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Extraocular myofascial release: introduction of a new method for treatment of esodeviations and assessment of its effectiveness on patients with convergence spasm: a clinical trial

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HIGHLIGHTS

This article introduces a noninvasive method for treating esodeviations. The EOMR technique may reduce the amount of deviation by releasing the medial rectus myofascial tissue in patients with non-accommodative and non-paralytic esodeviations.

ABSTRACT

Purpose: We examined the effect of Extraocular Myofascial Release (EOMR) on the amount of esodeviation in patients with convergence spasms to evaluate its efficacy, maintenance, and effect size.

Methods: 29 patients with esodeviations due to convergence spasm participated in this study. After the initial measurement of the deviation, we conducted 2 treatment sessions the following week. Then, we stopped treatment for 2 weeks to assess the maintenance of the treatment. To perform the EOMR technique, we apply extremely gentle and continuous pressure to the medial rectus and its associated connective tissue with the index finger pulp for 300 s per eye.

Results: According to repeated-measures analysis of variance, the amount of esodeviation significantly decreased at far 1.22_{Δ}, 95% CI: 0.64–1.81 and near 4.9, 95% CI: 4.13–5.67 immediately after the first session of EOMR. More decrease occurred after the second session of therapy for far 1.83_{Δ}, 95% CI: 1.02–2.63, which was 44.6% of the total pre-treatment amount of esodeviation, and at near 5.52_{Δ}, 95% CI: 4.41–6.63, which was 71.6% of the pre-treatment amount of eso-

deviation. The amounts of far and near esodeviation were still significantly lower than pre-treatment measurements even 2 weeks after the termination of the treatment at far 1.52_{Δ}, 95% CI: 0.74–2.29 and near 5.4_{Δ}, 95% CI: 4.05–6.74.
Conclusions: The EOMR technique reduces the amount of esodeviation in patients with convergence spasm non-invasively by decreasing the force derived by the medial rectus tonus, its passive characteristics, and smooth muscle contraction. It can be a reliable therapeutic technique for esodeviations with non-accommodative and non-paretic etiologies.

Key words: extraocular muscles, strabismus, esodeviation, connective tissue, myofascial release

INTRODUCTION

Strabismus treatment has always been a critical consideration in clinical optometry and ophthalmology. However, the intra-orbital complex anatomy and our insufficient knowledge about extraocular muscles' kinematics have made the treatment of strabismus challenging. Today, various methods like surgery, botulinum toxin injection, vision therapy, and prescription of prisms or corrective lenses are used to treat strabismus. Nevertheless, sometimes these methods are not efficient enough or may cause complications [1–5]. In addition, most therapeutic approaches only focus on muscles and do not consider connective tissue pathologies.

The extraocular connective tissues have found their place in modern strabismology. Over the past few decades, an increasing number of studies have emphasized extraocular connective tissues' role in strabismus pathogenesis. They urged researchers to find effective treatments for strabismus based on the new findings [6–14]. Thus, developing treatment methods that act on both connective tissues and muscles would be worthwhile.

Myofascial release is a manual therapy that includes long-duration gentle pressure and stretching to the myofascial tissue. Myofascial release techniques are rising as a therapeutic strategy with solid evidence for efficacy in skeletal muscle pathologies [15]. Despite considerable differences, extraocular and skeletal muscles are both striated [16]. Therefore, it seems reasonable to expect that myofascial release techniques be applicable to extraocular myofascial tissue [17].

Convergence spasm as a part of near reflex spasm (which can be isolated or in combination with accommodation spasm and miosis) is a relatively rare condition that causes esodeviations due to the medial rectus overaction [5, 18, 19]. No specific etiology is known for this condition. However, it has been speculated that some neurologic and psychogenic factors or too much accommodative demand may be involved [5]. Studies on convergence spasm found that their tested treatment methods were mostly unsuccessful. Botulinum toxin injection [20, 21], cycloplegic drugs [21], plus lenses [21], orthoptic exercises [21], base-out prisms [22], medial rectus recession [23], and pharmaceutical treatment for psychiatric disorders [24] are some of those methods.

We developed a novel non-invasive treatment method for strabismus based on the myofascial release of the extraocular muscles, specifically the medial rectus. This article describes this new procedure termed Extraocular Myofascial Release (EOMR) and discusses its scientific basis and possible applications. EOMR may be used to treat esodeviations by releasing the contractured or spastic medial rectus and its interrelated connective tissue. Finally, we examined the effect of EOMR on the amount of esodeviation in patients with convergence spasms to evaluate its efficacy, maintenance, and effect size.

METHODS

Study design

Considering the necessity of assessing the effectiveness of our proposed technique, we designed a clinical trial. Extraocular Myofascial Release (EOMR) was applied to 29 patients with convergence spasms aged from 20 to 35 years. Patients with the following criteria were included to ensure that the esodeviation is due to convergence spasm and does not have an accommodative or paretic origin. They had encountered esophoria-related symptoms in the past six months while they had a normal gradient AC/A ratio 2.86 (±2.40) (mean ±SD) [25] and no apparent hyperopia. Cyclopentolate 1% was used for cycloplegic refraction and -2.00 D lenses at a 40 cm distance for gradient AC/A ratio measurement. The comitancy of phoria confirmed the non-paralytic nature of esophoria.

First, the amount of deviation (prism-diopters) was measured by alternate cover testing and prism bar (Luneau, Pont-de-l'Arche, France). Then the EOMR technique was performed on each eye for 300 s, and the amount of deviation was measured again after 5 min of rest. The EOMR and deviometry were repeated after a week. After another

2 weeks of no intervention, deviometry was repeated to examine the maintenance of the treatment effect.

Sample size calculation

The sample size was calculated by PASS 15 (Power Analysis and Sample Size Software 2017, NCSS, LLC. Kaysville, Utah, USA, ncss.com/software/pass.) using the test for pair means. Because the effect size was smaller for far, the far mean of paired differences and standard deviation were used after a pilot and recalculated at the end of the sampling: 1.52 (±2.03). As a result, the sample size of 20 was calculated with $\alpha = 0.05$ and 0.90 power. However, we enrolled 29 individuals in our study, which makes the far mean of paired difference detectable with $\alpha = 0.01$ and 0.90 power.

Participants were recruited from the Noor Eye Hospital Orthoptics Clinic, Tehran, Iran. Informed consent was obtained from all participants, and the therapeutic intervention and research method were clearly explained.

The study has been approved (IR.IUMS.REC.1399.1241) by the Ethics Committee of the Iran University of Medical Sciences, a branch of the Iran National Committee for Ethics in Biomedical Research, and adheres to the principles of the Helsinki Declaration.

The clinical trial is registered in the Iranian Registry of Clinical Trials (IRCT), a primary registry in the WHO registry network (IRCT20210130050183N1).

Extraocular Myofascial Release procedure

The following steps describe the EOMR technique for releasing the medial rectus. The patient is first asked to abduct one eye behind closed lids so that the anterior portion of the target muscle becomes accessible as much as possible (fig. 1). Then, the medial rectus and its associated connective tissue are touched with the index finger pulp over the eyelid. The finger pulp should be placed on the central and medial parts of the globe (fig. 2), and the touch should be maintained for at least 300 s with extremely gentle but steady pressure [15].

The EOMR technique is designed based on the indirect myofascial release approach. Myofascial release is used in direct and indirect methods for skeletal muscles. The direct process exerts a relatively intense pressure (a force of about several kilograms) on tissue, whereas the indirect method applies a gentle stretch with low pressure (a force of about a few grams) that should be maintained until the tissue releasing [15].

The minimal force should be constant without intensification to obtain the desired viscoelastic condition without damaging the tissue [26]. In our practice, to ensure that the pressure applied to the globe is gentle enough, we ask the patients to report any pressure, pain, or phosphene sensation immediately. If this occurs, it is necessary to reduce the force and keep it as slight as a touch.

During the procedure, the fingertip tactile sensation could distinguish the medial rectus hypertonia. A hypertonic muscle is felt like a rigid tissue that becomes soft and elastic after release. Sometimes the muscle release occurs layer by layer, and sometimes it happens all at once, creating a butter-melting sensation on the fingertip [27]. Occasionally, the released muscle is trapped in an unreleased epimysium (i.e., muscle sheath) and simulates the sense of touching a bag of water. Perceiving and distinguishing these sensations in the fingertip requires training and experience. An experienced finger can well monitor the condition of the muscle and its interconnected fascia during the release process.

The patient should sit comfortably with a headrest supporting their head and neck. Performing the technique in silence without a conversation between the patient and the therapist is recommended to prevent emotional stress. The silence also helps the therapist focus on the fingertip sense, which receives real-time information about the muscle condition and applied pressure force. The therapist's position should also be comfortable to continue the technique without strain for a long duration. To better control the index finger and avoid applying excessive pressure on the globe, the therapist should place the thumb on the lateral edge of the orbit and the middle finger below it (fig. 2). The other hand could also be placed on the patient's head over the ipsilateral occipitofrontalis muscle's frontal belly (fig. 2). The occipitofrontalis fascia connects to the intra-orbital fascial network through attaching to the levator palpebrae superioris fascia [28]. Thus, placing the other hand on the patient's head may indirectly help release the medial rectus myofascial tissue. Likewise, the headrest support could prevent tension in the occipitofrontalis muscle's occipital belly and release its fascia by applying mild pressure.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA). The significance level was considered 0.005 after the Bonferroni adjustment. Deviometry measurements were compared by repeated-measure analysis of variance, followed by the Bonferroni t-tests.

RESULTS

29 patients (22 females) aged 26.7 (±5.7) years old (20–35) attended this study. Their cycloplegic refraction [mean (±SD)] was -0.68 (±1.26) for the right eye, -0.64 (±1.27) for the left eye, and their AC/A ratio was 2.48 (±0.77). All 29 patients attended the 4 measurement sessions. The mean interval time was 7.7 days between the initial treatment session and the first follow-up, and 21.2 days between the initial treatment session and the second follow-up.

FIGURE 1

The abduction of the right eye. Note the anterior portion of the medial rectus that becomes accessible for performing the Extraocular Myofascial Release (a). The circle shows the abducted right eye beneath the closed eyelid, and the rectangle represents the place of the medial rectus (b) [17].

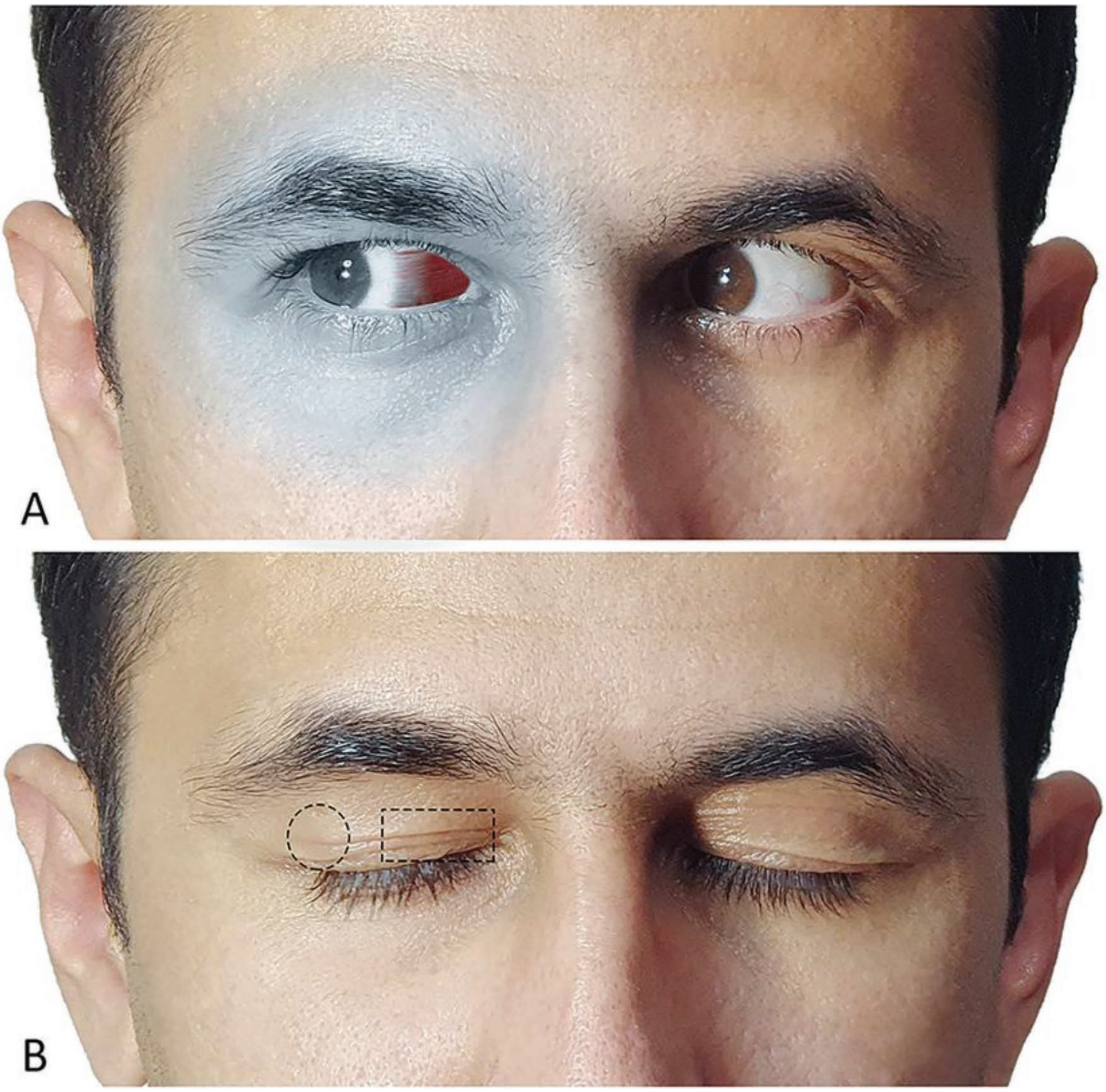


Figure 3 shows the changes in the amount of deviation (prism-diopters) during the 4 measurement sessions at far and near.

The amount of esodeviation decreased significantly at both far 1.22_{Δ}, 95% CI: 0.64–1.81 and near 4.9, 95% CI: 4.13–5.67 after one session of EOMR (tab. 1). The decrease in esodeviation was more after the second session of EOMR at far 1.83_{Δ}, 95% CI: 1.02–2.63, which was 44.6% of the total pre-treatment amount of esodeviation, and near 5.52_{Δ}, 95% CI: 4.41–6.63, which was 71.6% of the pre-treatment amount of esodeviation. The amount of esodeviation remained significantly lower than before treatment measurements 2 weeks after the termination of the treatment at far 1.52_{Δ}, 95% CI: 0.74–2.29 and near 5.4_{Δ}, 95% CI: 4.05–6.74] (fig. 3, tab. 1).

Among the participants, 5 subjects had more than 2 weeks post-treatment follow-up times. The findings of these 5 cases are shown in table 2. Our results showed that after the period of no intervention, the amount of far and near esodeviation were 1.1_{Δ} and 5.2_{Δ} lower than the first measurement, respectively. Only in one case, the amount of far deviation increased by 2_{Δ}.

DISCUSSION

We developed a non-invasive treatment method that may reduce the magnitude of esodeviations by decreasing the medial rectus tonus. We suggest that the EOMR technique could help to treat some extraocular muscles and their

FIGURE 2

Performing the Extraocular Myofascial Release high-angle photograph (a) and low-angle photograph (b) [17].

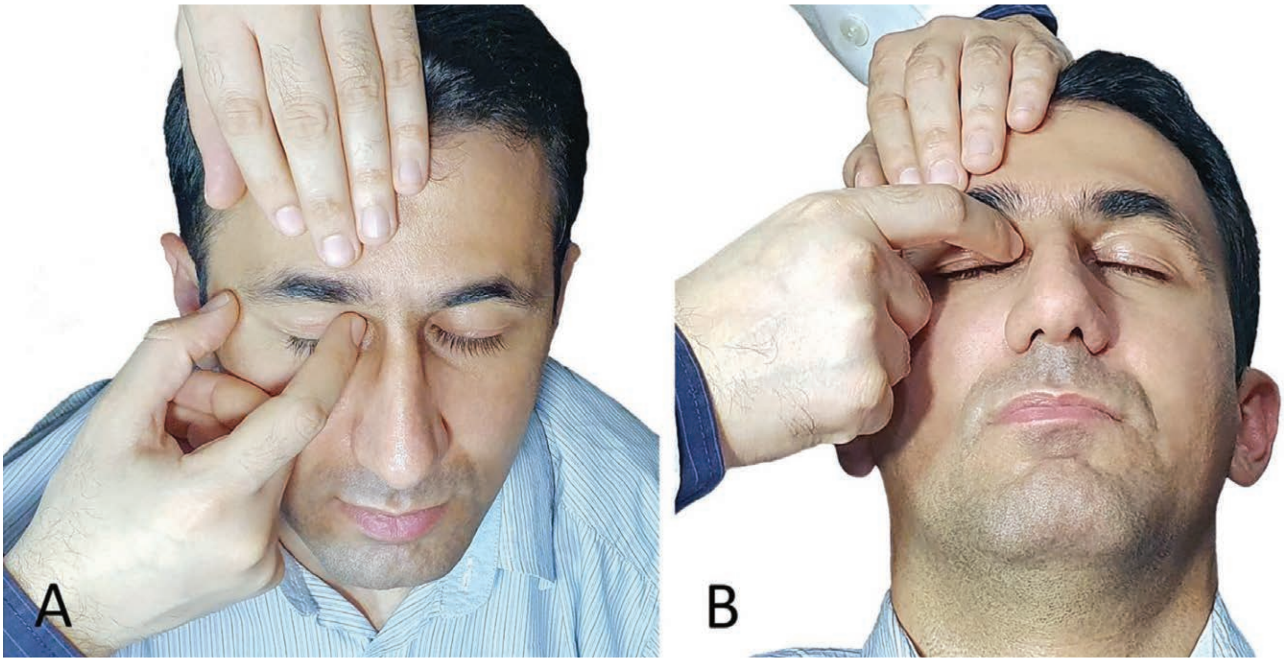
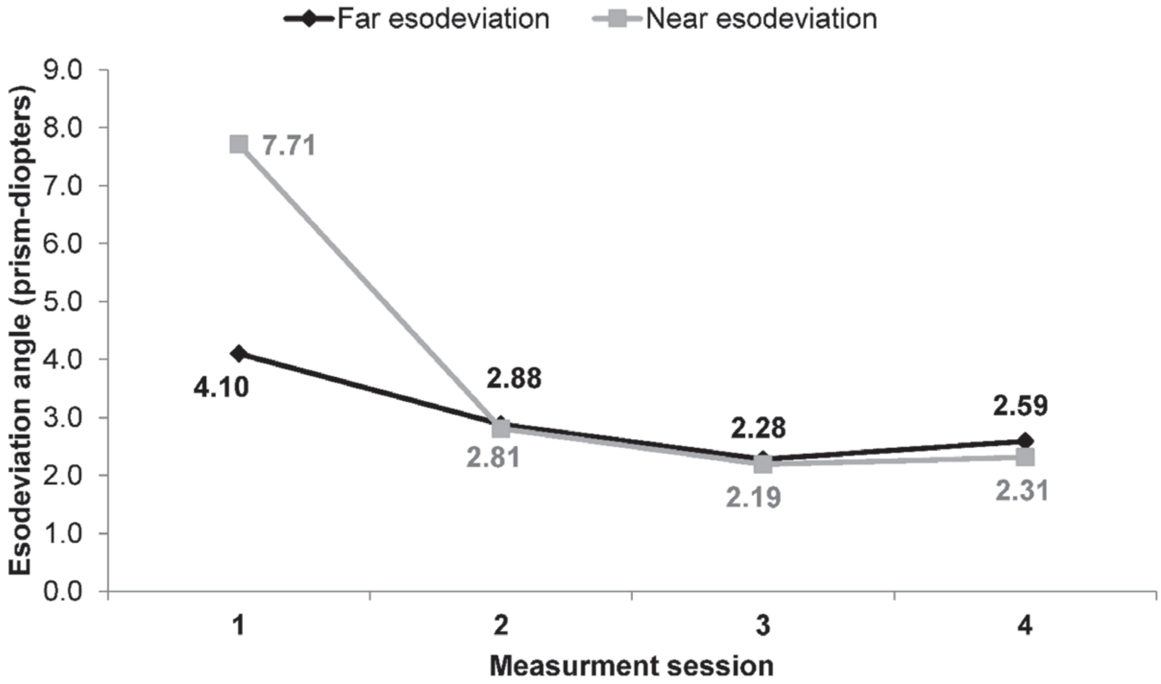


FIGURE 3

Changes in the amount of esodeviation (prism-diopters) during the four measurement sessions at far and near.



associated connective tissue abnormalities. Furthermore, we used our approach to treat strabismus, unlike typical myofascial release applications in skeletal muscles (e.g., pain relief or increasing the muscle's length and range of motion) [15]. The main advantage of our technique is its ability to reduce the amount of deviation non-invasively. Strabismus surgery and botulinum toxin injection are highly invasive, and other non-invasive treatments, such as vision therapy and relieving prism prescription, rarely reduce the amount of deviation.

TABLE 1

Differences of the deviometry measurements (prism-diopters) at far and near. Positive measures demonstrate the decrease, and the negative measures demonstrate the increase in esodeviation.

	Far deviation		Near deviation	
	Mean difference (95% CI)	P-value*	Mean difference (95% CI)	P-value*
M1–M2	1.22 (0.64–1.81)	**<0.001**	4.9 (4.13–5.67)	**<0.001**
M1–M3	1.83 (1.02–2.63)	**<0.001**	5.52 (4.41–6.63)	**<0.001**
M1–M4	1.52 (0.74–2.29)	**<0.001**	5.4 (4.05–6.74)	**<0.001**
M2–M3	0.6 (0.08–1.13)	**0.026**	0.62 (-0.31–1.55)	0.182
M2–M4	0.29 (-0.08–0.66)	0.114	0.5 (-0.5–1.5)	0.316
M3–M4	-0.31 (-0.81–0.19)	0.213	-0.12 (-0.81–0.57)	0.723
P <0.001**			P <0.001**	

M – deviometry measurement (prism-diopters). M1 – pre-intervention, initial amount of deviation. M2 – post-intervention, immediately after the first session of treatment. M3 – post-intervention, after the second session of treatment. M4 – post-intervention, after 2 weeks without treatment.
* bolded measures are significant (P <0.05).
** P-value calculated by repeated-measures analysis of variance, followed by the Bonferroni t-tests.

TABLE 2

Deviometry measurements (prism-diopters) at far and near in five cases with more than 2 weeks of follow-ups.

Case	Sex	Age	Far deviation		Near deviation		Post-treatment follow-up (days)*
			M1	M4	M1	M4	
1	female	27	8	4	6	0	39
2	female	29	3	0	5	2	38
3	female	20	0	0	6	1	19
4	male	22	0	-0.5	4	-2	16
5	male	20	0	2	6	0	16

M – deviometry measurement (prism-diopters). M1 – pre-intervention, initial amount of deviation. M4 – post-intervention, last follow-up.
*the number of days after the termination of treatment.

The EOMR technique significantly reduced the amount of esodeviation in patients with convergence spasms immediately after the first treatment session. This reduction continued even further after the second EOMR session. Two weeks after the termination of the treatment, the esodeviation was still significantly lower than its pre-treatment amount. Although long-term follow-ups are required to ensure maintenance, we can state that the EOMR results would remain for at least 2 weeks. The reduction in the amount of esodeviation was enough to resolve some patients' deviations, but the ones with greater initial esodeviations did not cure completely. However, we managed their residual deviations with lower-power base-out prisms. This finding implies that many patients with small-angle esodeviations may be treated by EOMR, alone or combined with base-out prisms, without the need for invasive treatments.

Myofascial release may affect tissue's passive and contractile conditions through several mechanisms. A necessary adjustment is to change the state of a highly viscous ground substance to a solution (*gel to sol*). This alteration may occur due to a piezoelectric event. Applying mechanical force generates an electric charge in the collagen and proteoglycans within the extracellular matrix, altering the ground substance's ionic conditions. The new ionic state leads to water absorption, especially in bonding with proteoglycans, preparing appropriate viscoelasticity for the extracellular matrix [29]. Some authors believe that the electric charge excites the fibroblasts and alters their metabolism to digest abnormal collagen fibers and produce new ones [30]. These mechanisms take time. However, therapists observe a rapid tissue release during the myofascial release procedure. Similarly, we observed an immediate response in the medial rectus to the EOMR. Schleip suggested that the nervous system activity is the most likely mechanism for the rapid tissue response to manipulation [31].

Numerous studies on limb skeletal muscles and connective tissues have proven that the fascia is rich in mechanoreceptors, including Golgi tendon organs, Pacini and Pacini-form, Ruffini, and interstitial receptors. This feature introduces the fascia as a sensory organ. Each mechanoreceptor responds to specific stimuli, and the stimulation of each induces specific responses in tissue [28, 30–32]. Although what is seen in skeletal muscle proprioception does not necessarily applicable to extraocular muscles, the presence of some mechanoreceptors like muscle spindles, and palisade endings (myotendinous cylinders) have proven in orbital connective tissue [33–36]. These mechanoreceptors are sensitive to touch or pressure, and the information they receive is used to control the muscle's length and contraction. Therefore, they may have a role in releasing the muscle spasm after the EOMR [35].

In response to proprioception, the central nervous system reacts via somatic or autonomic efferent nerves [35]. Receiving both sympathetic and parasympathetic nerves, smooth muscles have a dynamic role in ocular motility [37, 38]. Since there is a relatively high density of smooth muscle fibers in medial rectus-associated connective tissue [11], we hypothesize that smooth muscle contraction may stretch the medial rectus and restrict its flexibility during sympathetic stimulation. Therefore, the smooth muscle fibers' contraction can be expected to contribute to esodeviations. We suggest that the EOMR technique could release the contraction of smooth muscles via sympathetic inhibition and parasympathetic excitation.

Since the EOMR technique applies extremely gentle and continuous pressure, the Ruffini (type II) and interstitial (types III and IV) mechanoreceptors seem to be involved. Stimulation of the Ruffini receptors reduces sympathetic activity, leading to tissue relaxation. However, interstitial receptors stimulation may release the tissue through extravasation of plasma, which alters the extracellular matrix viscosity and fluid dynamics. Stimulation of the Interstitial receptors also increases parasympathetic activity, leading to activation of a trophotropic tuning in the hypothalamus (i.e., the tendency to recover energy through rest). As a result, global relaxation occurs in the neuromuscular system. Ruffini and interstitial receptors also increase proprioceptive and introspective awareness, regulating the corresponding striated muscles tone through the central nervous system [30–32, 39].

An extraocular muscle that remains functionally hypertonic for an extended period may develop structural changes that alter its passive characteristics (e.g., stiffness, tightness, and length). Authors attributed these structural changes to the increased collagen content of the myofascial tissue, reducing elasticity and increasing stiffness [14, 40–42].

The main load on an extraocular muscle is the passive force of its antagonist. Thus, the contracture of the hypertonic medial rectus may produce a force against the lateral rectus, which results in a more demanding esophoria. Besides, in contrast to the medial rectus active force inhibited when the lateral rectus contracts (Sherrington's law of reciprocal innervation), the passive force increases with the medial rectus stretch and lengthening [43]. However, manipulation of the myofascial tissue helps regenerate the extracellular matrix and improves the muscle's passive characteristics [44]. Using the EOMR technique, we decrease the medial rectus and its associated connective tissue passive force, eventually reducing the amount of esodeviation.

STUDY LIMITATIONS

Since the extraocular muscles are in close proximity to the globe, applying much force may be harmful. Therefore, we can only use the indirect myofascial release, which involves a constant, gentle pressure. Besides, we did not have an instrument to measure the pressure exerted on the tissue. We suggest measuring and reporting the amount of pressure exerted on the medial rectus in future researches. Since convergence spasm is relatively rare, recruiting a control group would take a long time. Thus, we used a self-controlled design. However, we suggest that randomized controlled trials with larger sample sizes and longer follow-ups are required to assess the efficacy and maintenance of EOMR. We also recommend applying this technique to treat other spastic problems related to the eye and its appendices and the issues that involve smooth muscles and the autonomic nervous system. Furthermore, we believe the EOMR technique may help treat iatrogenic connective tissue abnormalities after strabismus surgery.

The EOMR technique would not be applicable for accommodative or paralytic strabismus. However, we believe this technique would be an appropriate treatment option for the deviations resulted from muscle spasms, hypertonicity, contracture, or connective tissue abnormalities.

CONCLUSION

The EOMR technique significantly reduced the amount of esodeviation at both far and near distances and the achieved reduction in esodeviation remained for at least 2 weeks after the termination of the treatment.

We introduced a novel non-invasive therapeutic technique for esodeviations, considering the contribution of the medial rectus tonus, its passive characteristics, and smooth muscle contraction. The EOMR technique may reduce the amount of deviation by releasing the medial rectus myofascial tissue in patients with non-accommodative and non-paralytic esodeviations. In addition to extraocular muscles, this technique also targets the extraocular connective tissue and autonomic nervous system as other contributing factors in strabismus, which are almost neglected in today's clinical settings.

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Conflict of interest:

None.

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Ethics:

The content presented in the article complies with the principles of the Helsinki Declaration, EU directives and harmonized requirements for biomedical journals.