SCIENTIFIC ARTICLE

The Use of Relative Motion Flexion Orthoses for Chronic Boutonniere Deformity

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Purpose This study investigated the effectiveness of a relative motion flexion orthosis (RMFO) for increasing the range of motion for boutonniere deformity.

Methods We included 28 patients aged 13−62 years with chronic boutonniere deformity who could complete 0° proximal interphalangeal (PIP) joint extension with the pencil test and were stage 1 according to the Burton classification of boutonniere deformity. At the initial hand therapy appointment, the RMFO was made. The duration of the orthosis usage at the initial therapy session, after stopping the use of the orthosis (posttreatment), and at the follow-up period were noted.

Results The mean time for orthosis usage of all patients was 11.7 weeks (6−40 weeks). The mean initial active distal interphalangeal joint flexion was 47° (0° to 90°) and improved to 66.8° (5° to 110°). The mean initial extension lag of the PIP joint was 22.5° (5° to 55°) and improved to 12° (0° to 30°). This did not change between discontinuation of the orthosis and final follow-up.

Conclusions The use of RMFO is effective in increasing active distal interphalangeal joint flexion and improving PIP extension in patients with Burton stage 1 chronic boutonniere deformity. *(J Hand Surg Am. 2024;49(5):488.e1-e8. Copyright © 2024 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Boutonniere deformity, orthosis, relative motion orthosis.

Online Exclusive

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Received for publication October 25, 2021; accepted in revised form August 5, 2022.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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0363-5023/24/4905-0015$36.00/0
https://doi.org/10.1016/j.jhsa.2022.08.007

THE UNDERLYING PATHOLOGY in closed boutonniere injuries is the weakening, elongation, or partial deterioration of the central slip.[1−3] Alteration of the triangular ligament results in the palmar displacement of the lateral bands, which results in an extension defect of the proximal interphalangeal joint (PIP) and hyperextension of the distal interphalangeal joint (DIP).[2,3] Nonsurgical treatment is primarily used in closed boutonniere injuries. If there is no passive extension limitation in the PIP joint, a static and/or dynamic PIP joint extension orthotic brace, which keeps the PIP joint in full extension, is used full-time for 6−8 weeks.[4] The

results after nonsurgical treatments are often unsatisfactory because of the inability to correct the deformity and stiffness of the PIP joint. Surgery is indicated when the orthosis is ineffective and the patient cannot tolerate the deformity. Late reconstruction usually has poor results.[2,5–7]

In chronic boutonniere deformities, surgical procedures like lateral band reconstruction, central slip reattachment, central slip reconstruction, and transverse retinacular ligament release have been described to repair or reconstruct the central slip.[2,7] Merritt suggests managing most boutonnieres, both acute and chronic, nonsurgically with a relative motion flexion orthosis (RMFO).[8] This orthosis is intended to accelerate postoperative rehabilitation by encouraging the immediate full active function of the hand.[1,8,9] The injured finger is splinted in 15° to 20° more flexion at the metacarpophalangeal (MCP) joint than the other fingers. With the MCP joint in passive flexion, the lumbrical muscles, long flexors, and interosseous muscles relax. The lateral bands are displaced dorsally, the tendinous rhombus narrows, and the load on the injured central slip decreases. Although this position allows the central slip to heal, the patient continues daily life with the RMFO. The orthosis should be used full-time for 4–6 months in chronic cases.[1,8]

In the literature, the relative motion orthosis has been modified and extended to a variety of hand conditions, such as flexor and extensor tendon repairs, sagittal band injury, digital nerve repairs, trigger digit, and joint stiffness.[8–11] The effectiveness of the RMFO in the treatment of boutonniere deformity has been demonstrated biomechanically, and some case reports demonstrated its clinical efficacy.[1,8,9] Therefore, the aim of this study was to investigate the effectiveness of RMFO for increasing PIP joint extension and DIP joint flexion for boutonniere deformity. We also aimed to examine the relationship between the outcome and duration of orthosis use. We hypothesized that RMFO would afford an excellent early-term range of motion recovery.

MATERIALS AND METHODS

This study was carried out at Hacettepe University, Faculty of Health Sciences, Occupational Therapy Department, and Diskapi Y. B. Training and Research Hospital, Department of Hand Surgery. The study was approved by the local clinical research ethics committee, and informed consent forms were signed by the patients.

We assessed the treatment program for individuals with chronic boutonniere deformities who were seen at the Hand Surgery department by hand surgeons between June 2019 and January 2021. The patients were diagnosed as having a boutonniere deformity if the Elson and Boyes tests were positive. When the Boyes and Elson tests were negative but the patient had a boutonniere deformity posture, they were diagnosed as pseudoboutonniere deformity. Pseudoboutonniere deformity is distinguished clinically as a flexion contracture of the PIP joint without hyperextension of the DIP joint.

For the Elson test, the hand is rested on a table, with the PIP joint of the involved finger flexed to 90° over the edge of the table. The test is positive if the patient has a weak extension at the PIP joint with (hyper)extension at the DIP joint. The Boyes test is performed by comparing passive resistance to flexion of the DIP joint while the PIP is maximally extended and then with the PIP fully flexed. The test is considered positive if the patient cannot flex the DIP joint when the PIP is extended.[8]

There were 50 patients with a diagnosis of traumatic boutonniere deformity. Patients with chronic boutonniere deformity (≥4 weeks), able to complete 0° PIP joint extension with the pencil test,[11] and stage 1 according to the Burton classification (supple, passively correctable deformity)[3,12] were included (Table 1). While performing the pencil test, the affected finger of the patient is placed in the flexion position with a pencil (Fig. 1). The patient is asked to flex and extend the fingers several times. The pencil rebalances the forces of active movement in such a way that injured structures can heal. When a closed injury has developed a boutonniere deformity, the placement of a pencil over the dorsal proximal phalanx may then allow recovery of full proximal interphalangeal active extension when the injured digit metacarpophalangeal joint is in approximately 15° to 20° degrees greater flexion than the uninjured finger metacarpophalangeal joints.[8,11] For patients who cannot complete the full PIP joint extension with the pencil, serial casting of the PIP joint or static PIP extension orthosis fabrication is recommended before RMFO.[8] In our study, patients who could complete the full PIP joint extension with the pencil test were included.

The exclusion criteria were a diagnosis of a pseudoboutonniere deformity, having surgery for a boutonniere deformity, an injury involving all 4 fingers, using the orthosis for <6 weeks,[13] diagnosis with another neurological and/or orthopedic condition such as rheumatoid arthritis that may affect hand

TABLE 1. Burton Classification of Boutonnière Deformity

Stage	Description
1	Supple, passively correctable deformity
2	Fixed contracture, contracted lateral bands, no joint involvement
3	Volar plate and collateral ligament contractures, intra-articular fibrosis
4	Volar plate and collateral ligament contractures, intra-articular fibrosis plus proximal interphalangeal joint arthritis

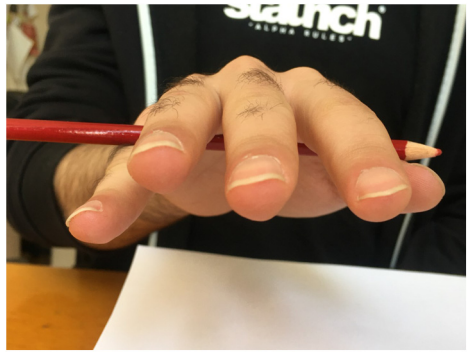


FIGURE 1: The pencil test.

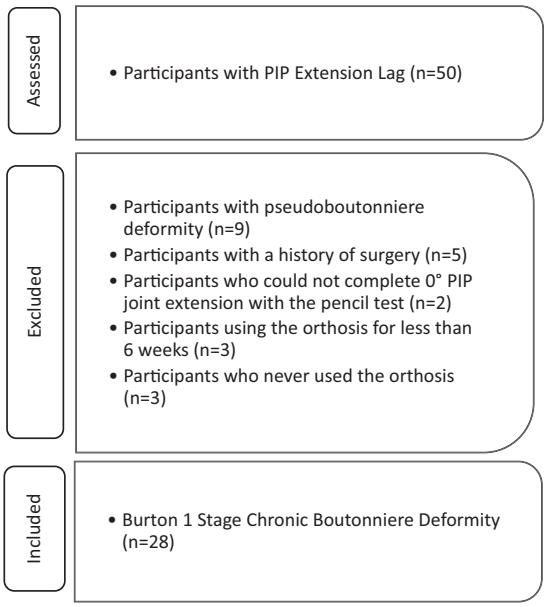


FIGURE 2: Study flowchart.

function. Overall, 28 patients were included (Fig. 2). Four patients were included in the study after being treated with serial casting (cases 1 and 10, 2-week cast; case 7, 3-week cast; and case 9, 30-week cast) to restore passive extension of the PIP joint.[13] There were patients who used static extension orthoses before beginning hand therapy (Table 2). These patients used RMFO after restoring full passive PIP joint extension.

Demographic findings and the duration of orthosis use were noted. PIP and DIP joint movements of injured digits were assessed with a goniometer by the first author (O.B.A.) at the initial hand therapy session, after stopping the use of the orthosis (post-treatment), and at least 8 weeks after completion of treatment (follow-up period). During measurements, the patient had the elbow in a flexed position resting on the examination table and the forearm and wrist in a neutral position. The examiner asked the patient to actively extend the fingers as much as possible. The measurement of lag in the PIP joint was performed with the MCP joint actively extended. To measure DIP flexion, the PIP joint was positioned at 70° to 90° of flexion. Then, the axis of the goniometer was placed over the dorsal surface of the DIP joint being measured (Fig. 3). The follow-up duration of the patients varied according to the ability to contact them.

At the initial hand therapy session, patients were educated about the injury and a RMFO was made by therapists using a thermoplastic sheet or tape (Orficast, Orfit Industries) (Fig. 4). The orthosis keeps the MCP joint of the injured finger in a position that is 15° to 20° more flexed than the uninjured fingers. PIP and DIP movements of all the fingers were free in the orthosis. However, because of the shape of the orthosis, abduction and adduction of the fingers were somewhat restricted. The patients were informed that they should wear the orthosis full-time, except for hand hygiene, for at least 6 weeks. If the PIP joint extension lag did not fully resolve after 6 weeks, patients were encouraged to use the RMFO for a longer period.[8,11] Because continuous wearing of the orthosis was recommended, each patient completed a daily record of the number of hours the orthosis was worn and an indication of whether it was continuous. They could do a full active range of motion and use their hands in daily living activities with the RMFO, such as using a computer or cooking. However, the patients were told that they should not use the orthosis in activities involving hot water, such as taking a shower or washing dishes, because the flexion angle of the orthosis may change. In patients with edema, edema management was initiated in the first week of therapy. The patients were not given any specific range of motion exercises for PIP and/or DIP

TABLE 2. Participants' Characteristics

Case	Age (years)	Sex	Treatment History Before RMFO Orthosis	Injured Hand/ Finger	Time From Injury to Treatment (wk)	Duration of Orthosis Usage (wk)	Follow-up Time (wk)	PIP ext Lag Pretreatment	PIP ext Lag Posttreatment	PIP ext Lag Follow-up	DIP Flex (°) Pretreatment	DIP Flex (°) Posttreatment
1	51	F	2-week cast	R/2	20	20	12	25	20	20	20	30
2*	17	F	None	R/5	52	24	24	55	0	0	85	85
3	31	F	3-day ext. orthosis	R/5	12	16	12	35	30	30	30	40
4*	18	F	None	L/4	8	12	17	25	20	20	65	80
5	62	F	None	R/5	4	9	12	10	0	0	20	60
6	34	F	10-day ext. orthosis	R/5	4	6	12	15	10	10	20	44
7	13	M	3-week cast	R/2	4	6	12	10	0	0	40	90
8*	39	F	None	R/4	8	6	12	10	0	0	60	85
9	17	F	30-week cast	R/3	156	6	30	20	5	5	85	85
10	22	F	2-week cast	R/5	32	8	8	40	10	10	75	85
11	45	M	None	L/2	32	6	12	10	5	5	50	80
12	45	M	None	L/4	32	20	12	6	0	0	75	90
13*	56	F	10-day ext. orthosis	R/2	16	10	12	30	20	20	20	25
14*	40	M	1-day ext. orthosis	R/2	4	40	12	15	0	0	20	55
15*	14	M	10-day ext. orthosis	R/5	6	6	12	05	0	0	35	70
16*	47	M	None	L/3	4	8	12	30	25	25	5	30
17	45	M	None	L/4	4	8	12	15	10	10	80	90
18	47	M	7-day ext. orthosis	L/5	16	6	24	35	30	30	30	110
19	39	F	None	R/5	20	24	12	30	20	20	60	60
20*	35	F	None	L/4	8	14	20	30	20	20	40	70
21	40	M	None	R/2	8	6	12	30	28	30	70	85
22	26	F	10-day ext. orthosis	L/4	12	12	18	45	30	10	35	37
23*	16	F	7-day ext. orthosis	R/5	20	6	12	05	5	5	60	65
24	40	M	28-day ext. orthosis	L/5	4	12	12	25	18	18	0	65
25*	26	M	None	R/5	8	12	24	30	25	25	60	76
26	35	F	42-day ext. orthosis	R/4	12	6	19	10	2	2	0	5
27	16	M	None	R/5	52	6	20	15	3	3	85	85
28	25	M	10-day ext. orthosis	L/5	6	12	20	20	0	0	90	90

Ext: Extension; Flex: Flexion

*Patients who do not use the orthosis while writing, using a computer or sleeping.

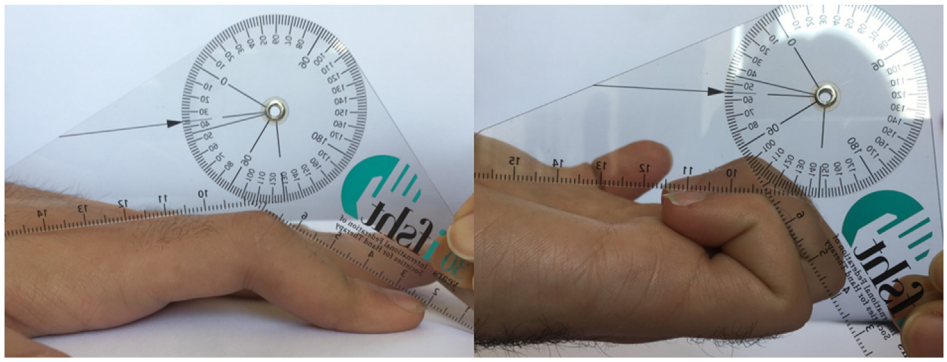


FIGURE 3: Range of motion measurements.

FIGURE 4: The relative motion flexion orthosis.

joints because RMFO allows the use of these joints freely during activities of daily living.

Statistical analysis

Lacking relevant information about therapy referral rates for an *a priori* sample size calculation, we initially randomly selected 50 patients from patients with PIP extension lag for data extraction (Fig. 2). For a clinically relevant effect, we calculated the effect size with the formula $r = Z/\sqrt{N}$ ($r = -4.57/5.29 = 0.86$, $\eta^2 = 0.74$) according to the change in the PIP joint extension lag after treatment.[14,15] We performed a *post hoc* power analysis with a sample of 28 people and 5% type 1 error and calculated the power of our study (1-β) as 0.9573.[16]

Descriptive statistics (mean, standard deviation, median, interquartile range, and minimum and maximum values) were calculated for demographic data evaluation. The normal distribution of the data was tested using the Shapiro-Wilk test, a histogram, skewness−kurtosis, and the coefficient of variation. According to this analysis, the data obtained from the assessments were not found to have a normal distribution. The Wilcoxon test was used to compare the changes in the DIP joint flexion and PIP joint extension lag measures between pre- and posttreatment. Pre and posttreatment DIP joint flexion and PIP joint extension lag measures were compared using a two-sample test, with 95% confidence intervals and estimates of effect size using Cohen's d to account for the related sample.[17] Spearman correlation analyses were used to determine the relationship between PIP joint extension lag, and the duration of orthosis usage in weeks The following Spearman's correlation coefficient classifications were made: r = 0.05−0.3, weak; r = 0.3−0.4, lower moderate; r = 0.4−0.6, moderate; r = 0.6−0.7, strong; r = 0.7−0.75, very strong; and r = 0.75−1.0, excellent relationship. The *P* value for statistical significance was set to.05.[18]

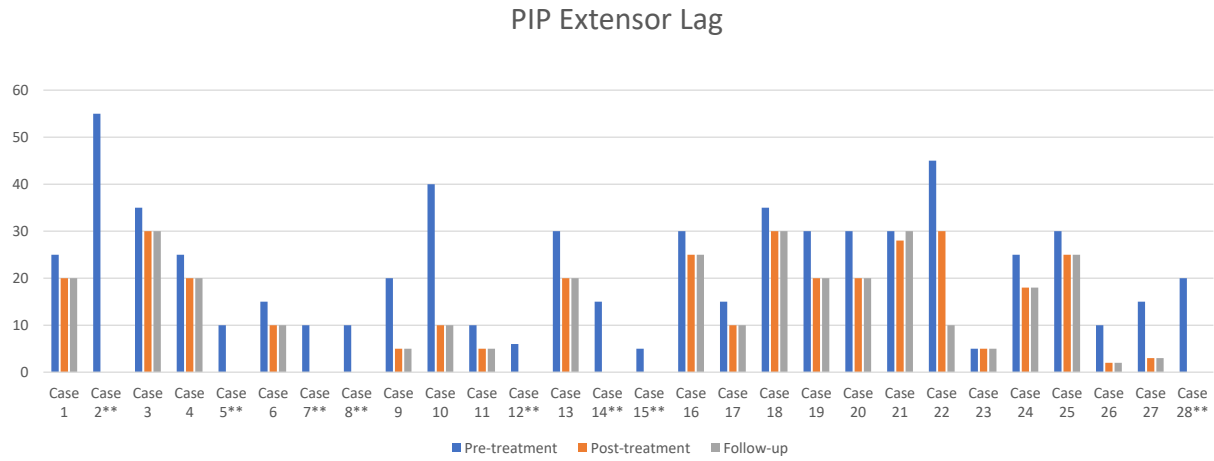
RESULTS

Twenty-eight patients (15 women and 13 men) participated in the study. The mean age of the patients was 34 years (range, 13−62 years). The index finger was affected in 6 patients, the middle finger in 2 patients, the ring finger in 7 patients, and the little finger in 13 patients. The median time from the date of injury to the initial assessment was 10 weeks (interquartile range [IQR], 5−20 weeks), the median

TABLE 3. Range of Motion Values Before and After the Use of RMFO

	Pretreatment	Posttreatment		
	Mean (min−max)	Mean (min−max)	*P*	Effect Size
DIP joint flexion	47.0 (0−90)	66.8 (5−110)	<.05	0.7
PIP joint extension lag	22.5 (5−55)	12.0 (0−30)	<.05	0.9

Min−Max = minimum-maximum



**Post-treatment and follow-up PIP extensor lag degrees were 0°.

FIGURE 5: Pretreatment, posttreatment, and follow-up PIP extensor lag.

of using the orthosis was 9 weeks (IQR, 6−13 weeks), and the median for follow-up after stopping the use of RMFO was 12 weeks (IQR, 12−19 weeks). A detailed summary of the characteristics of included participants is shown in Table 2.

Seven patients stated that they did not use the orthosis at night, and 3 patients stated that they did not use the orthosis in some activities, such as writing and using a computer.

Each patient's range of motion is noted in Table 2. The PIP joint extension motion was increased in 27 of 28 patients. The range of motion did not change after patients stopped using the RMFO (follow-up). The mean initial extension lag of the PIP joint was 22.5° (5° to 55°) and improved to 12° (0° to 30°) (P <.05). The mean initial active DIP flexion was 47° (0° to 90°) and improved to 66.8° (5° to 110°). The mean extension lag of the PIP joint was also not changed during the final follow-up period (Table 3).

There was no statistically significant association between the difference in PIP joint extension lag and the duration of orthosis usage (r = -0.26, P =.18;). For each patient, PIP joint extension lag is presented in Figure 5.

DISCUSSION

Although many nonsurgical treatments have been described for the management of the chronic boutonniere deformity, there is still no consensus on which is most effective. There are only 2 case reports describing the use of RMFO for chronic boutonniere deformity and postoperative central slip repairs.[13,19] Our study results show that the use of RMFO is associated with an improvement in increasing active DIP flexion and improving PIP extension in patients with Burton stage 1 chronic boutonniere deformity.[12]

The main aim of treatment in boutonniere deformity is to restore balance in the extensor mechanism so that both PIP and DIP joint movement is brought closer to normal. Immobilization of PIP joint extension with traditional nonsurgical therapies will result in frequent stiffness, possibly because of extensor hood adherence and PIP joint ankylosis.[1] Choosing a method that actively forces the PIP joint to extend rather than immobilize it is important to prevent PIP joint stiffness.[1,20] The RMFO keeps the MCP joint in flexion, does not allow for MCP joint hyperextension, and forces the PIP joint to extend. It is important in chronic boutonniere deformity to control the MP joint hyperextension. When the MP joint is in

hyperextension, this force takes the extensor force away from the PIP joint. Tension on the central tendon is decreased with MCP flexion because of the distal migration of the sagittal band.[1] With the RMFO, the central slip heals while the PIP joint is active throughout the day. The superiority of active motion over long-term immobilization has been demonstrated with the early active short arc motion protocol for open and repaired central slip injuries. This allows patients with central slip repairs to flex the PIP joint 30° while the injured finger is in an orthosis.[5,6,21]

When the lateral bands are abnormally positioned below the PIP joint axis of rotation, intrinsic muscle function causes PIP joint flexion and DIP joint hyperextension. In the treatment of chronic boutonniere deformity, a frequent complication is the inability to correct the deformity fully.[8] We observed that PIP joint extension lag decreased in most cases, but of the 28 PIP joints, 12 had 5° or less improvement in PIP joint extension. We must emphasize that 12 of 28 (>40%) did not have discernible improvement. Although 5° is above the minimal discernible difference, for many patients it does not represent a functional improvement. However, for those cases, the changes in DIP flexion increased by 5° or more.

In chronic boutonniere deformity, once the deformity becomes established, treatment is much more difficult. The maximum change in PIP joint extension lag in our study was measured as 55°. Merritt stated that the maximum change of PIP joint extension lag following orthosis fabrication was 35.9°. In all patients included in that study, the reduction of the lag below 30° was achieved.[13] In the presence of full active PIP and DIP joint active flexion, an extension deficit of approximately 20° affects finger function to a limited extent. If that amount of movement is obtained, treatment does not necessarily need to be continued.[2,5,6] In our study, 22 of 28 (over 78%) of our cases had 20° or less PIP joint extension lag, which means little functional disturbance of that finger after using RMFO. The PIP joint extension lag did not change in any of the patients after stopping the use of RMFO during at least 8 weeks of follow-up. We acknowledge that an 8-week follow-up period is relatively short, and with a longer follow-up period, the rate of recurrence may increase. In addition, DIP joint flexion loss is observed in boutonniere deformity because of the tension of the oblique retinacular ligament. In all patients, we observed that DIP joint flexion also increased. This may be because the RMFO allows the oblique retinacular ligament to re-tension and the DIP joint to be flexed as it allows the lateral bands to be displaced dorsally.

In our study, the duration of orthosis usage ranged from 6 to 40 weeks, with a mean duration of 12 weeks. The literature indicates that traditional nonsurgical treatment takes 6−12 weeks, or longer if a chronic injury is treated.[4] As a result of our study, we could not conclude how long RMFO should be used for the treatment of chronic boutonniere deformity. Studies with a larger sample size are needed to determine the length of treatment required using RMFO.

This is a proof of concept study with small sample size. Therefore, smaller differences may not have been detected in our study. Another limitation of the study was that only patients with Burton stage 1 were included. Four patients used serial casting for various periods to achieve better passive extension before participating in our study. In future studies, the effect of RMFO should be evaluated by including patients at different stages.[12] Another limitation of our study is that we only included patients wearing the RMFO for >6 weeks. This could be a potential bias for complying with the orthosis. Also, there was a lack of consistent orthosis wear in some patients. Future studies that assess treatment compliance are needed. Finally, studies with 6 months or 1-year follow-up are necessary to identify the long-term effects of RMF orthosis.

ACKNOWLEDGMENTS

We sincerely thank the individuals who participated in this study and Osman Topaç for English editing.

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