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Solution to Slow Down Myopia Progression

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Abstract

Purpose: To examine the effectiveness of various treatments; bifocal spectacles, orthokeratology, atropine, and time spent in outdoors; in slowing down the myopia progression for Asian adolescents (6-18age).
Methods: The research focused on examining the most effective treatment in controlling myopia based on the literature sources that have been published. Through meta-analysis of various research papers that already has been done in this field, a lot of data was collected. For each treatment, the difference in axial length and spherical equivalent over time was measured and recorded. To quantitatively record the difference, both axial length and spherical equivalent was determined by value of control group value of treatment group. The paper compared the effectiveness of each treatment based on the data that was measured.
Results: Adolescents who chose to spend time outdoors in order to slow down myopia progression had axial length difference of 0.03 mm and spherical equivalent difference of 0.17 D. Adolescents that used atropine had axial length difference of 0.36 mm and spherical equivalent difference of 0.92 D. Bifocal spectacle resulted in axial length difference of 0.21 mm and spherical equivalent difference of 0.59 D, and for orthokeratology 0.23 mm and 0.04 D, respectively. Axial length wise, myopia was most controlled by the atropine since there was a greatest difference between the group that got the treatment and the group that did not have the treatment. According to the spherical equivalent difference data, myopia was most controlled by atropine.
Conclusion: Atropine showed the most effective result in controlling myopia among the four treatment. Again, compared to other three treatment, using atropine appeared to have greatest ability in slowing down myopia progression since adolescents who were treated with atropine had greatest difference from adolescents in the control group that had the same condition but didn't get the treatment. However, every treatment was only used for 2 or 3 years which is quite short time period to measure the long term effect of the four treatments. Also, since atropine is a pharmaceutical method to control myopia, it may harm adolescents' eyes compared to optical or environmental treatment.

Key words: accommodation, atropine, axial length, bifocal spectacles, contact lens, orthokeratology, spherical equivalent.

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1. Introduction

Vision is one of the central sensory systems in a human body which allows to perceive and interpret surrounding information by sight. This crucial sensory system, however, cannot function properly if a person has an eye condition such as myopia. Myopia, also known as nearsightedness, is a condition in which the visual images come to a focus in front of the retina of the eye resulting especially in defective vision of distant objects[27]. The way human eyes see various objects is by initially collecting light from the pupil, a hole in front of the eye, then light will get refracted in the lens, and images will be focused on the retina where the light impulse to travel to the brain through the optic nerve. In order to see distant objects, eyes will flatten their lens to see closer objects, the process will be vice versa where eyes will thicken their lens[25]. However, people with myopic vision struggle to flatten their lens so even though they are seeing a distant object the lens is thickened. Thus, with the elongated eye length, the image focus will not reach the retina and they will have a hard time seeing that distant object[35].

In general, low (< 3.00 D) and medium (3.00 D - 6.00 D) myopia do not cause a major problem in eyes but high (> 6.00 D) myopia may lead to serious eye diseases[15]. Therefore, to prevent high percentile of high myopia, scientists came up with various treatments to limit myopia growth. Treatments can be essentially divided into three categories: environmental, pharmaceutical, and optical. This research seeks to examine which treatment is effective specifically for Asian teenagers from age 6 to 18, reporting that outdoor activity time for environmental, atropine for pharmaceutical, and orthokeratology and glasses for optical were compared in their effectiveness in slowing down the myopia growth. Their effectiveness were analyzed by the amount controlled for axial length and spherical equivalent. The one treatment with the smallest increase in axial length and spherical equivalent means that it controlled the progression of myopia. Data already existing about each treatment's effect on Asians will be collected and their reduction percentile will be measured which is easily replicable. Based on the research that has already been done, my hypothesis is that atropine will be most effective since it is a medicine that helps lens to be thinner so it will have greater reduction rate for eye axial length so that the progression of myopia is reduced.

2. Literature Review

Recently, myopia is considered an epidemic considering its tremendous growth rate. The prevalence rate for myopia in the United States has risen from 25% to 41%, and in some Asian countries, the rate has increased to 70-90%[26]. As it was founded that the prevalence rate was 85% in Taiwan, 82% in Singapore, 70% in Hong Kong, and 96% in South Korea[1]. Especially 60% of the myopia is classified as juvenile myopia which is the younger generations (age 7-13) having myopia[26]. For the growing teenagers or children, having myopia from a young age is especially risky since, as time passes, their eyes will get longer which can further lead to higher degree of myopia contributing to various eye diseases. Therefore, it is crucial to investigate methods to control myopia for Asian adolescents.

A lot of researches have argued that the prevalence rate of myopia has increased drastically by various factors. Myopia growth first seemed to be largely due to genetic factors[22]. For example, Yap et al. conducted an experiment to examine “the risks of passing myopia from parents to children[22].” According to their research, “associated development risk rates are 7.6% for no myopic parents, 14.9% for one myopic parent, and 43.6% for two myopic parents.” A majority of data proved that there is a connection between genes and risk of having myopia but “genetic changes happen too slowly to explain this rapid change[11].” Thus, genetic factor alone can not explain the rapid myopia growth. Another potential cause of myopia growth could be measures of education. People “spend more time engaged in reading, studying or ―more recently―glued to computer and smartphone screens,” and that might be the reason behind the growth[11]. To add on, Mountjoy et al. have created an experiment to find out “whether more years spent in education is a causal risk factor for myopia,” and it showed that myopia prevalence rate has risen by more exposure to more years in education[24]. On the other hand, Saw et al. have concluded that “neither reading nor parental myopia history was associated with values for anterior chamber depth, corneal curvature, or lens thickness,” which are factors that help determine the presence of myopia[7][32]. Therefore, Aldama concludes that the lack of outdoor activity is the cause of myopia growth especially in Asian countries[1]. Organization for Economic Co-operation and Development (OECD) reported that “the average 15-year-old in Shanghai now spends 14 hours per week on homework, compared with 5 hours in the United Kingdom and 6 hours in the United States,” showing that Asian teenagers are in high risk of experiencing myopia growth[30].

Having a myopia boom in teenagers are particularly dangerous. When people experience myopia from a young age, they will have trouble developing a normal, healthy eye because of errors in eye development. National Eye Institute has cautioned that having myopia from a young age will give the same effect to people's eyes as inflating a balloon. For example, “if the ciliary muscle restricts the expansion of the eye, the lens will not stretch as the eye grows. The frozen ciliary muscle no longer stretches the lens to keep pace with the growing eye, and that makes the eye myopic[27].” Eventually, people's eyes will become longer and longer and become high myopic which may lead to serious eye diseases such as “retinal detachment, glaucoma, and the early development of cataracts[27].” Thus, being high myopic is extremely dangerous but the rate of high myopia is constantly increasing. The high myopia prevalence rate was only 2.7% back in 2000, but in 2010 it increased to 4% and is predicted to increase as the decades pass and eventually reach 9.8% in 2050[19].

To slow down the exponential myopia growth rate, there are various treatments such as outdoor time, atropine, orthokeratology, and wearing glasses. A lot of studies have shown that each of the treatment is the most effective. The first treatment outdoor activity is the only environmental approach to control myopia where teenagers would increase the amount of time they spend at outdoors[16]. A decrease in outdoor activity was a major factor that caused a drastic increase in myopia rate so having more outdoor activity could be the answer to slow down the increase rate[16]. Atropine is a medication so it is a pharmaceutical approach where low-dose atropine eye drops such as 0.01% will dilate eye and makes an eye shorten the axial length. This medication does a remarkable job in retarding myopia growth but faces problems with its side effects[36]. Orthokeratology, commonly knowns as the Ortho-K lens also commonly knowns as 'Dream lens' in Korea, is one of the two optical approaches where teenagers wear a hard contact lens overnight. The thick, hard lens is designed to press eye and shorten the eye length for the day time. This treatment is known to be safe yet not remarkable in its effect[21]. Last but not least, glasses are the most common optical approach available for Asian teenagers but it does not physically affect human eyes so it will have less effect on decreasing the axial length and spherical equivalence[2].

It is very important to research on the effectiveness of different treatments available for myopia control and compare the effects on Asian teenagers since they are experiencing the most myopia growth so they have the highest risk of being infected to various serious eye diseases. However, there are not a lot of researches that discussed the effectiveness of myopia control treatments specifically on Asian teenagers which will be a significant gap in this research compared to others. Therefore, this research has a distinctive gap compared to previous studies that have already been done in this field since the effect on Asian teenagers are underserved and finding a treatment that best suits Asian teenagers have never been done in previous research. This research will add on to previous studies by finding the best treatment for Asian teenagers specifically.

3. Methodology

In order to find out which treatment works most effectively for Asian teenagers, the first step is to choose which treatment to focus on. As I have mentioned previously, there are three major treatment categories: environmental, pharmaceutical, and optical. Increase in the amount of time spent outdoors is the only environmental treatment possible for controlling myopia. Thus, I chose the amount of time spent outdoors as my environmental treatment. For pharmaceutical treatment, there are atropine and 7 - methylxanthine. They are both pharmaceutical medications that retard myopia progression. Like atropine, 7 - methylxanthine works in the same concept where a drop of the medication will slow down the elongation of an eye. However, compared to atropine, 7 - methylxanthine "increases the thickness of the posterior sclera, increases the content of collagen-related amino acids in the posterior sclera, and at the same time increases the diameter of the collagen fibrils in the posterior sclera[34]." It may actually be helpful in controlling myopia since myopia happens because of the "decrease in the scleral content of proteoglycans and collagen[28]." However, I decided to focus on atropine rather than 7 - methylxanthine because atropine is the only pharmaceutical treatment that has been consistently effective in retarding myopia progression[36]. Last but not least, there are a lot of optical treatments including usage of various spectacles and contact lens. For spectacles, executive bifocal and Progressive Power Lens (PPL) are used most commonly. The difference between executive bifocal lens and progressive power lens is that bifocal lens, as its name states, has two lens powers whereas progressive power lens "gradually change in power from the top half of the lens to the bottom, and thus contain many lens powers[18]." I chose to focus on spectacles with an executive bifocal lens because according to Cheng, et al, bifocal lens successfully slowed myopia growth in the long term. For contact lens (CL), there was a lot of candidates such as Rigid Gas Permeable CLs (RGP CLs), Soft CLs (SCLs), Ortho-k lens, and more[5]. I chose orthokeratology among the lens category since RGP lens and other lenses are not effective as much as orthokeratology and other lens do not slow down myopia progression[33]. Also, other contact lenses such as RGP CLs does not have any effect on slowing down myopia without Ortho-K[33]. The final list of the treatments that I will be comparing throughout my research will be shown in **Table 1.**

Table 1. List of Treatments Being Compared and Their Description/ Condition

Treatment	Description/Condition
Time Outdoors	At least 10 hours of outdoor activities per week.
Atropine	Low-dose (1%) of atropine.
Spectacle	Bifocal lens.
Lens	Orthokeratology.

Also, since I am conducting research on which treatment will be the most effective for retarding myopia progress in Asian teenagers, I will compare each treatment in the most ideal and effective means. Each treatment will be compared in a condition when they provide the greatest effect on slowing myopia. For example, French, et al, founded that at least 10 hours of time spent outdoor needs to happen like a threshold in order for retardation of myopia growth to occur[13)]. Also, injecting low-dose of atropine appeared to be more effective than injecting high-dose of it. After 5 years of using low-dose of atropine versus high-dose of atropine, low-dose showed a significant decrease in axial length and it even caused fewer side effects such as pupil dilation and loss of accommodation[6)]. In the spectacle category, a bifocal lens will be tested out as a representative of spectacle since it gives the greatest influence in retardation of myopia[5)]. Same for lens category, orthokeratology was the most effective one so it will be representing whole lens section[33)].

The second step is to see which factor to evaluate so that I can compare the effectiveness of each treatment. There are several factors that determine if the treatment is working or not in slowing the myopia progression such as visual acuity, K-reading value (corneal curvature value), Spherical Equivalent, and Axial length. Visual acuity is the actual eyesight measured in decimals without any aids such as contact lens or spectacle. I didn't choose visual acuity as a measurement factor in this research because visual acuity might not be reliable. Since visual acuity is measured by humans instead of a machine and the result highly depends on the answer of the subject so there will a lot of human errors[23)]. K-reading value is the radius of corneal curvature measured in mm[31)]. I didn't choose K-reading value in my measurement factors since K-reading value did not show any significant change. The difference in K-reading value was so little which made any analysis from the data meaningless[31)]. Therefore, measurement factors for my research have cut down to two factors which is spherical equivalent and axial length as shown in **Table 2**.

Spherical equivalent estimates the refractive error in the subject's eye which is measured in diopter (D)[12)]. Normal human eyes have a refractive power of approximately 60D. However, people with myopic eyes have higher refractive power than 60D which eventually causes the light to focus in front of the retina. This makes people see near objects well but not distant objects. Refractive error will be measured in sphere power and cylinder power. Different sphere power and cylinder power contributes to astigmatism. In spherical equivalent, a special equation, sphere power + (cylinder power)/2, is used to remove astigmatism in the component. Therefore, I thought using spherical equivalent value would be an accurate measurement factor for seeing whether refractive error did or did not increase[3)]. Also, spherical equivalent will be measured by an autorefractor so there will be less human errors which prove the reliability of the measurement[3)]. Axial length is the distance between the anterior and posterior poles of the eye[10)]. The axial length reaches 24mm in normal adults. People with myopia tend to have longer axial length than 24mm which makes it even harder for light to be focused on the retina and is likely to focus in front of the retina[10]. Axial length is also measured by machines such as IOL Master which will lower the possibility of human error and thus result in a more accurate value[29].

Table 2. Measurement Factors and Its Description

Measurement Factors	Description
Spherical Equivalent (D)	Increase in refractive error from the initial value.
Axial Length (mm)	Increase in axial length from the initial axial length.

After making the decision of the treatment that I will focus on my research and the measurement factors that I will be comparing have been decided, I will be collecting data regarding each of the treatment's (time outdoors, atropine, spectacle with bifocal lens, orthokeratology) spherical equivalent and axial length difference before and after using it.

4. Results

The data that I've collected are the change in spherical equivalent and axial length after using each treatment for several years. In this case, every student's myopia will be in progression so it is correct for both spherical equivalent and axial length to get a worse result than it originally was. Thus, spherical equivalent will have a negative value since children's eye will still have a greater refractive error now than before and axial length will get longer as time pass so we have to expect that result from every data that will be collected. However, the point is to see which treatment least change in spherical equivalent and axial length.

The first data that I have collected is the change in spherical equivalent and axial length in the teenagers' eyes after spending time outdoors as shown in **Table 3**. Each treatment group and control group was randomly selected among 6 different school students from grade one to twelve in Guangzhou, China. Six schools that were the treatment group had an extra class of outdoors activity 40 minutes every day for three years whereas the other six schools which were the control group did their normal curriculum. The result has shown that students who got the treatment had -1.42 Diopter refraction change from their original spherical equivalent refraction. The -1.42 Diopter means that spherical equivalent refraction got 1.42 D worse than it used to be. However, in the control group where students didn't have extra class of outdoor activity had -1.59 D change in spherical equivalent. Compared to the control group, students in the treatment group had less development of refractive error. Also the treatment group had less amount of increase for axial length than that of the control group since treatment group had increase of 0.95mm whereas control group had increase of 0.98mm[17].

Table 3. Time Spent Outdoors: Change in Spherical Equivalent and Axial Length

Time Spent Outdoors	Treatment Group	Control Group
Spherical Equivalent	-1.42 D	-1.59 D
Axial Length	0.95 mm	0.98 mm

The data I collected that proves the effectiveness of atropine is shown in **Table 4**.

Children from age six to twelve were randomly divided into two groups: treatment group and control group. Treatment group was prescribed to use 1% atropine while control group was prescribed vehicle eye drops. Each group was assigned to put 3 drops of each treatments every night for 2 years. As shown in **Table 4**, treatment group had noticeably low growth of spherical equivalent and axial length compared to the control group. Treatment group had -0.28 D of increase in refractive error and 0.02 mm growth in axial length whereas control group children

had -1.20 D of increase in refractive error and 0.38 mm growth in eye length[7].

Table 4. Atropine: Change in Spherical Equivalent and Axial Length

Atropine	Treatment Group	Control Group
Spherical Equivalent	-0.28 D	-1.20 D
Axial Length	0.02 mm	0.38 mm

According to **Table 5**, bifocal spectacles was fairly effective in slowing down myopia progression. The data was collected by an experiment where Chinese Canadian children from age 8 to 13 wore bifocal lens spectacles or single lens spectacles and measured the spherical equivalent and axial length of the children after 2 years. Compared to single lens spectacles which had -1.55 D increase in refractive error and 0.62 mm of increase in axial length, children with bifocal spectacles had only -0.96 D and 0.41 mm increase[5].

Table 5: Bifocal Spectacles: Change in Spherical Equivalent and Axial Length

Bifocal Spectacles	Treatment Group	Control Group
Spherical Equivalent	-0.96 D	-1.55 D
Axial Length	0.41 mm	0.62 mm

In **Table 6**, the data for orthokeratology is collected. Children from age 8 to 16 participated in the experiment. The randomly selected treatment group wore orthokeratology while control group wore spectacles instead of OK lens for 2 years. The result collected have shown that orthokeratology did not do a great job in controlling myopia progression in spherical equivalent wise but did do a great job in controlling the growth of axial length. Treatment group had -2.55 D of spherical equivalent which does not have a big difference between control group with -2.59 D of spherical equivalent. However, treatment group had only 0.39 mm increase in eye length whereas control group had 0.61 mm increase in axial length[20].

Table 6. Orthokeratology: Change in Spherical Equivalent and Axial Length

Orthokeratology	Treatment Group	Control Group
Spherical Equivalent	-2.55 D	-2.59 D
Axial Length	0.39 mm	0.61 mm

Therefore, from the data that I have collected, I found the difference between treatment and control group for each treatments. **Figure 1** and **Figure 2** show the difference between treatment and control group in spherical equivalent and axial length for all four treatments. I figured that comparing the difference in control and treatment group would be the most objective and accurate result to analyze the effectiveness of each treatment since the condition for every experiment would be different and the most accurate way is to compare the result of treatment group to that of control group. More difference between the control and treatment group means the treatment had greater effect on controlling myopia progression since it means that originally spherical equivalent or axial length should have grown that much but the treatment controlled the progression.

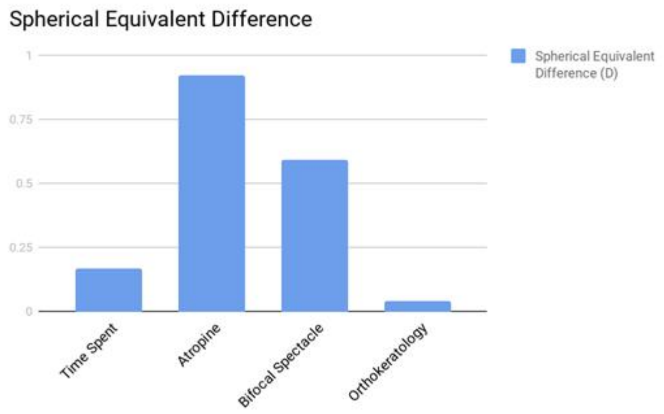

Figure 1. Spherical Equivalent Difference Chart

According to **Figure 1**, for spherical equivalent difference, atropine had greatest effect in controlling the growth of refractive error. Atropine was the most effective one by having 0.92 D difference, followed by bifocal spectacle by having 0.59 D difference. Then, time spent outdoors was ranked third in effectiveness since it had 0.17 D difference and orthokeratology became the least effective one by having only 0.04 D difference.

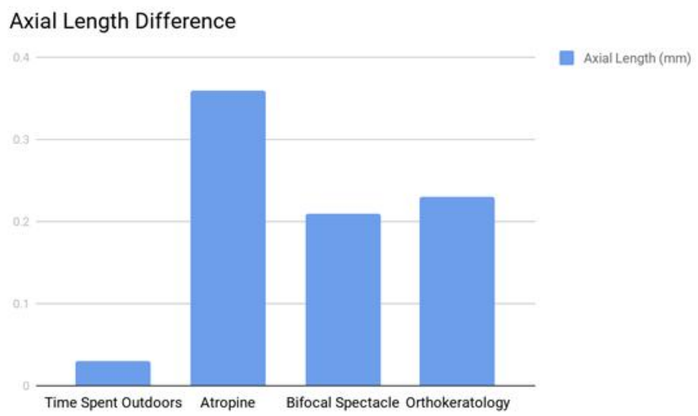

Figure 2: Axial Length Difference Chart

Figure 2 shows that for axial length difference atropine was again the most effect in slowing down the progression of myopia. Atropine was the lead in controlling axial length since it had 0.36 mm difference. Orthokeratology was the second by having 0.23 mm difference and bifocal spectacle was close but came third by having 0.21 mm difference. Last but not least, time spent outdoor was least effective by only having 0.03 mm difference in axial length between the treatment and control group.

5. Discussion

From the data, I analyzed that atropine is the most effective treatment considering both spherical equivalent and axial length. It had the greatest difference between control group and treatment groups, which prove that it prevented or slowed down myopia progression that much. The data validates that my initial assumption which was that atropine would be most effective for Asian teenagers was correct. However, a downside to atropine usage is that first of all we can not ignore the side effects that atropine might trigger. The side effects of atropine can be blurred vision, sensitivity to light, dizziness, nausea, and hypersensitivity reactions such as skin rash. Using low dose of atropine is mostly unsusceptible of getting side effects but a few people experience various side effects even though they used low dose of it. Also, some people might misuse or overuse the medicine which is very harmful to human body[8)]. Secondly, the other downside to using atropine is its impracticality. Atropine is an official medicine that only doctors can prescribe to patients. Thus, no optical shops will own any or sell any atropine which makes it commercially impractical, especially in Korea. To get a treatment for nearsightedness Asian teenagers would go to an optical shop and buy glasses or contact lens instead of going to hospital and get that medicine prescribed. Also, doctors will not prescribe that medicine to anyone but only for those who are in high myopic stages so those who are in low or medium myopic stage won't have any other options to prevent their myopic progression[14)].

Atropine is most effective treatment and teenagers suffering from high myopia should definitely use atropine after getting prescribed by a doctor. However, teenagers who can not get atropine prescribed should have an alternative treatment. Therefore, alternative that I recommend for the Asian teenagers is using orthokeratology instead of medicine. First of all orthokeratology is a good alternative according to my data, Orthokeratology is the second highest in the difference in axial length chart but third highest for spherical equivalent. Bifocal spectacles is the third highest for axial length and second for spherical equivalent. According to DelMonte, axial length is more accurate and precise in showing myopia progression[9)]. Spherical equivalent, on the other hand, can be flawed and is not accurate compared to axial length. As a result, orthokeratology is more effective treatment than bifocal spectacles and is the better alternative for those who can not use atropine. Secondly, unlike atropine orthokeratology can be found commonly in optical shops which means that it will be more practical than atropine.

Although there are no treatment such as atropine that will be effective in slowing down the myopia progression, considering every aspect orthokeratology is a better treatment for Asian teenagers specifically. According to high school students in Fenghua city and eastern China, more than the majority of students have low or moderate myopia in which 45.7% are moderate myopic and 24.4% are low myopic. However, only 16.6% are high myopic and 0.92% are very high myopic.[4] Data from the high school students in Fenghua city may not be an accurate data to generalize it to all

Asian teenagers but I can assume that Asian teenagers will have similar ratio of high, moderate, low myopia. Considering the fact that patients with only high myopia can get atropine prescribed, more commercially practical orthokeratology would be the most effective treatment for Asian teenagers.

6. Conclusion

Atropine showed the most effective result in controlling myopia among the four treatment. Again, compared to other three treatment, using atropine appeared to have greatest ability in slowing down myopia progression since adolescents who were treated with atropine had greatest difference from adolescents in the control group that had the same condition but didn't get the treatment. However, every treatment was only used for 2 or 3 years which is quite short time period to measure the long term effect of the four treatments. Also, since atropine is a pharmaceutical method to control myopia, it may harm adolescents' eyes compared to optical or environmental treatment.

References

1. Aldama, Z. China's myopia epidemic: Why the solution is being ignored. 2017, April 11. Retrieved from https://www.scmp.com/magazines/post-magazine/long-reads/article/2085125/chinas-myopia-epidemic-why-simple-solution-being
2. American Optometric Association. Multifocal contact lens effective at treating myopia in kids. 2016, April 25. Retrieved from https://www.aoa.org/news/clinical-eye-care/multifocal-contact-lens-effective-at-treating-myopia-in-kids
3. Bedinghaus, T. Refraction Test: Overview, Purpose & Procedure. 2018, November 2. Retrieved from https://www.healthline.com/health/refraction-test
4. Chen, M., et al. The increasing prevalence of myopia and high myopia among high school students in Fenghua city, eastern China: a 15-year population-based survey. BMC ophthalmology, 2018. 18(1), 159. DOI: 10.1186/s12886-018-0829-8
5. Cheng, D., et al. Effect of Bifocal and Prismatic Bifocal Spectacles on Myopia Progression in Children. JAMA Ophthalmology, 2014. 132(3), 258.
DOI: 10.1001/jamaophthalmol.2013.7623
6. Chia, A., et al. Five-Year Clinical Trial on Atropine for the Treatment of Myopia 2. Ophthalmology, 2016. 123(2), 391-399. DOI: 10.1016/j.ophtha.2015.07.004
7. Chua, W., et al. Atropine for the Treatment of Childhood Myopia. Ophthalmology, 2006. 113(12), 2285-2291. DOI:10.1016/j.ophtha.2006.05.062
8. Cunha, J. Common Side Effects of Atropine Drug Center. 2018, July 20. Retrieved from https://www.rxlist.com/atropine-side-effects-drug-center.htm
9. DelMonte, D. Biometry for Intra-Ocular Lens (IOL) power calculation. 2018, November 08. Retrieved from http://eyewiki.aao.org/Biometry_for_Intra Ocular_Lens_(IOL)_power_calculation
10. Dictionary of Optometry and Visual Science. (n.d.). Axial Length of the Eye. Retrieved from https://medical-dictionary.thefreedictionary.com/axial length of the eye
11. Dolgin, E. The myopia boom. 2015, March 18. Retrieved from https://www.nature.com/news/the-myopia-boom-1.17120
12. EyeQue. What is a Spherical Equivalent?. 2018, July 20. Retrieved from https://eyeque.zendesk.com/hc/en-us/articles/115008523768-What-is-a-Spherical-Equivalent-
13. French, A. N., et al. Time outdoors and the prevention of myopia. Experimental Eye

Research, 2013. 114, 58-68. DOI: 10.1016/j.exer.2013.04.018

14. Gallagher, R. Myopia Dystopia. 2018, June 06. Retrieved from https://theophthalmologist.com/business- profession/myopia-dystopia
15. Goss, D. A. Nearwork and myopia. The Lancet, 2000. 356(9240), 1456-1457. DOI: 10.1016/s0140-6736(00)02864-6
16. Guo, Y., et al. Outdoor activity and myopia progression in 4-year follow-up of Chinese primary school children: The Beijing Children Eye Study. PloS one, 2017. 12(4), e0175921. DOI: 10.1371/journal.pone.0175921
17. He, M., et al. Effect of Time Spent Outdoors at School on the Development of Myopia Among Children in China. Jama, 2015. 314(11), 1142. DOI: 10.1001/jama.2015.10803
18. Heiting, G. What's the Difference Between Bifocals & Trifocals?. 2018, February. Retrieved from https://www.allaboutvision.com/lenses/multifocal.htm
19. Holden, B. A., et al. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. Ophthalmology, 2016. 123(5), 1036-1042. DOI: 10.1016/j.ophtha.2016.01.006
20. Kakita, T., et al. Influence of Overnight Orthokeratology on Axial Elongation in Childhood Myopia. Investigative Opthalmology & Visual Science, 2011. 52(5), 2170. DOI: 10.1167/iovs.10-5485
21. Lee, Y. C., et al. Effect of Orthokeratology on myopia progression: twelve-year results of a retrospective cohort study. BMC ophthalmology, 2017. 17(1), 243.DOI: 10.1186/s12886-017-0639-4
22. Li, J., & Zhang, Q. Insight into the molecular genetics of myopia. Molecular vision, 2017. 23, 1048-1080. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5757860/
23. Lovie-Kitchin, J. E. Validity and reliability of viscual acuity measurements. Ophthalmic and Physiological Optics, 1988. 8(4), 363-370. DOI: 10.1111/j.1475-1313.1988.tb01170.x
24. Mountjoy, E., et al. Education and myopia: assessing the direction of causality by mendelian randomisation. BMJ, 2018. 361, [k2022]. Retrieved from https://doi.org/10.1136/bmj.k2022
25. Myers, D. G., & DeWall, C. N. Myers psychology for AP. 2018. New York, NY: Bedford, Freeman & Worth High School.
26. Myrowitz, E. 2011. Juvenile myopia progression, risk factors and interventions. Saudi journal of ophthalmology: official journal of the Saudi Ophthalmological Society, 2011. 26(3), 293-7. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3729802/pdf/main.pdf
27. National Eye Institute. Facts About Myopia. 2017, October 01. Retrieved from https://nei.nih.gov/health/errors/myopia
28. Nie, H. H., et al. Effects of 7-methylxanthine on form-deprivation myopia in pigmented rabbits. International journal of ophthalmology, 2012. 5(2), 133-7.
29. Ocular Surgery News Europe/Asia-Pacific Edition. New instrument uses laser, not ultrasound for axial length. 2000, March 15. Retrieved from https://www.healio.com/ophthalmology/news/print/ocular-surgery-news-europe-asia-edition/{f6bf6bfe-4bef-443e-bfe2-a71493411fe8}/new-instrument-uses-laser-not-ultrasound-for-axial-length
30. OECD, "Does Homework Perpetuate Inequities in Education?", PISA in Focus, No. 46, OECD Publishing, Paris,2014. Retrieved from https://doi.org/10.1787/5jxrhqhtx2xt-en
31. Optometry Times. Why keratometry is important | Optometry Times. 2014, May 31. Retrieved from https://www.optometrytimes.com/modern-medicine-cases/why-keratometry-i

mportant

32. Saw, S. M., et al. Eye growth changes in myopic children in Singapore. The British journal of ophthalmology, 2005. 89(11), 1489-94.
33. Swarbrick, H. A., et al. Myopia Control during Orthokeratology Lens Wear in Children Using a Novel Study Design. Ophthalmology, 2015. 122(3), 620-630.
    DOI: 10.1016/j.ophtha.2014.09.028
34. Trier, K., et al. Systemic 7-methylxanthine in retarding axial eye growth and myopia progression: a 36-month pilot study. Journal of ocular biology, diseases, and informatics,2008. 1(2-4), 85-93.
35. WebMD. (n.d.). Eye Problem Pictures: Farsightedness, Nearsightedness, Cataracts, and More. Retrieved from https://www.webmd.com/ eye-health/ss/slideshow-eye-conditions-overview
36. Wu, P., et al. Update in myopia and treatment strategy of atropine use in myopia control. Eye, 2018. 33(1), 3-13. DOI: 10.1038/s41433-018-0139-7