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RESEARCH AND EDUCATION

FitJaw Mobile, a virtual reality device applied to dentistry: An analysis based on two patient treatments

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ABSTRACT

Statement of problem. Virtual reality (VR) has improved significantly in the last decade and has been applied to different fields, including medicine, dentistry, and physiotherapy. VR has been used for the innovative treatment of painful conditions, especially when traditional exercise therapies were unsuccessful because of patient noncompliance.

Purpose. The purpose of this study was to analyze the use of VR as an aid when using exercises to manage temporomandibular disorders (TMDs).

Material and methods. Two White women diagnosed with TMDs of muscular origin (one with muscular pain and the other with reduced mouth opening) were referred to the Department of Prosthodontics of the University of Seville, where they were enrolled in an exercise program using the VR software program FitJaw Mobile. Both had been treated the previous year with an occlusal device for TMD of muscular origin, but their symptoms had not improved.

Results. For both patients, the functional movement limitation and the chronic pain improved noticeably.

Conclusions. The use of VR when doing jaw exercises can improve outcomes and compliance. (J Prosthet Dent 2023;■:■-■)

Virtual reality (VR) is a technology that completely immerses the user in a world in which they can undergo sensations and experiences that are close to reality.[1-5] Special equipment such as goggles, gloves, headsets, or remote controls may be required for VR.

Recently, VR has been applied to health care, including in medicine.[6,7] For example, it has been used to treat phobias,[8] where it has been found to be a useful tool in reducing anxiety and depression symptoms or to control pain in patients undergoing cancer treatment.[9] Statistically significant improvements have been reported when rehabilitating upper limbs after a stroke or when training professionals.[10] In physiotherapy, sports trainers have reported VR to be a motivational engine to improve the exercise technique and adherence to the exercises.[11-17] It has even been used to rehabilitate injuries and distract patients from pain, allowing a faster recovery than with traditional procedures for certain types of lesions.[18-20] In dentistry, different uses of VR have been described, such as for distracting children during dental anesthesia and caries removal,[21] for chronic neck pain treatment,[22] and for teaching predoctoral and postgraduate students.[23-25]

Since VR is a new technology, there is still a wide range of possibilities to explore. A group of investigators from the University of Seville (Spain) focused on one of these by developing a virtual reality software program (FitJaw Mobile; Virtual Fisio Co) to be used in physiotherapy for patients with temporomandibular disorders

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Clinical Implications

VR can be a useful tool when proscribing jaw exercises and can lead to improvement of the symptoms, pain, and limited mouth opening associated with TMDs.

(TMDs). The goal was for the exercises to be undertaken in a more agile and leisurely way by participating in a video game. This article describes how this VR software program was used in 2 patients with muscular TMD who had previously been treated by using an occlusal device without functional or pain improvement. The patients carried out an exercise program using FitJaw Mobile, and their progress and perception of the device were analyzed. The null hypothesis was that VR as an adjunctive therapy would not contribute to physiotherapy to improve the symptoms of TMDs.

MATERIAL AND METHODS

Two White women, 65 and 58 years old (patients 1 and 2, respectively) were referred to the Prosthodontics Department of the University of Seville because of muscular pain in patient 1 and limited mouth opening in patient 2. They underwent a detailed clinical examination, with their medical history and the clinical assessment being obtained according to the diagnostic criteria for the investigation of temporomandibular disorders (CDI/TTM, axis II), as described by Dworkin and LeResche.[26]

Informed patient consent was obtained. Once the diagnosis had been established, both were instructed to use their occlusal device as well as the FitJaw Mobile VR tool as they felt appropriate. A physiotherapist (A.B.A.C.) trained in the use of this device explained its application to each patient (Fig. 1).

The software program was downloaded onto their mobile devices, which were then placed inside virtual reality cardboard goggles (Google Cardboard; SPLAKS 3D VR). This allowed them to virtually perform the physiotherapy exercises on a daily basis (Fig. 2). The software program encouraged the patient to complete forced mastication and speaking exercises to gradually strengthen muscles and increase jaw opening (Fig. 3).

Two follow-up appointments took place, a week and a month after starting the virtual exercises program, and the progression of the symptoms was analyzed in both patients (Tables 1 and 2).

RESULTS

For patient 1, both her limitation with functional movements and chronic pain improved noticeably after 1 week and even more after 1 month. In terms of pain, it was more intense in the masseter in all 3 areas of palpation, varying from 3 (maximum pain) to 1 or even 0. The increase in pain in the distal mandible area at the 1-month follow-up appointment may have been associated with an influenza infection, which increased the pain in areas surrounding the throat. The results also showed a functional improvement that led to a normal opening.[27] She reported that she perceived the VR software program as satisfactory, that it was straightforward to use, and that she felt a general improvement, as specified in Table 1.

Patient 2 reported a noticeable improvement in mouth opening, a limitation before treatment. She

Figure 1. Instructions of how to use software program at practice with virtual reality goggles.

Figure 2. Google Cardboard and software program downloaded in mobile device of patient.

Figure 3. Software program images.

Table 1. Patient 1 dates

	Diagnostic Criteria	1st Appointment		1 Week After		1 Month After	
Patient 1	Jaw Functional Limitation Scale (scale 0-10: 0 "no limitation"-10 "severe limitation")						
	Masticating hard food	0		0		0	
	Masticating soft food	0		0		0	
	Opening to eat an apple	4		4		0	
	Swallowing, speaking	0		0		0	
	Yawning	5		4		1	
	Facial gestures	0		0		0	
	Graded Chronic Pain Scale (scale 0-10: 0 "no pain"-10 "pain as bad as could be" in the last 30 days)						
	Facial pain right now	5		3		3	
	Worst facial pain	9		10		4	
	Average facial pain	5		4		3	
	Everyday life limitations	7		8		0	
	Days where daily routine affected	3-4 days		3-4 days		0 days	
	Limitation in social and family life	3		0		0	
	Limitation to work life	7		6		0	
	Extraoral and cervical muscle palpation (scale 0-3: 0 "no pain"-3 "severe pain")						
	–	Right	Left	Right	Left	Right	Left
	Posterior temporalis	0	0	0	0	0	0
	Middle temporalis	0	0	0	2	1	0
	Anterior temporalis	2	3	1	1	1	0
	Masseter origin	0	0	1	2	0	1
	Masseter body	3	3	0	3	1	1
	Masseter insertion	3	3	0	2	0	1
	Post mandibular region	0	0	0	1	2	3
	Submandibular region (under chin)	0	0	0	0	0	0
	Joint pain (scale 0-3: 0 "no main"-3 "severe pain")						
	–	Right	Left	Right	Left	Right	Left
	Lateral pole (outside)	0	0	0	0	0	1
	Posterior attachment (inside ear)	0	0	0	0	0	0
	Pain-free opening						
	mm	37 mm		38 mm		39 mm	

Table 2. Patient 2 dates

	Diagnostic Criteria	1st Appointment		1 Week After		1 Month After	
Patient 2	Jaw Functional Limitation Scale (scale 0-10: 0 "no limitation"-10 "severe limitation")						
	Masticating hard food	10		6		5	
	Masticating soft food	6		0		0	
	Opening to eat an apple	10		8		6	
	Swallowing, speaking	0		0		0	
	Yawning	10		9		6	
	Facial gestures	6		0		0	
	Graded Chronic Pain Scale (scale 0-10: 0 "no pain"-10 "pain as bad as could be" in the last 30 days)						
	Facial pain right now	6		8		4	
	Worst facial pain	7		6		7	
	Average facial pain	7		5		5	
	Everyday life limitations	5		5		3	
	Days where daily routine affected	22 days		6 days		4 days	
	Limitation in social and family life	5		5		3	
	Limitation to work life	4		0		3	
	Extraoral and cervical muscle palpation (scale 0-3: 0 "no pain"-3 "severe pain")						
	–	Right	Left	Right	Left	Right	Left
	Posterior temporalis	0	0	0	0	0	0
	Middle temporalis	0	0	0	0	0	0
	Anterior temporalis	1	0	1	1	0	0
	Masseter origin	0	0	2	0	1	0
	Masseter body	0	0	0	1	0	0
	Masseter insertion	0	0	0	0	0	0
	Post mandibular region	1	1	2	1	2	1
	Submandibular region (under chin)	0	0	0	0	0	0
	Joint pain palpation (scale 0-3: 0 "no pain"-3 "severe pain")						
	–	Right	Left	Right	Left	Right	Left
	Lateral pole (outside)	3	0	2	1	2	1
	Posterior attachment (inside ear)	0	0	0	0	0	0
	Pain-free opening						
	mm	24 mm		24 mm		30 mm	

seemed especially motivated because of the perceived improvement of the functional limitation and the articular pain. She mentioned doing the exercises as she walked on the street. She was also more used to the use of technology than patient 1.

DISCUSSION

Virtual reality as an adjunctive therapy to physiotherapy in the symptomatic treatment of TMD may be useful in reducing muscular pain and functional limitation. TMD can not only cause absenteeism but has also been associated with deterioration of the stomatognathic system.[25]

Physiotherapy exercises traditionally used in the treatment of TMDs have sometimes been tedious for the patient,[14] and a lack of patient motivation to do these exercises, low levels of adherence with the exercises, and therefore a reduction in positive outcomes has been reported.[12-14] The motivation that both patients showed with the exercises with the FitJaw Mobile, especially the younger patient, was unexpected. The increased motivation may have positively affected the results, consistent with studies that reported the essential role motivation plays.[15,16] For example, Negrín et al[15] reported that the lack of motivation was one of the 2 most frequently documented causes of the lack of adherence to the exercises, the other being failure to understand the instructions. Liu et al[16] studied the differences in motivation of young adults when comparing immersive VR, nonimmersive VR, and traditional stationary cycling sessions and reported greater levels of intrinsic motivation in immersive VR cycling in comparison with the other 2 options; it promoted greater participation and adherence to physical activity in young adults. Another advantage of using the FitJaw Mobile VR system is that while the patients focus on the game, they might forget about pain when doing the exercises. The program also awards points gradually, allowing the patient to interact with determined stimuli and providing feedback, making this a pain distraction technique. Mestre et al[17] noted that in VR feedback, the participants perceived less effort when undertaking physical activity. They felt that VR promoted a dissociative approach

distracting from the performed exercise. Gokeler et al[18] evaluated how the immersion in a VR environment affected the biomechanics of the knee, testing the hypothesis that VR techniques aimed at changing the attention focus could affect the angle of flexure, the knee extension movement, and the vertical peak of reaction strength in patients after reconstructing the anterior cruciate ligament compared with a control group with no VR immersion. They reported that the outcomes of the group with VR were better than those of the control group and suggested that VR may reduce internal focus, that is, less attention was aimed at controlling the knee, which leads to a more efficient performance when moving it.

Gutiérrez-Martínez et al[19] reported that participants exposed to cold pressure tolerated pain better with VR conditions than without VR. Tejera et al[21] compared the effects of VR to conventional exercise treatment in patients with unspecific chronic neck pain analyzing different variables but only finding differences between both procedures in individuals with kinesiophobia. For all other variables, including pain intensity, anxiety, and movement range, no differences were found between the procedures. Therefore, existing evidence suggests that VR can be as effective in modulating pain and reducing the perception of the painful stimuli of neck exercises. A meta-analysis[20] of controlled clinical trials that studied the efficacy of VR in orthopedic rehabilitation reported that VR is promising in managing chronic neck pain and shoulder impingement syndrome. VR and the exercises were found to have similar effects in rheumatoid arthritis, knee arthritis, ankle instability, and the posterior reconstruction of the anterior crossed ligament. The evidence of the efficacy of using VR for exercises in fibromyalgia, back pain, or following a knee arthroplasty was nonexistent or nonconclusive.

Perez-Marcos[2] stated that VR has become a means on its own, capable of generating unique experiences, as happens with FitJaw Mobile. VR was initially considered as a well-known technology by laypeople but unknown at the same time; many people knew of its existence but few had experienced it. The lack of accessibility to technology has been resolved mainly by access to smartphones, an ideal and economical way[11] for both business and private users to access the experiences that VR provides. FitJaw Mobile also shares this advantage, since there is no need to purchase the VR goggles "oculus Quest," and the patient can carry out the exercises at home with their own mobile device as described in the 2 treatments presented in this article. Limitations of this study included that only 2 patients were evaluated. Nevertheless, the favorable results encourage additional research on the impact of this accessible technology for patients with TMDs.

CONCLUSIONS

Based on the findings from this clinical study, the following conclusions were drawn:

1. Virtual physiotherapy with FitJaw Mobile contributed toward improving the painful and functional symptoms in patients suffering from TMDs.
2. The development and expansion of this technology is limitless, with a wide range of possibilities and a promising future.

REFERENCES

1. Cibeira N, Lorenzo-López L, Maseda A, López-López R, Moreno-Peral P, Millán-Calenti JC. Virtual reality as a tool for the prevention, diagnosis and treatment of cognitive impairment in the elderly: a systematic review. *Rev Neurol*. 2020;71:205–212.
2. Perez-Marcos D. Virtual reality experiences, embodiment, videogames and their dimensions in neurorehabilitation. *J Neuroeng Rehabil*. 2018;15:113.
3. Steuer J. Defining virtual reality: dimensions determining telepresence. *J Commun*. 1992;42:73–93.
4. Sanchez-Vives MV, Slater M. From presence to consciousness through virtual reality. *Nat Rev Neurosci*. 2005;6:332–339.
5. Weiss PL, Rand D, Katz N, Kizony R. Video capture virtual reality as a flexible and effective rehabilitation tool. *J Neuroeng Rehabil*. 2004;1:12.
6. Heiling ML. *Sensorama simulator*. 1962. New York; 3,050,870.
7. Heiling ML. *Stereoscopic-television apparatus for individual use*. 1960. New York; 2,955,156.
8. Botella C, Fernández-Álvarez J, Guillén V, García-Palacios A, Baños R. Recent progress in virtual reality exposure therapy for phobias: a systematic review. *Curr Psychiatry Rep*. 2017;19:42.
9. Zeng Y, Zhang JE, Cheng ASK, Cheng H, Wefel JS. Meta-analysis of the efficacy of virtual reality-based interventions in cancer-related symptom management. *Integr Cancer Ther*. 2019;18:1–8.
10. Uruthiralingam U, Rea PM. Augmented and virtual reality in anatomical education - a systematic review. *Adv Exp Med Biol*. 2020;1235:89–101.
11. Farley ORL, Spencer K, Baudinet L. Virtual reality in sports coaching, skill acquisition and application to surfing: a review. *J Hum Sport Exerc*. 2020;153:535–548.
12. Newman-Beinart NA, Norton S, Dowling D, et al. The development and initial psychometric evaluation of a measure assessing adherence to prescribed exercise: the Exercise Adherence Rating Scale (EARS). *Physiotherapy*. 2017;103:180–185.
13. Beinart NA, Goodchild CE, Weinman JA, Ayis S, Godfrey EL. Individual and intervention-related factors associated with adherence to home exercise in chronic low back pain: a systematic review. *Spine J*. 2013;13:1940–1950.
14. Crandall S, Howlett S, Keysor J. Exercise adherence interventions for adults with chronic musculoskeletal pain. *Phys Ther*. 2013;93:17–21.
15. Negrín R, Olavarría M. Exercise and arthrosis. *Rev Med Clin Condes*. 2014;25:805–811.
16. Liu W, Zeng N, Pope ZC, McDonough DJ, Gao Z. Acute effects of immersive virtual reality exercise on young adults' situational motivation. *J Clin Med*. 2019;8:1947.
17. Mestre DR, Ewald M, Maiano C. Virtual reality and exercise: behavioral and psychological effects of visual feedback. *Stud Health Technol Inform*. 2011;167:122–127.
18. Gokeler A, Bisschop M, Myer GD, et al. Immersive virtual reality improves movement patterns in patients after ACL reconstruction: implications for enhanced criteria-based return-to-sport rehabilitation. *Knee Surg Sports Traumatol Arthrosc*. 2016;24:2280–2286.
19. Gutiérrez-Martínez O, Gutiérrez-Maldonado J, Loreto-Quijada D. Control over the virtual environment influences the presence and efficacy of a virtual reality intervention on pain. *Stud Health Technol Inform*. 2011;167:111–115.
20. Gumaa M, Rehan Youssef A. Is virtual reality effective in orthopedic rehabilitation? A systematic review and meta-analysis. *Phys Ther*. 2019;99:1304–1325.
21. Custódio NB, Costa FDS, Cademartori MG, da Costa VPP, Goettems ML. Effectiveness of virtual reality glasses as a distraction for children during dental. *Care Pediatr Dent*. 2020;42:93–102.
22. Tejera DM, Beltran-Alacreu H, Cano-de-la-Cuerda R, et al. Effects of virtual reality versus exercise on pain, functional, somatosensory and psychosocial outcomes in patients with non-specific chronic neck pain: a randomized clinical trial. *Int J Environ Res Public Health*. 2020;17:5950.

23. Huang TK, Yang CH, Hsieh YH, Wang JC, Hung CC. Augmented reality (AR) and virtual reality (VR) applied in dentistry. *Kaohsiung J Med Sci*. 2018;34:243–248.
24. Joda T, Gallucci GO, Wismeijer D, Zitzmann NU. Augmented and virtual reality in dental medicine: a systematic review. *Comput Biol Med*. 2019;108:93–100.
25. Casanova-Rosado JF, Medina-Solís CE, Vallejos-Sánchez AA, Casanova-Rosado AJ, Hernández-Prado B, Avila-Burgos L. Prevalence and associated factors for temporomandibular disorders in a group of Mexican adolescents and youth adults. *Clin Oral Investig*. 2006;10:42–49.
26. Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. *J Craniomandib Disord*. 1992;6:301–355.
27. Mezitis M, Rallis G, Zachariades N. The normal range of mouth opening. *J Oral Maxillofac Surg*. 1989;47:1028–1029.

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