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Orthokeratology

New findings in correcting vision overnight

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1 Introduction

Orthokeratology is a procedure to decrease or eliminate myopia (short-sightedness) and astigmatism (corneal irregularity) by using a specific kind of rigid gas permeable contact lenses. The concept behind these lenses is that by wearing them overnight sufficient visual acuity is gained making it unnecessary to wear contact lenses or spectacles through the day. This could appeal to people who need to wear contact lenses, for example in rooms with air-conditioning or dusty environments, but experience a lack of comfort in doing so. Furthermore, this kind of myopia correction is suggestive for people who do regular sports where wearing spectacles is not possible and the use of conventional contact lenses bears the danger of loosing them (for example in swimming or diving).

The ideal patient for applying orthokeratology is slightly myopic in the range of - 0.75 to - 4.00 dioptre and with astigmatism up to - 1.50 dioptre. Patients with an ammetropia of - 0.25 to - 0.50 dioptre can be treated, too, but with an increased degree of difficulty. If the short-sightedness is higher than - 4.00 dioptre, a thorough eye-examination is necessary to clarify whether orthokeratology can be applied or not. The bad news for patients with myopia greater than - 5.50 dioptre is that orthokeratology is unfortunately excluded in any event.

Besides these optical preconditions, healthy eyes are required to apply orthokeratology. Additionally to the requirements for conventional contact lens wearing, such as no disease of the anterior eye segment, orthokeratology lenses cannot be used if the patient has undergone a cornea surgery (refractive surgery, cornea graft surgery) or suffers from keratoconus (an irregular forward bulging and thinning of the cornea).

2 History

Back in the seventeenth century the Chinese discovered a way to reduce short-sightedness by deforming of the cornea: they used flat stones or bags filled with rice which were placed on the eyes for a couple of hours. This extremely painful method was unpredictable and thus the results were rarely satisfying, however, it represented the beginning of orthokeratology.

In the 1950's the optometrists used to fit hard lenses (made of Perspex) flat, which means the lens's back surface radius was bigger than the cornea's front surface radius, in order to get a better tear replacement. When the clients complained about blurred vision with their spectacles just after removing their lenses, they found out that the lenses caused a change in the cornea's shape. Thus the free visual acuity was increased – even if that was not intended.[1]

In 1960, the American Jessen developed an adjustment method that made it possible to reduce or eliminate myopia by using conventional rigid gas permeable lenses. These lenses were fitted flat and were replaced frequently (about six times) and it took up to one year until the short-sightedness was removed.[2]

The first time a lens design was developed for this particular purpose was in 1991. The contact lens manufacturer Nick Stoyan invented a contact lens whose back surface had three different curves. At this point of time lenses with three different curves were not uncommon but the radii of curvature became bigger from the centre to the periphery. In contrast to these conventional lenses, the orthokeratology lenses had a reverse zone, which means that the second curve was steeper (a smaller radius) than the other curve radii. The benefits of this method were a much better lens centring and the fact that the lenses had to be replaced only twice. Still the prospect of success was unpredictable and the lenses could only be worn for

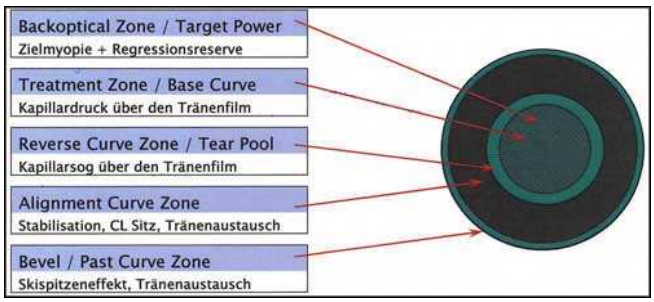
[1] http://www.phtla-hall.tsn.at/0405/projekte/Orthokeratologie.pdf (page11)
[2] http://augen.uniklinikum-dresden.de/seite.asp?ID=116

up to three hours with the result that a maximal myopia reduction of only two dioptre was possible.[3]

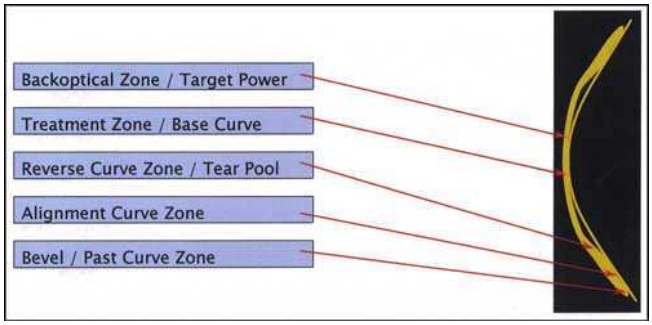
In 1996 a new orthokeratology lens was launched to the market, its innovation was the "double reverse geometry". This kind of lens is still state of the art and will be described in detail in the following chapter.

3 The design

The treatment zone with its base curve is much flatter than the cornea's front surface curvature. The cornea begins to adapt this curvature while wearing the lenses. Additionally, in this zone the lens contains the target power, thus the patient can see clearly with the lens onto the eye as well (this could be vital while driving at night while the regression has proceeded too much). Attached to the first zone is the reverse curve zone which is very steep (a small curve radius). It gives the epithelium cells (the cornea's anterior cell layer) the freedom to wander from the centre, where they were repressed, to the periphery and accommodates a tear pool which is advantageous for the oxygen supply (the cornea is able to absorb the oxygen from the tear fluid). The third zone, the alignment curve zone, is parallel to the cornea and is responsible for a comfortable fit and for an exact lens centring. An excellent lens centring is



Assembly of a topical orthokeratology lens (frontal)



Assembly of a topical orthokeratology lens (sideways)

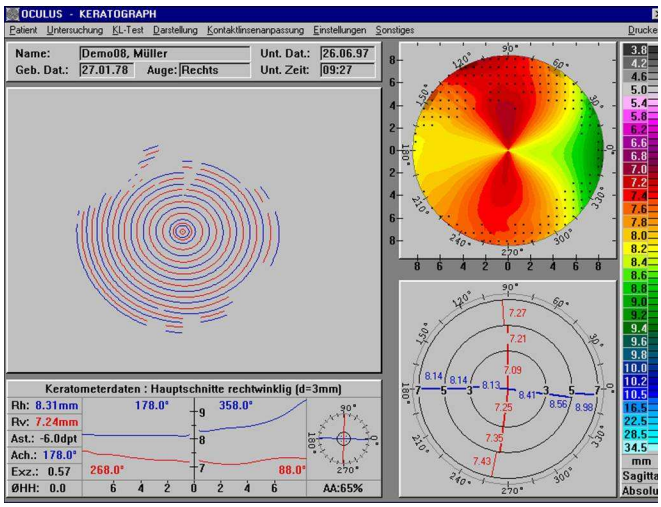
[3] http://augen.uniklinikum-dresden.de/seite.asp?ID=116

essential in order to precisely reshape the right part of the cornea in front of the pupil; otherwise the vision would not be as good as possible. The last zone is called bevel and supplies a comfortable lens fit as well as an excellent tear fluid exchange.[4]

4 The fitting-process

Optometrists or ophthalmologists who want to fit orthokeratology lenses have to attend a specific training course. Not until they finish one of these courses successfully can they get permission to fit this kind of lenses. This points out that this type of contact lens fitting is more sophisticated and therefore it requires an in-depth knowledge from the optometrist and an excellent compliance by the customer.

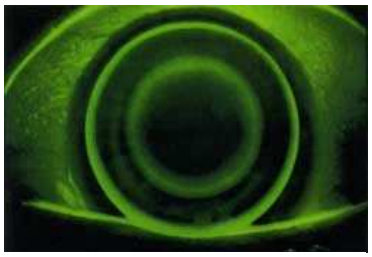
The first examination is carried out by a slit lamp. Using this device the optometrist is able to inspect the anterior eye segment. It has to be absolutely healthy – the cornea especially must not show any noticeable problems. Also a complete refraction has to be performed to get the current amount of myopia. After that, it is necessary to measure the cornea radii by using a videokeratoscope. At this point the fitting process differs from the fitting process of a conventional rigid gas permeable lens. A videokeratoscope determines the cornea's curvature at about 20,000 points (depending on the manufacturer) whereas an ophthalmometer only evaluates the curvature in the centre and in four peripheral positions (this device is still being used and is absolutely sufficient for fitting conventional lenses).



Display of cornea radii by a videokeratoscope

[4] http://www.optikum.at/modules.php?name=News&file=article&sid=204

Now the orthokeratology lenses can be ordered. The manufacturer produces the lenses exactly according to the information gained by the videokeratoscope and the refraction, thus every lens is unique. With a probability of about 80 percent, these lenses will usually be the final lenses. In the other 20 percent of cases, the need of alteration in the lens design will be noticed later and accordingly another lens will be ordered.[5]



Ideal fluorescein pattern

When the lenses have been delivered, it is the optometrist's task to inform the client of all the handling, wearing schedule and hygiene requirements. Additionally, the fit needs to be checked. To do this, the lenses are inserted and a dye called fluorescein is applied. This dye is then activated by the slit lamp's blue light and the optometrist is able to evaluate the fit by analysing the fluorescein pattern. The brighter the fluroescein shines the more tear fluid rests between cornea and lens. This picture shows an ideal fluorescein pattern of an orthokeratology lens: between the treatment zone and cornea is just an extremely thin layer of tear fluid (preferably 0.005 to 0.01mm) as well as between the alignment zone and cornea (here both are parallel to each other to provide good centring and a comfortable fit). The inner circle represents the tear fluid between the cornea and the reverse zone, which is desirable because it maintains the eye's oxygen supply. The outer circle comes into existence since the edge of the lens sticks out and therefore the tear fluid accumulates in this area.[6]

After a successful lens fitting, a close after-care schedule is essential. After the first night of wearing the lenses, the client does not remove them in the morning and seeks his optometrist for the first after-care examination. Now the fit can be evaluated for the first time after wearing the lenses for a longer period of time. The most important things for the optometrist to look out for are that the fluorescein pattern is the same as the previous day when the

5 http://www.technolens.de/inhalte/ORTHO-K%20Info%20Internet.pdf#search=%22OrthokeratologieLinsen%20aufbau%22 (page 7)
6 http://www.phtla-hall.tsn.at/0405/projekte/Orthokeratologie.pdf

lenses were dispensed and that the lenses do not stick onto the cornea (otherwise the client could damage the cornea's epithelium which makes the eye prone to inflammations). After one week the optometrist needs to examine the eyes again in the morning when the client is still wearing his lenses – besides the examinations which were carried out after the first night, a refraction shows the optical success of the treatment (at the latest now the desired effects should have taken place). The next check is arranged after the second week in the afternoon without lenses in order to measure the amount of regression, then after one month (again in the morning) and subsequently every three months.[7]

For comparison: in conventional contact lens fitting after-care is supposed to take place one week after dispensing and afterwards every twelve months.

5 Mode of action

Orthokeratology lenses cause a change in the cornea's shape due to its specific lens design. But how exactly does it work? In the treatment zone the lenses are flatter than the flattest cornea meridian which leads to a corneal thinning and flattening in this area. The tear fluid in this zone is extremely thin and in the middle periphery below the reverse zone it becomes much thicker. This creates different hydrostatic powers with the result that the centre of the cornea is exposed to a gentle pressure and the middle periphery to a suction effect. The epithelium cells are forced to wander to the periphery and, in this way, the refraction power is reduced because of the bigger cornea radii in the centre. A desirable side effect is the cornea thinning which results in a slightly shorter eye. This fact also plays a role in the myopia correction because with myopia the eyes are too long in proportion to their refractive power.[8]

[7] http://augen.uniklinikum-dresden.de/seite.asp?ID=116
[8] http://www.optikum.at/modules.php?name=News&file=article&sid=205

About 70% of the ametropia is abolished within three days of wearing the lenses every night.[9] At the latest, after one week the clients are free from optical devices during the day. Until then they are provided with disposable lenses in different dioptric powers. Especially in the evening when the regression is advanced the client needs to use them to retain a good vision. This is due to the cornea's shape regressing back to its old shape during the day. Taking this into account, the lenses are calculated to transform the myopic eye into a slightly hyperopic (long-sighted) eye. This means that in the morning the eye is far-sighted, with an amount of 0.50 to 0.75 dioptre, and becomes right-sighted in the late evening. Hence, in the morning the eye is forced to accommodate to balance out the hypermetropia which does not produce a problem at all – it is a natural process the eye is used to (necessary to adjust the eye to different object distances).

6 Prospects of success and risks

The prospects of success are excellent, provided that the optometrist did a good job and the client demonstrates a good compliance. The visual acuity obtained by this method is nearly always as good as with a conventional correcting method. Only occasionally it is slightly reduced due to a not fully corrected astigmatism. The biggest advantage of orthokeratology compared to a refractive laser surgery is the reversibility. If the client decides to stop wearing the orthokeratology lenses the cornea resumes to its old shape within one week and, respectively, the spectacles and/or the old contact lenses can be worn again.

One major risk for the eye is the oxygen supply; during sleep the eye receives much less oxygen than by day with the result that the cornea swells every night. A contact lens is a further barrier to an already reduced oxygen supply and the cornea swells more than natural. This swelling represents an elevated risk for corneal neovascularization (the fibrils in the cornea are not as tight as normal and enable the blood vessels to grow into the cornea). If the

[9] http://www.technolens.de/inhalte/ORTHO-K%20Info%20Internet.pdf#search=%22OrthokeratologieLinsen%20aufbau%22 (page2)

client tends to dry eyes, it is possible that the lenses will stick onto the cornea in the morning. If this happens only occasionally it is not necessary to worry about it too much – but the client needs to be instructed to wet the lenses before removing, otherwise it is likely that the epithelium will get damaged. However, if it happens frequently action is indicated – probably for this client orthokeratolgy is not suitable. A damaged cornea surface is very prone to inflammations because the epithelium is the only layer that keeps out the micro organisms. If the bacteria or viruses are able to invade the cornea a keratitis will be the result. This corneal inflammation is a serious complication; the eye becomes deep red and aches tremendously. Even the visual acuity could be decreased persistent if the inflammation is very deep and does not heal without scarring.

All these above-mentioned intricacies take place promptly, but nobody is able to say what happens to the cornea if a client wears these lenses continuously for longer than ten years – because of the fact that this method was introduced recently long-term studies could not have been carried out so far.

7 Conclusion

At the present point in time experts agree about the fact that a correction with orthokeratology lenses is more hazardous than with conventional lenses but less risky than a refractive laser surgery. As a result, it is up to the client whether he takes the risk or remains with his old correction-method. In return the client should get all information he needs to simplify his decision. It is likely that further developments and the presence of long-term-studies will make this method less hazardous and thus gain in importance. To achieve this goal there is no doubt about the necessity that enough volunteers are willing to try this method nowadays with the result that in near future customers will benefit from the experiences gained now. Even research to find a comparable method of correcting hyperometropia (long-sightedness) has recently started. Up to the present the results have not

been satisfying, but research in this field will be carried forward and it is quite likely that for this target group also orthokeratology lenses will be launched onto the market soon.

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