心定位的相关因素分析[J]. 眼科新进展, 2019, 39(7): 654-657.
Wei W, Wang XR, Sun XY, et al. The influence factors in orthokeratology decentration[J]. Rec Adv Ophthalmol, 2019, 39(7): 654-657.

[19] Hiraoka T, Mihashi T, Okamoto C, et al. Influence of induced decentered orthokeratology lens on ocular higher-order wavefront aberrations and contrast sensitivity function[J]. J Cataract Refract Surg, 2009, 35(11): 1918-1926. DOI: 10.1016/j.jcrs.2009.06.018.

[20] Wang A, Yang C. Influence of overnight orthokeratology lens treatment zone decentration on myopia progression[J/OL]. J Ophthalmol, 2019, 2019: 2596953[2022-08-23]. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6881772/. DOI: 10.1155/2019/2596953.

[21] Gifford P, Tran M, Priestley C, et al. Reducing treatment zone diameter in orthokeratology and its effect on peripheral ocular refraction[J]. Cont Lens Anterior Eye, 2020, 43(1): 54-59. DOI: 10.1016/j.clae.2019.11.006.

[22] Guo B, Cheung SW, Kojima R, et al. One-year results of the Variation of Orthokeratology Lens Treatment Zone (VOLTZ) study: a prospective randomised clinical trial[J]. Ophthalmic Physiol Opt, 2021, 41(4): 702-714. DOI: 10.1111/opo.12834.

[23] Marcotte-Collard R, Simard P, Michaud L. Analysis of two orthokeratology lens designs and comparison of their optical effects on the cornea[J]. Eye Contact Lens, 2018, 44(5): 322-329. DOI: 10.1097/ICL.0000000000000495.

[24] Pauné J, Fonts S, Rodríguez L, et al. The role of back optic zone diameter in myopia control with orthokeratology lenses[J/OL]. J Clin Med, 2021, 10(2): 336[2022-08-23]. https://pubmed.ncbi.nlm.nih.gov/33477514/. DOI: 10.3390/jcm10020336.

[25] Carracedo G, Espinosa-Vidal TM, Martínez-Alberquilla I, et al. The topographical effect of optical zone diameter in orthokeratology contact lenses in high myopes[J/OL]. J Ophthalmol, 2019, 2019: 1082472[2022-09-06]. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6334375/. DOI: 10.1155/2019/1082472.

[26] Maloney RK. Corneal topography and optical zone location in photorefractive keratectomy[J]. Refract Corneal Surg, 1990, 6(5): 363-371.

[27] Amano S, Tanaka S, Shimizu K. Topographical evaluation of centration of excimer laser myopic photorefractive keratectomy[J]. J Cataract Refract Surg, 1994, 20(6): 616-619. DOI: 10.1016/s0886-3350(13)80649-9.

[28] Tsai YY, Lin JM. Ablation centration after active eye-tracker-assisted photorefractive keratectomy and laser in situ keratomileusis[J]. J Cataract Refract Surg, 2000, 26(1): 28-34. DOI: 10.1016/s0886-3350(99)00328-4.

[29] Li J, Yang C, Xie W, et al. Predictive role of corneal Q-value differences between nasal-temporal and superior-inferior quadrants in orthokeratology lens decentration[J/OL]. Medicine (Baltimore), 2017, 96(2): e5837[2022-09-06]. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5266176/. DOI: 10.1097/MD.0000000000005837.

[30] 吴娟, 余惠文. 角膜塑形镜治疗后光学区偏离中心的角膜地形图参数分析[J]. 中国斜视与小儿眼科杂志, 2013, 21(2): 16-19, 10. DOI: 10.3969/j.issn.1005-328X.2013.02.004.
Wu J, Yu HW. Topographical evaluation on decentration of orthokeratology lenses[J]. Chin J Strabismus Pediatric Ophthalmol, 2013, 21(2): 16-19, 10. DOI: 10.3969/j.issn.1005-328X.2013.02.004.

[31] 吴纲跃, 赖仙球, 戴晓丹. 角膜塑形镜治疗后光学区偏离中心对控制近视的影响[J]. 国际眼科杂志, 2018, 18(1): 188-191. DOI: 10.3980/j.issn.1672-5123.2018.1.49.
Wu GY, Lai XQ, Dai XD. Effect of decentration in controlling the development of myopia after orthokeratology[J]. Int Eye Sci, 2018, 18(1): 188-191. DOI: 10.3980/j.issn.1672-5123.2018.1.49.

[32] Chen R, Chen Y, Lipson M, et al. The effect of treatment zone decentration on myopic progression during or-thokeratology[J]. Curr Eye Res, 2020, 45(5): 645-651. DOI: 10.1080/02713683.2019.1673438.

[33] 郭丽, 陈小虎. 角膜塑形镜离焦环偏心对近视发展的影响[J]. 川北医学院学报, 2021, 36(8): 990-993. DOI: 10.3969/j.issn.1005-3697.2021.08.010.
Guo L, Chen XH. Influence of the decentration of the orthokeratology defocus ring on myopia[J]. J North Sichuan Med College, 2021, 36(8): 990-993. DOI: 10.3969/j.issn.1005-3697.2021.08.010.

[34] Berntsen DA, Barr JT, Mitchell GL. The effect of overnight contact lens corneal reshaping on higher-order aberrations and best-corrected visual acuity[J]. Optom Vis Sci, 2005, 82(6): 490-497. DOI: 10.1097/01.opx.0000168586.36165.bb.

[35] Sun Y, Wang L, Gao J, et al. Influence of overnight orthokeratology on corneal surface shape and optical quality[J/OL]. J Ophthalmol, 2017, 2017: 3279821[2022-09-06]. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5642882/. DOI: 10.1155/2017/3279821.

[36] Hiraoka T, Okamoto C, Ishii Y, et al. Contrast sensitivity function and ocular higher-order aberrations following overnight orthokeratology[J]. Invest Ophthalmol Vis Sci, 2007, 48(2): 550-556. DOI: 10.1167/iovs.06-0914.

[37] Hiraoka T, Okamoto C, Ishii Y, et al. Time course of changes in ocular higher-order aberrations and contrast sensitivity after overnight orthokeratology[J]. Invest Ophthalmol Vis Sci, 2008, 49(10): 4314-4320. DOI: 10.1167/iovs.07-1586.

[38] Chen Z, Zhou J, Xue F, et al. Increased corneal toricity after long-term orthokeratology lens wear[J/OL]. J Ophthalmol, 2018, 2018: 7106028[2022-09-10]. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6218724/. DOI: 10.1155/2018/7106028.

[39] 王武, 毛欣杰. 角膜塑形术对角膜表面形态及角膜像差的影响[J]. 中华眼视光学与视觉科学杂志, 2011, 13(4): 269-273. DOI: 10.3760/cma.j.issn.1674-845X.2011.04.008.
Wang W, Mao XJ. Effect of overnight orthokeratology on corneal surface morphology and corneal aberrations[J]. Chin J Optom Ophthalmol Vis Sci, 2011, 13(4): 269-273. DOI: 10.3760/cma.j.issn.1674-845X.2011.04.008.

[40] 林思思, 陈镇国, 王建勇, 等. 角膜塑形术后光学治疗区大小及偏心对光学及视觉质量的影响[J]. 中华眼视光学与视觉科学杂志, 2018, 20(9): 530-535. DOI: 10.3760/cma.j.issn.1674-845X.2018.09.004.
Lin SS, Chen ZG, Wang JY, et al. Influence of the diameter and decentration of the treatment zone on optical quality and visual performance after orthokeratology[J]. Chin J Optom Ophthalmol Vis Sci, 2018, 20(9): 530-535. DOI: 10.3760/cma.j.issn.1674-845X.2018.09.004.

[41] 陈子扬, 叶照达, 张晔, 等. 角膜塑形镜的偏心对眼轴及视觉质量的影响[J]. 国际眼科杂志, 2020, 20(12): 2023-2027. DOI: 10.3980/j.issn.1672-5123.2020.12.02.
Chen ZY, Ye ZD, Zhang Y, et al. Effect of eccentricity of overnight orthokeratology lenses on axial growth and visual quality[J]. Int Eye Sci, 2020, 20(12): 2023-2027. DOI: 10.3980/j.issn.1672-5123.2020.12.02.

[42] Liu G, Chen Z, Xue F, et al. Effects of myopic orthokeratology on visual performance and optical quality[J]. Eye Contact Lens, 2018, 44(5): 316-321. DOI: 10.1097/ICL.0000000000000372.

[43] 刘桂华, 谷天瀑, 李颖, 等. 角膜塑形镜配戴后瞳孔与光学区的大小对视觉质量的影响[J]. 眼科新进展, 2017, 37(1): 38-41. DOI: 10.13389/j.cnki.rao.2017.0010.
Liu GH, Gu TP, Li Y, et al. Effects of pupil size and treatment zone diameter on optical quality after myopic orthokeratology treatment[J]. Rec Adv Ophthalmol, 2017, 37(1): 38-41. DOI: 10.13389/j.cnki.rao.2017.0010.

[44] Tomiyama ES, Logan AK, Richdale K. Corneal elevation, power, and astigmatism to assess toric orthokeratology lenses in moderate-to-high astigmats[J]. Eye Contact Lens, 2021, 47(2): 86-90. DOI: 10.1097/ICL.0000000000000721.

[45] Batres L, Piñero D, Carracedo G. Correlation between anterior corneal elevation differences in main meridians and corneal astigmatism[J]. Eye Contact Lens, 2020, 46(2): 99-104. DOI: 10.1097/ICL.0000000000000613.

[46] Zhang Y, Chen YG. Comparison of myopia control between toric and spherical periphery design orthokeratology in myopic children with moderate-to-high corneal astigmatism[J]. Int J Ophthalmol, 2018, 11(4): 650-655. DOI: 10.18240/ijo.2018.04.19.

（收稿日期：2022-10-10　修回日期：2023-06-30）

（本文编辑：刘艳　施晓萌）