Original Article

Evaluation of adolescent and adult patients treated with the Carriere Motion Class III appliance followed by fixed appliances

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ABSTRACT

Objectives: To determine dentoalveolar and skeletal effects produced in mature patients by the Carriere Motion Class III (CM3) appliance followed by fixed appliances.

Materials and Methods: This retrospective study evaluated 32 patients at three time points: T1 (initial), T2 (removal of CM3), and T3 (posttreatment). Serial cephalograms were traced and digitized, and best-fit regional superimpositions were constructed. Eleven linear and 7 angular variables were measured. The starting forms of the CM3 patients were compared with a sample of untreated subjects with normal occlusions and well-balanced faces.

Results: The CM3 phase lasted 6.3 months, followed by a phase of fixed appliances lasting 12.9 months; the total duration of treatment was 19.2 months. Minimal skeletal changes were measured sagittally, with only a slight increase in lower anterior facial height observed during treatment. Most treatment changes were dentoalveolar in nature. Wits appraisal increased 4.0 mm during treatment. The molar relationship improved by 6.0 mm during phase I, a value that rebounded slightly during phase II, resulting in an improvement toward Class I of 4.8 mm. Best-fit regional superimpositions revealed anterior movement of upper molars relative to the maxilla and posterior movement of lower molars relative to the mandible.

Conclusions: The Carriere Motion Class III appliance is an effective and efficient method of resolving occlusal problems in minimally growing Class III patients. Primary treatment effects are dentoalveolar in nature with minimal skeletal alterations. (*Angle Orthod.* 2021;91:149–156.)

KEY WORDS: Carriere Motion Class III appliance; Cephalometrics; Treatment effects; Class III; Mature patient

INTRODUCTION

The management of Class III malocclusion in mature or minimally growing individuals provides the orthodontist with unique challenges. A recently developed approach to Class III treatment is the Carriere Motion Class III (CM3) appliance, which was introduced in 2015 by Luis Carriere of Barcelona, Spain. The CM3 appliance, which is a modification of the Carriere Motion Class II (CM2) appliance,[1,2] consists of bilateral bars that are bonded to the mesial aspect of the

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mandibular canines and the lower first molars. Flat molded pads are attached to the molars at the center of their clinical crowns, presumably to facilitate lower molar distalization. Heavy intermaxillary Class III elastics are worn between hooks extending anteriorly from the bars on the lower canines to hooks or buttons bonded to the most distal maxillary molars; elastics are worn by the patient as nearly full-time as possible. A clear invisible retainer used for anchorage is fabricated for the maxillary arch, wrapping around the molars posteriorly.

Considering the limited literature concerning the Carriere Motion Class III appliance,[3,4] the purpose of this study was to describe in detail the treatment effects produced by the CM3 appliance in relatively nongrowing Class III patients. Is the correction to a Class I occlusion achieved by dentoalveolar or skeletal adaptations or both? Do the upper molars move anteriorly and the lower molars move posteriorly during CM3 treatment?

MATERIALS AND METHODS

This retrospective clinical study analyzed the results produced in adolescent and adult Class III patients who underwent an initial phase of treatment with the Carriere Motion Class III appliance followed by a second phase of fixed appliance therapy. The Institutional Review Board (IRB) of the University of Michigan determined that this research was exempt from IRB oversight (HUM00178048).

Sample size determination was calculated for the repeated-measures analysis of variance (ANOVA) based on an effect size of .25 for the primary outcome variable "molar relationship," a power of .80, and an alpha level of .05. The minimum sample size calculated was 28 patients (G*Power, Heinrich Heine, University of Dusseldorf, Germany).

CM3 Treatment Sample

Digital records of CM3-treated Class III patients were provided by two sources, Clinica Carriere of Barcelona, Spain, and McNamara Orthodontics of Ann Arbor, Michigan. First, the records from each patient had to include lateral cephalograms obtained at three specific times: T1, initial; T2, after removal of CM3; and at T3, after fixed appliances. Only patients having three serial head films were considered for inclusion.

The second selection criterion was the level of skeletal maturation of the patient. Chronological age was not an inclusion criterion. Rather, to evaluate the treatment effects in a sample of supposedly "minimally growing" Class III patients, the stage of cervical vertebral maturation (CVM) was determined.[5] Each patient had to have reached cervical stage CS-4 or greater in the T1 film. A total of 35 patients from Clinica Carriere and 14 patients from McNamara Orthodontics qualified for initial inclusion in the data base. The third criterion was an Angle Class III molar relationship in the T1 film. A total of 43 patients met these inclusion criteria.

Films were then evaluated further using exclusionary criteria. A total of 11 patients were subsequently eliminated from the initial sample for the following reasons: technical radiographic issues (4), missing posterior teeth (5), posterior implant (1), and extraction of a lower incisor (1). The final study sample analyzed was 32 Class III patients, 14 males and 18 females.

Comparison Samples

It would have been preferable to have compared the outcome of CM3 treatment to data from a matched untreated Class III sample, monitored at the same maturational level and for the same length of time as the treatment sample. Unfortunately, no longitudinal study of untreated Class III subjects in late adolescence or adulthood existed in the orthodontic literature. The hypothesis was made that CM3 patients who were at CVM level CS4 or greater in the T1 film would demonstrate minimal craniofacial growth during the study period. Thus, no matched controls were used.

To verify that the treatment sample was truly Class III, starting forms of the 32 CM3 patients were compared with previously published data from a much larger group ($N = 125$) of untreated Class I subjects with ideal occlusions and well-balanced faces.[6] The skeletal and dental relationships of 18 female and 14 male Class III patients were compared with 81 female and 44 male Class I ideal subjects, respectively.

Clinical Protocol

All patients initially wore the CM3 appliance (Figure 1). The size of each bar was determined by measuring the distance from the lower canine to the lower first molar, according to the manufacturer's instructions (Henry Schein Orthodontics, Carlsbad, Calif). In the maxillary arch, buccal tubes with elastic hooks were bonded to the distal molars, and a clear invisible retainer was fabricated from 1-mm-thick Essix A+ plastic (Dentsply Sirona, York, Penn) was placed (Figure 1). Elastic wear consisted of Force 1 elastics (Henry Schein Orthodontics, Carlsbad, Calif) that generated about 375 g of force on each side.[7] Elastics were worn throughout the CM3 phase and during the fixed appliance phase, if necessary.

Figure 1. Intraoral view of a Class III patient during CM3 treatment. Top row, pretreatment. Middle row, initial placement of the appliance. Note the invisible retainer worn on the maxillary dental arch. Bottom row, at the completion of phase I treatment, just before the removal of the CM3 appliance. Closure of the bite and the development of interdental spacing between the lower incisors is seen.

Cephalometric Analysis

Serial lateral head films of each patient were traced and analyzed simultaneously. Eleven skeletal and seven angular measures were used to evaluate changes following treatment. The cephalograms were traced by one investigator and then examined thoroughly by a second investigator to verify landmark locations; any disparities were resolved by mutual agreement. The cephalometric tracings were scanned; then, Viewbox cephalometric software (version 4.0, dHAL Software, Kifissia, Greece) was used to digitize the tracings.

The movements of the maxillary and mandibular dentition relative to their supporting bones were also examined. In addition to the usual cephalometric tracings, "best fit" superimpositions of the maxilla and mandible were constructed at each time point to

Table 1. Comparison of Starting Forms of Class III Female and Male Patients and Class I Female and Male Controls With Ideal Occlusions and Well-Balanced Faces[a]

	Females					Males				
	Treatment Group, n = 18		Control Group, n = 81			Treatment Group, n = 14		Control, n = 44		
	Mean	SD	Mean	SD	Diff	Mean	SD	Mean	SD	Diff
Maxillary skeletal, sagittal										
SNA, °	81.1	3.9	82.4	3.0	−1.3 ns	80.0	4.6	83.8	3.2	−3.8**
Pt A to Nasion perp	1.3	3.2	0.4	2.3	0.9 ns	−1.4	4.9	1.0	2.7	−2.4*
Midfacial length	90.1	5.4	91.0	4.8	−0.9 ns	94.6	2.4	99.8	6.0	−5.2**
Mandibular skeletal, sagittal										
SNB, °	82.3	3.4	80.0	2.8	2.3**	81.6	4.1	81.6	2.7	0.0 ns
Pogonion to Nasion perp	6.6	6.6	−1.8	4.5	8.4***	4.5	9.4	−0.3	3.8	4.8**
Mandibular length	130.9	8.0	120.2	5.3	10.7***	139.4	5.6	132.3	6.8	7.1***
Maxillomandibular										
ANB, °	−1.2	2.7	2.5	1.4	−3.7***	−1.8	2.9	2.2	1.8	−4.0**
WITS appraisal	−8.3	3.1	−0.9	2.2	−7.4***	−8.8	4.2	−0.7	2.8	−8.1***
Max-mand differential	40.9	4.6	29.2	3.3	11.7***	44.8	5.2	32.5	4.0	12.3***
Vertical skeletal										
Lower anterior facial height	72.1	5.5	66.7	4.1	5.4***	77.4	5.7	74.6	5.0	2.8***
FH to mandibular plane, °	26.7	4.9	22.7	4.3	4.0***	25.9	6.3	21.6	3.9	4.3**
Dentoalveolar										
Overjet	0.0	1.4	3.6	0.9	−3.6***	−0.9	2.5	3.3	1.0	−4.2***
Overbite	0.7	1.5	2.7	1.0	−2.0***	1.2	3.2	2.8	1.3	−1.6**
Molar relationship	6.9	1.6	N/A	N/A		8.3	2.4	N/A	N/A	
U1 to Pt A vert	6.6	2.4	5.4	1.7	−1.2*	6.3	2.1	5.3	2.0	1.0 ns
L1 to mandibular plane, °	80.1	7.4	94.9	6.3	−14.8***	79.6	9.7	92.3	7.4	−12.7***

[a] Linear measures are reported in millimeters. Control values are from McNamara and Ellis.[8] N/A indicates data not available.
* $P < .05$; ** $P < .01$; *** $P < .001$.

determine the movement of the central incisors and first molars relative to their respective bones based on stable areas of osseous morphology.[8,9]

Statistical Analyses

Interrater agreement on CVM staging was assessed with weighted kappa statistics with quadratic weights. The intrarater reproducibility for the cephalometric measurements was calculated on 15 redigitized cephalograms by means of intraclass correlation coefficients.

Starting form data of the Class III CM3 group were compared with data from the Class I well-balanced face sample,[6] using independent samples *t*-tests or Mann-Whitney *U*-tests when data were not distributed normally. All statistical computations were performed with statistical software (IBM Statistical Package for the Social Sciences, SPSS version 22, Armonk, NY).

Chi-square tests were used to assess differences in gender distribution between groups. All cephalometric data at T1, T2, T3, and for the T1–T2 (pretreatment to CM3 removal), T2-T3 (removal of CM3 to posttreatment) and T1–T3 (pretreatment to posttreatment) changes were tested for normal distribution (Shapiro-Wilk test). Intragroup comparisons within the CM3 group for the T1–T2, T2–T3, and T1–T3 changes were carried out with repeated-measures ANOVA or with Friedman tests if data were not distributed normally.

RESULTS

The interrater agreement on CVM staging was almost perfect (kappa = 0.87; 95% confidence interval 0.71–1.00). The intrarater reproducibility was very high, as it was greater than 0.95 for all the cephalometric variables.

The average age of the CM3 sample at T1 was 18.8 ± 6.7 years, T2 was 19.3 ± 6.8 years, and T3 was 20.4 ± 6.7 years. The T1–T2 interval was 6.3 ± 4.3 months, and the T2–T3 interval was 12.9 ± 4.6 months. The overall T1–T3 interval was 19.2 ± 6.5 months.

Comparison of Starting Forms

T1 cephalometric data from the CM3 sample was compared with the control sample of untreated Class I subjects.[6] Interestingly, all but 5 of the 30 comparisons were statistically significant (Table 1).

Skeletal Relationships

Both sexes demonstrated a tendency toward retrusion of the maxilla in the CM3 groups relative to

Table 2. Descriptive Statistics and Statistical Comparisons (Repeated-Measures ANOVA) of T1–T2 (Pretreatment to Removal of CM3), T2–T3 (Removal of CM3 to Posttreatment), and T1–T3 (Pretreatment to Posttreatment) Changes in the CM3 Group

	T1		T2		T3		T2–T1 changes		T3–T2 changes		T3–T1 changes	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SNA, °	80.6	4.2	80.8	4.2	80.7	4.1	0.2ns	1.2	−0.1ns	1.0	0.1 ns	1.1
A to Nasion perp	0.1	4.2	0.5	4.2	0.4	4.2	0.4ns	1.2	−0.1ns	1.0	0.3 ns	1.1
Midfacial length	92.1	4.9	92.6	4.7	92.5	4.4	0.5ns	1.3	0.0ns	1.2	0.5 ns	1.3
SNB, °	82.1	3.6	81.2	3.6	81.4	3.6	−0.9***	1.0	0.2ns	0.8	−0.7**	1.1
Pog to Nasion perp	5.7	7.9	4.0	7.5	5.0	7.9	−1.7**	2.2	1.0**	1.4	−0.7 ns	2.2
Mandibular length	134.6	8.2	134.8	8.3	135.9	7.9	0.2ns	1.1	1.1**	1.5	1.3***	1.4
ANB, °	−1.5	2.8	−0.4	2.6	−0.7	2.5	1.1***	1.1	−0.3ns	1.0	0.8***	1.0
Wits appraisal	−8.5	3.6	−3.6	3.0	−4.6	2.9	5.0***	2.5	−1.0ns	2.8	4.0***	2.8
Max/man diff	42.6	5.2	42.3	5.6	43.4	4.8	−0.3ns	1.2	1.1***	1.4	0.8*	1.5
FH-occlusal plane, °	6.6	4.3	2.7	3.7	3.5	3.8	−4.0***	3.0	0.9ns	3.2	−3.1***	2.8
FH-mandibular plane, °	26.4	5.5	27.4	5.5	26.9	5.8	1.1**	1.4	−0.5ns	1.1	0.6 ns	1.5
Lower anterior facial height	74.4	6.1	76.6	6.6	76.9	6.3	2.2***	2.0	0.3ns	1.4	2.5***	1.8
Overjet	−0.4	2.0	3.1	1.8	2.4	1.2	3.5***	2.1	−0.7ns	1.8	2.8***	2.2
Overbite	0.9	2.4	−1.2	1.9	1.7	1.0	−2.1**	2.9	2.9***	2.0	0.8 ns	2.6
Molar relationship	7.5	2.1	1.5	2.1	2.8	1.3	−6.0***	1.6	1.2**	1.9	−4.8***	1.8
Upper inc A perp	6.4	2.2	8.3	2.4	7.8	2.5	1.9***	1.5	−0.6ns	1.4	1.3**	1.8
Upper inc to FH, °	119.1	6.8	125.7	7.6	123.7	8.2	6.6***	6.3	−2.0ns	6.5	4.6**	8.0
Lower inc to MP, °	79.9	8.3	79.0	7.0	78.1	7.3	−0.9ns	4.5	−0.09ns	4.7	−1.8 ns	5.3

* $P < .05$; ** $P < .01$; *** $P < .001$.

the comparison group. Mandibular prognathism was noted in both CM3 males and females. Substantial differences (>11 mm) were noted in the maxillomandibular differential[10] between the treatment and control groups. Vertically, lower anterior facial height (ANS-Me) was longer and the mandibular plane angle was increased in comparison with those with near ideal occlusions.

Dentoalveolar

Statistically significant differences were observed in all dentoalveolar comparisons between the Class III and Class I samples. Both Class III males and females showed smaller T1 values for the overjet relative to their Class I counterparts (–4.2 mm and –3.6 mm, respectively). Overbite was smaller as well in both gender comparisons. The molar relationship at T1 was 8.3 mm in Class III males and 6.9 mm in Class III females.

Normal values for molar relationship (ie, horizontal distance between the mesial contacts of the upper and lower first molars) were not available for the Class I sample. It is well accepted that a normal molar relationship in an ideal occlusion is about 2 mm.[11,12] Thus, the molar relationship of the Class III sample was more than 6 mm greater in males and about 5 mm greater in females relative to the comparison group. Lastly, the lower incisors were tipped lingually by –12.7° in CM3 males and –14.8° in CM3 females as compared with controls.

Treatment Effects During T1–T2, T2–T3, and T1–T3

Table 2 displays the mean and standard deviation of the changes in the cephalometric variables and statistical significance at three observation points.

Sagittal Position of the Maxilla

No statistically significant or clinically relevant changes in the three maxillary variables were noted during either phase.

Sagittal Position of the Mandible

Only slight changes were observed in the position of the mandible. There was a mild decrease in the SNB angle (–0.9°) during the CM3 phase, with a decrease in the distance from the chin point at Pogonion to the Nasion perpendicular of –1.7 mm.

Maxillomandibular Relationships

Changes were minimal during overall treatment, with a 0.8° increase in the ANB angle and a 0.8-mm increase in the maxillomandibular differential.

Vertical Skeletal Relationships

Two relevant changes were noted in the vertical dimension. Lower anterior facial height (ANS-Me) increased by 2.2 mm during the CM3 phase, with an overall change of 2.5 mm from T1 to T3. The angle of the Frankfort horizontal to the functional occlusal plane decreased by –4.0° during the CM3 phase and

Table 3. Regional Superimpositions Based on Constructed Fiducial Landmarks[a]

REGIONAL SUPERIMPOSITIONS	T2 - T1		T3 - T2		T3 - T1	
	Mean	SD	Mean	SD	Mean	SD
Maxillary Dentoalveolar						
U1 horizontal (mm)	1.8***	1.6	−0.8*	1.5	1.0**	1.7
U6 horizontal (mm)	1.9***	1.7	−0.2ns	1.6	1.7***	1.6
U1 vertical (mm)	1.9***	1.7	−0.2ns	1.6	1.7***	1.6
U6 vertical (mm)	1.9***	1.7	−0.2ns	1.6	1.7***	1.6
Mandibular Dentoalveolar						
L1 horizontal (mm)	−0.5ns	1.4	−1.9***	1.9	−2.4***	2.2
L6 horizontal (mm)	−1.8***	1.4	0.5ns	1.3	−1.4***	1.7
L1 vertical (mm)	0.6**	0.9	1.7***	1.5	2.2***	1.6
L6 vertical (mm)	−0.5ns	1.4	0.8*	1.5	0.3ns	1.5

[a] Estimates of tooth movements relative to the maxilla or the mandible were derived from "best fit" superimpositions on the internal osseous structures of each jaw. Positive values reflect the downward and forward tooth movements; negative values indicate the upward and backward movements.

rebounded 0.9° during the fixed appliance phase, resulting in a net –3.1° closure of the FH-Occ Pl angle.

Dentoalveolar Relationships

The most profound change noted was in molar relationship. The starting value was –7.5 mm; at T2, the molar relationship was reduced by 6.0 mm to –1.5 mm. At T3, the residual value was 2.8 mm. Similar changes were seen in the anterior dentition.

The original Wits appraisal value was –8.5 mm, indicating a strong pretreatment Class III relationship. This value improved by 5.0 mm toward Class I during the CM3 phase. A rebound of –1.0 mm occurred during the second phase, leaving a residual net increase of 4.0 mm.

Regional Superimpositions

Much tooth movement was noted relative to the respective bony bases (Table 3). From a sagittal perspective, both the upper incisors and the upper molars moved forward relative to the internal structures of the maxilla by almost 2 mm (1.8 mm and 1.9 mm, respectively) during the CM3 phase. Minimal rebound (–0.2 mm) in the upper molar position occurred during phase II, resulting in a net forward movement of 1.7 mm at the end of treatment.

The most dramatic sagittal response in the lower arch was an average –1.8 mm movement posteriorly of the lower molars during phase I. A slight rebound (0.5 mm) occurred during phase II, resulting in a 1.4-mm distal movement of the lower molars at the end of treatment. In contrast, the lower incisors moved posteriorly slightly (–0.5 mm) during phase I, with an additional –1.9 mm occurring during phase II.

From a vertical perspective, both the maxillary incisors and molars erupted 1.9 mm during phase I, with minimal change occurring during phase II. The lower incisors erupted 0.6 mm and 1.7 mm during phases I and II, respectively. The vertical position of the lower molars remained relatively unchanged.

DISCUSSION

The Carriere Motion Class III appliance provides a novel approach to the management of Class III problems in mature patients. This protocol offers an alternative to more aggressive therapies that can involve orthodontics alone or a combination of orthodontics and orthognathic surgery, both with and without the extraction of lower premolars.

The focus of this initial study was on the minimally growing patient in whom growth during treatment presumably would not be a factor. In that the CM3 appliance was not available until 2015, longitudinal studies of treatment effects produced by the CM3 appliance do not exist. Thus, limitations of this research are its retrospective nature and the lack of long-term follow-up.

The two treatment samples evaluated were derived from the records of Clinica Carriere and McNamara Orthodontics. To be included in this retrospective study, three lateral cephalograms had to have been obtained during treatment. Many of the patients treated initially with the CM3 appliance had only pretreatment and posttreatment cephalograms taken, so these patients were not included in the current investigation.

This study was about the effects of treatment. When discussing changes in skeletal or dentoalveolar measures, the differences between statistical significance and clinical significance must be mentioned. For this study, a P value of at least $<.05$ was used to determine statistical significance. In prior clinical investigations,[13,14] a change of $\geq$2.0 mm or $\geq$2.0° in any cephalometric variable was used as an indication of clinical significance.

Were the CM3 Patients Truly Class III at the Beginning of Treatment?

Comparing the starting form of the CM3 sample to a nearly ideal Class I sample[6] (Table 1) indicated that the treatment sample was Class III skeletally and dentally.

Were the CM3 Patients "Minimally Growing"?

Because a longitudinal Class III control sample did not exist, the assumption was made, based on the CVM evaluation, that these patients would show a minimal rate of skeletal growth; indeed, that was the case. The average increases in midfacial and mandibular lengths during the 19-month CM3 treatment were only 0.5 mm and 1.3 mm, respectively (Table 2).

What Skeletal Changes Were Observed Both Sagittal and Vertically?

Significant skeletal changes were not observed. As described above, the amount of sagittal skeletal growth in the CM3 group was clinically irrelevant. Further, the overall change in the maxillomandibular differential was only 0.8 mm, indicating that the relationship between midfacial length and mandibular length remained unchanged during treatment.

What Dentoalveolar Changes Were Observed?

Most of the larger changes produced were dentoalveolar (Table 2). At the end of treatment, the Wits appraisal, reflecting the position of the dentition within their bony bases, moved toward Class I by 4.0 mm, and the molar relationship became more Class I by 4.8 mm.

Were the Teeth Moved Toward Class I Relative to Their Bony Bases?

Of interest were data from the regional superimposition-based "best-fit" superimpositions of serial tracings (Table 3). Statistically significant tooth movement was observed in both jaws. During the CM3 phase, the upper first molars moved anteriorly 1.9 mm when serial maxillary tracings were superimposed on internal morphology. In contrast, the lower first molars moved posteriorly 1.8 mm relative to the mandible. Slight rebounds in both arches occurred during the fixed appliance phase.

Was the Occlusal Plane Affected by CM3 Treatment?

Alterations in the occlusal plane during the management of Class III problems often is a treatment objective. Such approaches include occlusal plane rotation during orthognathic surgery[15,16] as well as Class III camouflage treatment with the multiloop edgewise archwire technique.[17]

In the current CM3 study, the occlusal plane rotated –4.0° in a counterclockwise direction during phase I. A slight rebound occurred during phase II so that, at the end of treatment, the net effect of the CM3 appliance on occlusal plane rotation was –3.1°, a statistically significant and clinically relevant change. An opposite occlusal plane rotation was observed in an earlier study of the CM2 appliance in adolescents[2]; a clockwise rotation of 3.9° was noted in phase I but rebounded in phase II (–3.6°). Thus, the occlusal rotational change in the CM3 patients remained at the conclusion of treatment but not in the CM2 patients.

CONCLUSIONS

- The Carriere Motion Class III appliance is an effective and efficient adjunct to fixed appliances in the management of Class III malocclusion in mature patients. Most of the treatment effects produced by the CM3 appliance were dentoalveolar in nature, with minimal skeletal adaptations observed. A counterclockwise rotation of the occlusal plane was evident, most of which remained at the end of treatment. The CM3 treatment produced anterior movement of the maxillary dentition relative to the mandible and posterior movement ("distalization") of the mandibular dentition relative to their bony bases.
- Thus, no noteworthy skeletal changes can be anticipated with CM3 treatment.

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