

Control of myopia with orthokeratology

Control de la miopía con ortoqueratología

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ABSTRACT

Orthokeratology has had a great boom in the last few years, due to the appearance of new materials and designs that have facilitated its application. For this reason, the study proposed to develop a review that would allow to analyze this technique based on the experience of patients who were treated with it. *Objectives:* To present scientific evidence of the use of orthokeratology for myopia control. *Materials and methods:* A bibliometric review of 50 scientific articles written between 1999 and 2015, with grade of recommendation B and level of evidence II-3, according to the United States Preventive Services Task Force (USPSTF) scale. The variables age, refractive defect, axial length and corneal curvature were considered. *Results:* 47% of the patients were younger than 15 years of age. The most important modifications through orthokeratology were found in patients with refractive values lower than -4.00 D (80%); one month after treatment, reductions of an average of -3.11 D were evidenced. The lenses used in the study mainly had an inverse geometry design, with materials with permeability greater than 100. *Conclusions:* Orthokeratology retards the progression of myopia; this is evidenced in 100% of the articles analyzed. There is a greater efficacy in the control of low myopia (myopia up to 4 D, according to Borish): 55% of patients with myopia from -0.25 to -1.00 D, while the remaining 45% is distributed between -1.25 and -7.00 D.

Keywords: orthokeratology, corneal shaping, myopia control..

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RESUMEN

La ortoqueratología ha tenido un gran auge en los últimos años, debido a la aparición de nuevos materiales y diseños que han facilitado su aplicación; por esta razón, se planteó desarrollar una revisión que permitiera analizarla desde aquellos pacientes en quienes se ha usado. *Objetivos:* mostrar la evidencia científica del uso de la ortoqueratología para el control de la miopía. *Materiales y métodos:* revisión bibliométrica de 50 artículos científicos escritos entre 1999 y 2015, con grado de recomendación B y nivel de evidencia II-3, según la escala United States Preventive Services Task Force (USPTS). Se consideraron las variables edad, defecto refractivo, longitud axial y curvatura corneal. *Resultados:* el 47 % de los pacientes eran menores de 15 años de edad. Las modificaciones más importantes a través de la ortoqueratología se encontraron en pacientes con valores refractivos menores de -4,00 D (80 %); al mes de tratamiento se presentaron reducciones en promedio de -3,11 D. En su mayoría, el diseño de los lentes utilizados fue de geometría inversa, con materiales con permeabilidad mayor a 100. *Conclusiones:* la ortoqueratología retarda la progresión de la miopía; esto se evidencia en el 100 % de los artículos analizados. Hay mayor eficacia en el control de la miopía en valores bajos (miopías de hasta 4 D, según Borish): un 55 % con miopías de -0,25 a -1,00 D, mientras que el 45 % restante se reparte con poderes entre -1,25 y -7,00 D.

Palabras clave: ortoqueratología, moldeamiento corneal, control de la miopía.

INTRODUCTION

Orthokeratology, which was initially called 'Orthofocus', was used to make lenses with Polymethyl Methacrylate material and was described by Jensen in the '60s. It is currently used for lenses of high permeability and geometry reverse designs and its lenses are for overnight use (1). These changes have allowed adaptations without major changes in corneal physiology, to such an extent that, in January 2002, the changes were approved by the Federal Drugs Administration (FDA) as a technique requiring trained professionals in order to apply it to patients (2). Orthokeratology is a non-surgical, effective and safe method for controlling myopia, as it has been reported that freeing the patient of the daytime use of optical correction improves their quality of life.

METHOD

Type of study: bibliometric review. A keyword search was performed and 65 articles on the subject of orthokeratology were found, covering its influence over the control of myopia between the years 1999 and 2015. From this search, 44 scientific articles with a II-3 level of evidence,

and a B-level of recommendation were found. The data found in Borish's book (3) was used to classify the degrees of myopia according to diopter value (3).

To share the results, we performed a comparative analysis of the different data: the ages during which most orthokeratology adaptations occurred, the proportion of myopia ranges adapted with orthokeratology lenses, the axial length changes in these patients and their relationship with those who only used eyeglasses, the most commonly used lens designs, and the materials used were for orthokeratology lenses.

RESULTS

PREFERRED AGES TO PERFORM ORTHOKERATOLOGY

Most of the research conducted on orthokeratology shows results with children and teenagers. It also shows that using orthokeratology has both a corrective and preventive effect in controlling myopia (4). Values were found with an average reduction of 2.09 ± 1.34 diopter in children between 7 and 12 years. Later, in 2012, some authors evaluated

the efficacy of orthokeratology and found that younger children benefit best from the use of the active axial lengthening process (5). Table 1 shows the proportion of research found in orthokeratology according to age group, and most studies are performed among patients younger than 15 years with a percentage of 47%.

TABLE 1. Ages in which orthokeratology is used

RANGE OF AGES	PROPORTION (%)
Children under 15 years of age	47
Between 16 and 24 years of age	22
Over 30 years of age	16
Unspecified age	15

According to Table 1, more changes are observed with orthokeratology patients under 15 years of age. The classification of myopia is according to Benjamin (3). There is evidence that the average age with the greatest chance of adapting orthokeratology is at age 15, with a 47% chance.

CORNEAL CURVATURE RANGES IN WHICH ORTHOKERATOLOGY IS MORE OFTEN PERFORMED

Although corneal curvature is a key element in the treatment of orthokeratology (2), the review did not find any quantitative evidence in the radio values of corneal curvature of these modifications, and the articles revised report modifications in values of dioptric refraction.

Changes were found in the curvature after 14 days of adaptation with night lenses (6). Some authors also reported changes after using orthokeratology lenses, including changes in the curvature observed 30 minutes after inserting the lenses (7). Other authors reported complete reduction of the value of myopia in a week in patients that used orthokeratology lenses (8).

The anterior layers above the cornea are the ones most often subjected to modification during treatment of Orthokeratology. An analysis was conduct-

ed of the anterior layer and posterior corneal, and the depth of the anterior chamber with pentacam in weeks 2, 4, 8, 12, 24, 36, and 53 (9). Refractive change is directly linked to the change of the anterior corneal curvature, and the authors found no changes in the posterior corneal curvature. Others authors did not find significant changes in the posterior corneal radius, after using orthokeratology for 14 consecutive nights, it was concluded that a total bending of the cornea is not generated in adaptation (10). Some authors worked with orthokeratology lenses controlling the changes through corneal topography and found that successful modifications were recovered after 3 hours of usage (11).

In a study done in Poland, 132 myopic patients between the ages of 5 and 18 years were adapted with values between -1.50 and -5.50 diopter according to prior assessment with a corneal topography of 3 to 5 months before the adaptation and subsequently between 2 and 6 years, and a reduction of the refractive power and a corneal radii increase were found in all previous patients. As such, the study concluded that the use of orthokeratology decreases myopia due to temporary changes in the corneal curvature (12).

Changes in the corneal curvature region were evaluated following the adaptation of the contact orthokeratology lenses, finding corneal asymmetries in the central and paracentral areas that directly influence the refractive behavior, finding there is a greater flattening of the nasal and temporal sectors (13).

DECREASE IN VALUES WITH ORTHOKERATOLOGY

A decrease in the refractive defect after adaptation with orthokeratology contact lenses became apparent in 100% of the analyzed articles (14), with maximum changes detected within a week of treatment, with variations between -0.16 and -0.66 D on the first night and reductions of up to 3.11 per month. They also found an average

reduction of 19 microns in the corneal epithelium after 3 months of orthokeratology.

A sample of 20 short-sighted patients between -1.00 and -7.00 dioptres was evaluated, finding that proper adaptation to a maximum range of myopia of -6.00 and astigmatism of up to -1.50 diopters must be handled, thus ensuring that orthokeratology is safe and effective (15). A decrease of 63 % was found in the progression of myopia in patients that used orthokeratology lenses (16). The orthokeratology technique creates an optical blur on the retina that contributes to a reduced progression of myopia (17) and generates a decreased spherical aberration on the cornea. The study found a reduction of 75% of the default refractive in a population of 54 young people between the ages of 11 and 15 with myopia of -1.25 and -5.00 diopters within the first 2 weeks of treatment with orthokeratology (18). A decrease of the refractive defect was also reported in the first weeks with an average of 92.2 % (19). Orthokeratology carried out a few years earlier had shown effectiveness in reducing the refractive value by 96.7 % per month for those using lenses without that damage that occurred on the corneal surface (20).

After analyzing a number of articles (12-14,17), a 55% reduction of myopia was found in values between 0.25 and 1.00 diopters; reduction of myopia was 21% when values were from 1.25 to 2.25 diopters and of only 24% with values of 2.50 to 7.00 diopters. The same analysis revealed that the astigmatism proportion of the reduction is 86% greater when astigmatism is less than 1.50 diopters and, when values are between 1.75 and 2.75 diopters, the reduction only occurs at 14%.

A research paper analyzed found partial reduction of myopia orthokeratology lens in children aged 8 to 11 with myopia of less than -5.00 diopters, corrected with contact lenses of -4.00 diopters and the residual optical glasses during the day (16). We worked with a control group that was only corrected with glasses and found that the progression of myopia in children adapted with

orthokeratology at 1 month was 0.13 diopters compared to children adapted with glasses who had 1.00 diopter (21). The comparison was made between the quality of life of the children adapted with orthokeratology and with eyeglasses, and the lenses were analyzed. An improvement in attitude of the children with adapted lenses was observed in: visual acuity, academic performance, symptoms, satisfaction, and appearance. Orthokeratology and better adaptation to various activities was observed in these children (22).

A study was conducted with 428 children between the ages of 6 and 12 in Singapore; they were myopic patients with -1.00 to -4.00 diopters who used contact lenses 8 hours a day during the week, and who used eyeglasses in the remaining time. The study was done over a period of 24 months and an increase on the equivalent -1.33 and -1.28 spherical diopters was observed (23).

Evidence was found on the usefulness of orthokeratology for almost 20 years. Compared to a group that was given eyeglasses, it was found that the spherical equivalent in patients was post average orthokeratology, reporting 0.29 ± 0.55 D and 0.37 ± 0.46 D in the group using glasses. The difference was statistically significant ($p = 0.03$) (24).

We investigated the relationship between myopic progression and the 3 axes (i.e. nasal, upper and lower) after a 2-year treatment with orthokeratology. The refractive changes by blur myopia generated in the peripheral retina of patients also found an increase in the corneal curves in all 3 axes (25).

MODIFICATION OF THE AXIAL LENGTH WITH ORTHOKERATOLOGY LENSES

The effect of using orthokeratology lenses in the defect of refraction and axial length in a young user of lenses for orthokeratology for more than 2 years was observed. Their refraction and progression levels were monitored every 8 months (26). After 38 months, the orthokeratology lenses were suspended for a period of 6 months; measure-

ments were made and the variation obtained was of -0.25 diopters and the progression of the axial length was 0.02 mm. The study shows that using orthokeratology contact lenses during childhood produces significant changes in the progression of myopia and its stabilization. When use of the lenses was suspended, no quick progression of the axial length was detected, and little progression of myopia was observed. The orthokeratology method delays axial elongation effectively in children with a moderate myopia level (27). Through a retrospective study, it was discovered that orthokeratology was an effective method to reduce the rate of progression of myopia in children (28). A similar study was performed on 92 subjects between the ages of 11.9 and 13.9 years of age, where 50 wore orthokeratology lenses and 42 wore glasses, with follow-up occurring throughout the 2 years. Axial length growth was of 24.66 ± 1.11 in the group wearing orthokeratology lenses and of 24.79 ± 0.80 mm in the group wearing glasses. Although the differences were not highly significant, the decrease in axial elongation in the orthokeratology group suggests that the technique can help to control myopia (29).

The adaptation of orthokeratology produced significant changes in the progression of axial length (19, 30). Changes in axial length during the orthokeratology process should be considered as reductions in the axial growth resulting from the use of contact lenses; it was also found that there was an average axial growth of 0.29 mm during the adaptation of orthokeratology, as compared to the growth with the adaptation of glasses, which was 0.69 mm. These data points were monitored and reported in articles revised between 6 and 8 months with measurements made with biometrics (31).

Axial growth was monitored for 2 years on children adapted with orthokeratology lenses and conventional glasses, taking into consideration the age of onset, the gender of the patients, and the myopia progression 2 years earlier. Smaller changes were observed in the group adapted with orthokeratology as compared to the group with glasses in

older children. Age and the refractive initial value are crucial to determining axial progression (22).

Adaptation was assessed with two different techniques in contact lenses. The first adaptation was in an orthokeratology lens during the night and a RGP lens in the contralateral eye for 6 months, with a break of 2 weeks during exchange of the lenses. They were monitored every 3 months with IOL Master corneal topography, finding evidence that, during the first 6 months of adaptation, axial growth and myopic progression were inhibited as compared to RGP lenses. It is confirmed in this study that axial growth is slower with the use of orthokeratology lenses (32).

A study was developed to track patients with orthokeratology for a period of five years, during which an increase of axial length of 24.66 ± 1.11 was found in those who used orthokeratology and 24.79 ± 0.80 mm in those who used glasses. The differences found were statistically significant (33). The axial elongation was also studied in the children using orthokeratology, where measurements were performed at home, and two years later, the adaptation of the lenses showed reductions of 0.39 ± 0.27 in the group using orthokeratology lenses against 0.61 ± 0.24 mm compared to the control group (7,34).

DESIGN OF LENSES USED IN ORTHOKERATOLOGY FOR CONTROL OF MYOPIA

The design of most commonly used orthokeratology lenses has an inverse geometry compared to 2% of aspheric lenses (35,36) because it provides better stability, centering, tear exchange and action areas that are spacious and generate optimum results for refractive and corneal physiology protection. Since the appearance of the inverse geometry design of lenses, it began to be used exclusively in orthokeratology.

Comparisons between different marks were made using this type of design, finding that refractive

changes for these types of lenses are similar in 0.84 diopters and that increases in high aberrations in the 20 degrees of the central corneal area, thus concluding that orthokeratology is a safe and effective method of adaptation for controlling myopia (37).

The authors developed the adaptation with Menicon Z contact lenses in children between the ages of 6 and 11, having an initial myopia of -4.00 and -5.00 D. They carried out the monitoring with a computer after 1 month of using the system, finding that this type of lens reduces myopia in patients by providing stable vision after a week of use (16).

A study conducted in 132 patients between the ages of 5 and 18 with myopia between -5.50 and -1.50 D, with 4 reverse curve contact lenses having reverse geometry found an average reduction of -3.00 D and an increase of 0.4 mm in the radius of corneal curvature (38).

We conducted a study between the treatment of the diameter of the orthokeratology area and visual performance in 23 myopic subjects wearing CRT lenses at night, which revealed flattening in the central cornea and increasing RADIUS at the periphery and finding that this area influences the behavior of the aberrations directly, mainly comatic aberration and thus visual performance, as well (39,40).

A comparison was made of 4 designs of reverse geometry lenses used with orthokeratology at night over the course of one month. The study was completed in 46 subjects and, at the end of that month, no significant differences were observed in its effect on visual acuity using 4 designs with high and low contrast, nor were any significant adverse ocular events found (41).

TYPES OF MATERIALS COMMONLY USED IN ORTHOKERATOLOGY

In 98% of the orthokeratology studies reviewed, rigid gas permeable lenses were used as materials,

while only 2% used soft lenses. In one study, the changes in progression of myopia over the course of one year were compared between users of silicone hydrogel contact lenses with high oxygen permeability and of low permeability lenses (12). In the group adapted with high permeability hydrogel there was a myopic regression of 0.33 to 0.18 diopters, while variations from 0.23 to 0.63 diopters were observed in the low permeability group. This study concludes that these changes are due to redistribution related to the pressure exerted on high permeability lenses, contrary to the low permeability lenses, which generated some degree of hypoxia. It also suggests a need for deeper research on this topic.

The security and efficiency of overnight orthokeratology compared to long-term use was evaluated in 342 subjects between children and adults with myopic values of less than -4.00 D and astigmatism of up to 150 D (14), which used three different designs of lenses made with Boston XO material, which has a high permeability (DK 100) that lasts 12 months. It was found that 60% of the subjects reached 20/20 during the month they underwent adaptation and that the use of the 3 different designs of the lenses used were effective for the adaptation. The authors educated patients on lens care, which allowed for these results, but it is worth noting that for these patients should always use high permeability materials.

A comparison was made between the oxygen transmissibility when using orthokeratology lenses and the optical and visual performance of Menicon MZ Dk/t: 90.6 contact lenses and Equalens II Dk/t: 47.2 lenses, finding a similar visual performance in both eyes after 12 hours (14,30).

The effects on corneal biomechanics during the adaptation of orthokeratology lenses and later the adaptation of CRT lenses were evaluated in 24 young people, divided in two groups. The first group underwent a 1-month adaptation while the second group had an adaptation of 1 year. Patients were assessed after 15 days and, one month after

finishing the treatment, there was a reduced corneal hysteresis but with a reversible change after suspension of the adaptation (36).

A pilot study was conducted in the United States with 29 children between the ages of 8 and 11 with myopic values from 0.75 to 5.00 and astigmatism of up to 1.50 diopters using Paragon Vision Sciences contact lenses for orthokeratology for a period of 6 months (42). Table 2 shows the objective findings according to the characterization of the articles selected and analyzed.

TABLE 2. Characterization of the articles about orthokeratology

VARIABLE	PROPORTION
Recommendation level	100 %
Evidence level	Q1: 60%, Q2: 32 %, Q3: 6 %, C: 2 %
Type studies	Prospective: 68 %
Years	2012-2015: 44 %; 2006-2011: 36 %; 1999-2005: 20 %
Time scale studies	Between 1 month and a maximum of 96 months

CONCLUSIONS

- In the analyzed articles, there is scientific evidence of the 98 % control of myopia with orthokeratology, which shows that it is safe and effective method of visual correction. Thus, it is possible to achieve significant refractive changes (-3.11 D) in one month if the adaptation is conducted properly and safely.
- According to the US Preventive Services Task Force (USPSTF) scale, the level of evidence between Q1 and Q2 was 92%, which indicates the quality and reliability of the information gathered. Furthermore, 100% of the reviewed articles had a B-level or moderate recommendation, since the benefits outweigh the damages.
- During analysis of these articles, no changes were found in the rear corneal curvature, while

changes in the anterior layers of the cornea were confirmed, as the treatment zone in orthokeratology.

- In 67 % of the analyzed studies that used orthokeratology, there is evidence of control in axial length growth in children of 0.4 to 0.39 mm; according to the research reviewed, this makes it possible to believe that it can be an effective method to control myopia.
- Ninety-eight percent of the analyzed studies took place in foreign countries, with a low participation of Latin American countries. It would be very important to conduct a research in our region in order to analyze if those changes occur in the same way in this demographic type, despite the fact that, according to medical records, there is a lower number of myopic patients in European and Eastern countries.

RECOMMENDATIONS

- It is proposed that, during the planning of future research, a full description be made of the physical-chemical characteristics of the materials used and of the changes of the Dioptric values on the corneal curvature.
- It is recommended that optometrists continuously update the aspects to consider in the adaptation of orthokeratology.

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