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Three-dimensional palatal morphology and upper arch changes following nonsurgical and surgical maxillary expansion in adults

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Objective. The objective of this study was to evaluate the effects of nonsurgical rapid maxillary expansion (RME) and surgically assisted RME (SARME) on palatal morphology and upper arch dimensions using three-dimensional (3D) models in skeletally mature patients.

Study Design. Thirty-eight skeletally mature patients with a maxillary transverse deficiency were divided into RME and SARME groups. Nineteen patients in the RME group (mean age, 19.16 ± 2.25 years) were treated using a full-coverage bonded acrylic splint expander; 19 patients in the SARME group (mean age, 20.38 ± 3.36) were treated using the banded palatal expansion appliance with hyrax screws. The 3D models were obtained before and after expansion. The maxillary dental arch widths, maxillary first molar angulation, palatal area, and palatal volume were calculated on the 3D models.

Results. All variables showed statistically significant changes after the retention period ($P < .001$). The maxillary arch width between first premolars ($P < .05$), the palatal area ($P < .01$), and the palatal volume ($P < .05$) significantly increased in the SARME group compared to the RME group. The maxillary first molar tipping in the RME group was significantly higher than that in the SARME group ($P < .01$).

Conclusions. Although SARME has more positive effects in skeletally mature patients, nonsurgical RME can be considered as an alternative by evaluating surgical risks, periodontal status, and the need for skeletal expansion. (Oral Surg Oral Med Oral Pathol Oral Radiol 2022;134:425−431)

Rapid maxillary expansion (RME) is a standard treatment method used in the correction of the maxillary transverse discrepancy that is one of the most common dentoskeletal problems encountered in the field of clinical orthodontic treatment.[1,2]

Conventional RME is a successful method when used before sutural closure in children and adolescents; however, in skeletally mature patients, the resistance to mechanical forces increases and the possibility of a successful maxillary expansion may decrease because of the sutural closure.[3] The increased resistance in the midpalatal suture due to skeletal maturation may negatively affect the success rate of RME.[4] Although the consensus is that nonsurgical maxillary expansion is no longer feasible after the adolescent period and, instead, surgically assisted RME (SARME) is required, it has been shown in the literature that successful results can be achieved with nonsurgical maxillary expansion in adults.[5-7]

Bishara and Staley[8] reported that unpredictable and unstable results could occur in older patients, so the optimal age for maxillary expansion is before 13 to 15 years. Alpern and Yurosko[9] stated that female patients up to the age of 18 and male patients to the age of 21 could be treated with RME without any additional surgical procedure. Handelman et al.[6] performed maxillary expansion using fixed tooth and tissue-borne expanders in adults aged 18.8 to 49.3 and stated that nonsurgical RME in adults is a clinically successful and safe method to correct transverse maxillary arch deficiency. However, unwanted situations may be encountered when using RME in skeletally mature patients, such as the inability to open the midpalatal suture, instability of the expansion, and undesirable effects seen in dental, periodontal, and palatal tissues.[10] SARME for maxillary expansion in adult patients provides reliability in skeletal expansion and stabilization.[3,11] Clinicians should consider the magnitude of the need for maxillary expansion, periodontal status, costs, and surgical risks when deciding whether

Statement of Clinical Relevance

In adults with maxillary transversal discrepancy, maxillary expansion can be achieved both surgically and nonsurgically. However, the positive effects of surgically assisted rapid maxillary expansion on molar tipping and palatal morphology should be considered when planning treatments for adults.

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it is best to expand the maxilla with nonsurgical or surgical assistance for adult patients.[5]

Many reports[2,3,5-7,12-16] on the effects of nonsurgical and surgical maxillary expansion in adult or skeletally mature patients are available in the literature. Posteroanterior films and dental models are generally used to evaluate transversal skeletal and dental changes caused by maxillary expansion.[13] In addition, palatal area and palatal volume changes can be evaluated using three-dimensional (3D) dental models.[15] Owing to the complexity of palate morphology, it is thought that the changes in this region can be properly investigated by 3D volumetric measurements.[16]

This study aimed to evaluate the effects of SARME and nonsurgical RME on palatal morphology and upper arch dimensions in skeletally mature patients using 3D models and to compare the changes that occur with both applications.

MATERIALS AND METHODS

Sample

This retrospective study was approved by the Clinical Trials Ethical Committee of the Erciyes University, Kayseri, Turkey (approval number: 2019/800). The palatal volume changes for the first 5 patients in each group were evaluated, and a power analysis was performed using these data. A sample size of 19 subjects in each group would provide >85% power to detect significant differences at a 0.05 significance level, based on a 1:1 ratio at a 0.92 effect size.

The patient selection criteria were determined as maxillary expansion indication due to bilateral posterior crossbite, complete skeletal maturation, no previous orthodontic treatment, healthy palatal and periodontal structures, and adequate oral hygiene. Exclusion criteria were the presence of craniofacial anomalies such as cleft lip or palate, tooth loss on the maxillary dental arch, or low-quality 3D models that do not allow the evaluation of palatal morphology and linear measurements.

The study consisted of 38 patients (27 women and 11 men) with a mean age of 19.77 ± 2.89 years treated to correct transverse maxillary discrepancies in the 2 centers (Faculty of Dentistry, Erciyes University and Faculty of Dentistry, Bezmialem Vakıf University). Previously recorded data of the patients were examined and the 3D models were selected from the archives of these centers according to patient selection criteria. Two study groups with an equal number of patients in each group were constructed to evaluate the changes caused by surgical and nonsurgical rapid palatal expansion in 3D models.

RME group

The RME group was composed of 19 patients (14 women, 5 men) with a mean age of 19.16 ± 2.25 years (range, 16.00-24.33). A full-coverage bonded acrylic splint expander with hyrax screws (Dentaurum, Ispringen, Germany) was used in patients in the RME group. The expander was activated 2 turns a day (0.2 mm per turn) for the first 2 days, followed by 1 turn a day for the next 7 days, and then activation continued every other day until the desired width was achieved.[17] The midpalatal suture opening was determined using occlusal radiograph records. The expansion was completed when the palatal cusps of the maxillary molars reached the buccal cusps of the mandibular molars. The full-coverage expanders were kept in the mouth as a retainer for at least 4 months.

SARME group

Nineteen patients (13 women, 6 men) with a mean age of 20.38 ± 3.36 (range, 16.83-29.92 years) comprised the SARME group. A fixed palatal expansion appliance with a hyrax screw was used by banding upper first premolars and upper first molars for soldering the arms of the expansion screws. The expansion appliance was cemented the day before the surgery.

All surgeries were performed under general anesthesia by the same surgeons. Bilateral incisions were made in the buccal vestibule from the region of the mesial aspect of the first premolars to the mesial aspect of the first molar. Bilateral maxillary corticotomies were achieved starting from the aperture piriformis to the pterygomaxillary fissure. The surgical procedure for SARME consisted of interradicular midline osteotomy between the roots of the upper central incisors through the posterior nasal spina and did not include the releasing osteotomy of pterygoid plates. Shortly after, the expansion appliance was turned by about 1.6 mm to verify symmetric expansion and the wound was closed.

After a latency period of 5 days, the hyrax screws of expansion appliances were activated with 2 turns a day (0.2 mm per turn).[13] When the palatal cusps of the maxillary molars occluded with the buccal cusps of the mandibular molars, the expansion was terminated, and the appliance was kept in place for a retention period of at least 4 months.

3D evaluations of palatal morphology and upper arch dimensions

In both groups, the dental model casts obtained before expansion (T0) and after at least 4 months of the retention period (T1) were scanned using a 3D model scanner (3Shape R700, 3Shape A/S, Copenhagen, Denmark; Production: Szczecin, Poland) and evaluations were made on these 3D models.

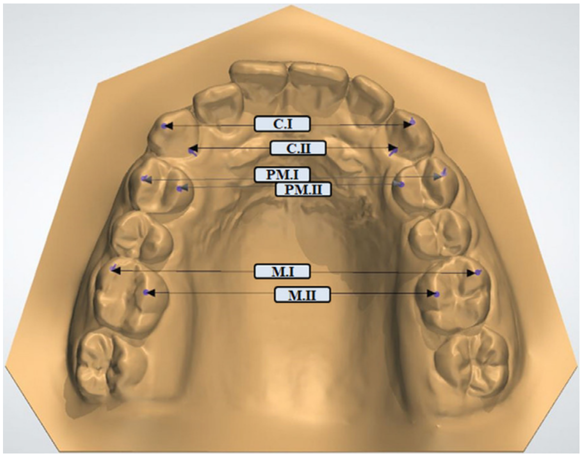

Fig. 1. Measurements of the maxillary dental arch widths on three-dimensional models.

Linear and angular measurements on the 3D models were performed with 3Shape OrthoAnalyzer (3Shape A/S, Copenhagen, Denmark) software. The maxillary dental arch widths were measured between the left and right vestibular and palatal cusp tips of the canine, first premolar, and first molar teeth (Figure 1). The angle between the intersecting lines of the mesiobuccal and mesiopalatal cusp tips of the right and left first molars was measured to determine the maxillary first molar axial angulation (Figure 2).[13]

Three-dimensional models previously obtained as standard tessellation language format using a 3D model scanner were transferred to Geomagic Studio (Geomagic, Inc., Morrisville, NC, USA) software to evaluate the palatal area and palatal volume. The palatal area (Figure 3A) and palatal volume (Figure 3B) were

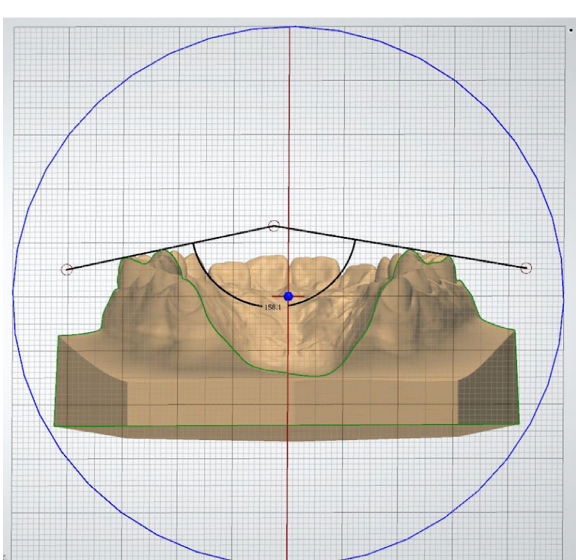

Fig. 2. Measurement of the maxillary first molar axial angulation.

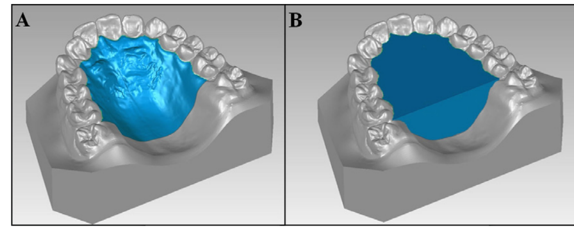

Fig. 3. Calculation of the **(A)** palatal area and **(B)** palatal volume on three-dimensional models.

calculated by creating median sagittal, distal, and gingival planes to determine the palate boundaries (Figures 4A-4D).[16] The median sagittal plane was created by the guidance of the median palatal raphe. The distal plane was created through 2 points at the distal surface of the maxillary first molars perpendicular to the median sagittal plane. The gingival plane was created as a plane passing through the center of the incisive papilla and perpendicular to both the sagittal and distal planes. All of the planes were perpendicular to each other.

A blinded investigator performed all measurements on 3D models obtained at time point T0 and time point T1. All collected data were stored on a password-protected computer.

Statistical analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences v24.0 (SPSS Inc., Chicago, IL, USA) software. Descriptive statistics of the arithmetic means and standard deviations were calculated for all variables. The level of significance was set at $P < .05$.

The Shapiro-Wilk test of normality was used to evaluate the normal distribution of variables. Paired samples *t* test was used to compare intragroup differences. Intergroup comparisons were determined using the independent samples *t* test.

The measurements of 40 randomly selected 3D models were repeated by the same investigator after 2 weeks to determine intra-observer reliability. The intraclass correlation coefficients were calculated and ranged from 0.905 to 0.996, which indicated sufficient reliability for all measurements. The paired samples *t* tests used to detect systematic differences between initial and repeated measurements revealed that the differences were insignificant.

RESULTS

Before the expansion, the intergroup comparison showed no statistically significant difference in the values of linear, angular, area, and volume measurements (Table I).

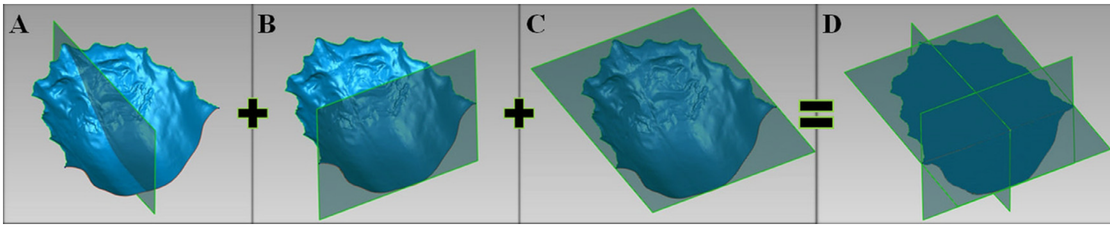

Fig. 4. Determination of palate boundaries. The creation of **(A)** median sagittal, **(B)** distal, and **(C)** gingival planes and **(D)** delimited palatal volume.

Table I. Comparison between RME and SARME groups before expansion (T0)

Measurements	*RME (T0)*		*SARME (T0)*		*P value*
	Mean	*SD*	*Mean*	*SD*	
C.I (mm)	32.23	3.22	30.96	3.22	.235
C.II (mm)	25.18	2.99	23.65	3.47	.154
1. PM.I (mm)	35.94	3.01	35.64	3.51	.781
1. PM.II (mm)	26.23	1.85	25.52	3.44	.431
M.I (mm)	46.86	3.79	45.90	3.71	.434
M.II (mm)	36.84	3.70	35.86	3.54	.407
Molar inclination (°)	156.82	9.95	156.70	13.07	.976
Area (mm^2)	1213.19	122.08	1196.80	143.60	.707
Volume (mm^3)	4635.96	979.83	4675.66	1179.64	.911

RME, rapid maxillary expansion; *SARME*, surgically assisted rapid maxillary expansion.

In both groups, the maxillary first molar axial angulation was significantly decreased, and all other measurements showed significant increases after the retention period compared to values before expansion ($P < .001$; Table II).

The comparisons of the intergroup values showed that all linear measurements were higher in the SARME group than in the RME group in the T0-T1 period (Table III). However, statistically significant differences in linear measurements were seen only in the first premolar measurements ($P < .05$). The molar tipping caused by the expansion was significantly higher in the RME group (−9.81° ± 6.83°) compared to the SARME group (−3.68° ± 3.11°; $P < .01$). Owing to the expansion, the increases in the palatal area were 148.37 ± 61.40 mm^2 in the RME group and 218.91 ± 64.03 mm^2 in the SARME group, and this difference was statistically significant ($P < .01$). The palatal volume also increased significantly in the SARME group (1325.78 ± 633.45 mm^3) compared to the RME group (923.56 ± 565.04 mm^3; $P < .05$; Table III).

Comparing the SARME and RME groups after the retention period (T1) showed no significant difference between the groups (Table IV).

DISCUSSION

The idea that surgical assistance is required for the successful maxillary expansion in adults is widely accepted in orthodontic treatment but, contrary to this idea, nonsurgical maxillary expansion in adults has been reported to be successful.[5] Therefore, this study aimed to evaluate the effects of RME with and without surgery on palatal morphology and upper arch dimensions after a retention period of at least 4 months in adults.

In the nonsurgical RME group, a full-coverage bonded acrylic splint expander was used to provide efficient maxillary expansion. The activation protocol

Table II. Comparison of before expansion (T0) and after retention (T1) measurements of the patients in the study groups

Measurements	*RME (T0)*		*RME (T1)*		*P value*	*SARME (T0)*		*SARME (T1)*		*P value*
	Mean	*SD*	*Mean*	*SD*		*Mean*	*SD*	*Mean*	*SD*	
C.I (mm)	32.23	3.22	35.50	3.14	< .001*	30.96	3.22	34.81	2.88	< .001*
C.II (mm)	25.18	2.99	28.78	3.05	< .001*	23.65	3.47	28.31	2.77	< .001*
1. PM.I (mm)	35.94	3.01	42.48	2.64	< .001*	35.64	3.51	43.20	2.35	< .001*
1. PM.II (mm)	26.23	1.85	32.46	2.56	< .001*	25.52	3.44	33.61	2.37	< .001*
M.I (mm)	46.86	3.79	53.06	3.83	< .001*	45.90	3.71	52.59	3.10	< .001*
M.II (mm)	36.84	3.70	42.83	4.38	< .001*	35.86	3.54	41.98	3.46	< .001*
Molar inclination (°)	156.82	9.95	147.01	10.77	< .001*	156.70	13.07	153.01	12.23	< .001*
Area (mm^2)	1213.19	122.08	1361.56	112.07	< .001*	1196.80	143.60	1415.71	125.94	< .001*
Volume (mm^3)	4635.96	979.83	5559.52	1044.76	< .001*	4675.66	1179.64	6001.44	1272.87	< .001*

*$P < .001$.*RME*, rapid maxillary expansion; *SARME*, surgically assisted rapid maxillary expansion.

Table III. Comparison of expansion differences (T0-T1) between RME and SARME groups

Measurements	*RME (T0-T1)*		*SARME (T0-T1)*		*P value*
	Mean	*SD*	*Mean*	*SD*	
C.I (mm)	3.27	1.17	3.84	2.21	.327
C.II (mm)	3.59	1.20	4.66	2.59	.113
1. PM.I (mm)	6.54	2.78	7.56	2.98	.042*
1. PM.II (mm)	6.23	1.69	8.09	3.05	.026*
M.I (mm)	6.19	2.20	6.69	2.97	.560
M.II (mm)	5.59	2.65	6.12	3.80	.896
Molar inclination (°)	−9.81	6.83	−3.68	3.11	.001†
Area (mm^2)	148.37	61.40	218.91	64.03	.002†
Volume (mm^3)	923.56	565.04	1325.78	633.45	.046*

*$P \leq .05$.
†$P \leq .01$.*RME*, rapid maxillary expansion; *SARME*, surgically assisted rapid maxillary expansion.

was applied as recommended by Zimring and Isaacson,[17] considering the increase in skeletal resistance in adult patients. The full-coverage expansion appliance can increase the skeletal effect of the expansion by distributing the expansion forces to the entire maxilla. The posterior bite-block effect of these devices also can control unwanted buccal tipping and vertical eruption of the posterior teeth during expansion.[18]

The tooth-borne banded appliance used in the SARME group was applied with an activation of 0.4 mm per day. This appliance is more hygienic and comfortable than the full-coverage bonded acrylic splint expander.[13] Kunz et al.[19] stated that both the tooth-borne hyrax appliance and the transpalatal distractor could be used successfully to provide transversal expansion of the maxilla with surgical assistance, and it was expected that a parallel expansion pattern would occur when the hyrax device was applied. Recently, a systematic review evaluating the skeletal and dental effects of SARME reported that there was no significant difference in pattern and amount of expansion following tooth-borne and bone-borne SARME.[11] In the literature, postoperative activation amounts of SARME range from 0.25 to 1 mm per day. It is also generally recommended that appliance activation be started during surgery to ensure removal of the areas of resistance of the 2 halves of the maxilla.[10,11]

Three-dimensional models are used to evaluate palatal morphology, including palatal volume and palatal area; measure dental arch dimensions; and determin axial angulation of teeth.[14-16,20] In our study, palatal morphology, upper arch dimensions, and axial angulation of the maxillary first molars were evaluated using 3D models. In the 3D evaluation, patients with SARME showed less molar tipping and a greater increase in all arch dimensions, palatal area, and palatal volume than the nonsurgical RME group. Gracco et al.[20] evaluated the palatal volume after RME in mixed dentition and stated that the RME was effective and stable in increasing palatal volume, and 3D models removed the limitations of two-dimensional analysis. In a study conducted with adults, Prado et al.[15] evaluated the stability of SARME and reported that the palatal area and palatal volume increase was 13.4% and 26.79%, respectively, after the 4-month retention period, and the changes remained stable for 6 months without relapse after the expander was removed. In our study, after at least 4 months of retention, the palatal area increased by 218.91 mm^2 (18.29%) and the palatal volume by 1325.28 mm^3 (28.35%) in the SARME group, and the increases in the RME group were 148.37 mm^2 (12.23%) and 923.56 mm^3 (19.92%), respectively. These findings suggest that both applications could be used with the correct indication for maxillary transverse deficiency treatment after evaluating the periodontal status, skeletal growth direction, severity of the deficiency, and surgical risks.

Some studies reported successful results with nonsurgical maxillary expansion in older adolescents and adults.[5-7,12] Baydas et al.[12] presented the results of nonsurgical expansion in young adult women, and both

Table IV. Comparison between RME and SARME groups after retention (T1)

Measurements	*RME (T1)*		*SARME (T1)*		*P value*
	Mean	*SD*	*Mean*	*SD*	
C.I (mm)	35.50	3.14	34.81	2.88	.483
C.II (mm)	28.78	3.05	28.31	2.77	.231
1. PM.I (mm)	42.48	2.64	43.20	2.35	.381
1. PM.II (mm)	32.46	2.56	33.61	2.37	.159
M.I (mm)	53.06	3.83	52.59	3.10	.683
M.II (mm)	42.83	4.38	41.98	3.46	.513
Molar inclination (°)	147.01	10.77	153.01	12.23	.117
Area (mm^2)	1361.56	122.07	1415.71	125.94	.170
Volume (mm^3)	5559.52	1044.76	6001.44	1272.87	.314

RME, rapid maxillary expansion; *SARME*, surgically assisted rapid maxillary expansion.

skeletal and dental effects were observed on young adult patients on craniofacial structures with bone scintigraphy. Handelman et al.[6] showed that the results obtained with nonsurgical expansion in adult patients >18 years were stable after an average of 5.9 years of follow-up. The same study[6] stated that with nonsurgical RME in adults, the increase in transarch width for the first molars was similar to that of the expansion group of children, but the molar tipping, at 6.2° ± 11.5° in adults, was greater than that in children.

Kurt et al.[13] demonstrated that the effect of nonsurgical RME on transarch widths in skeletally mature patients was generally similar to the effect on patients in the pubertal peak period. This effect was less than that of SARME patients, especially in transarch widths of premolars. However, in the same study,[13] the greatest molar tipping was measured in skeletally mature patients without surgery. In another SARME study[14] using 3D models, application without pterygomaxillary disjunction was recommended because the additive effect of pterygomaxillary disjunction on SARME was not significant, and it was observed that the angular inclination of the upper molars in the group without pterygomaxillary disjunction varied from 161.36° ± 18.51° to 159.35° ± 15.13°. In our study, SARME was applied without pterygomaxillary disjunction, and it was observed that the transarch widths of maxillary first premolars, palatal area, and palatal volume in the SARME group were significantly increased compared to the RME group. Considering that the maxillary first molar tipping of nonsurgical patients with RME was greater than that of patients with SARME, SARME could be considered as a good option in patients with gingival recession or periodontal bone loss and severe maxillary transverse deficiency.

The most important limitation of our study is that the changes obtained by maxillary expansion did not include long-term follow-up results. However, at the end of the retention period of at least 4 months, positive changes were obtained in both surgical and nonsurgical maxillary transarch widths and palatal morphology. It should be kept in mind that the full-coverage expansion appliance used for nonsurgical RME could potentially cause food accumulation, demineralization, and white point lesions.[18] In addition, although it was claimed that the dental side effects of SARME in adult individuals are less severe than those of conventional RME and an almost parallel expansion movement occurs in the alveolar processes,[21] there may be important complications associated with SARME, such as hemorrhage, pain, devitalization of the teeth, sinus infection, injury to the branches of the maxillary nerve, and asymmetric expansion.[10]

CONCLUSIONS

Both surgical and nonsurgical RME provided significant improvement in transarch widths, palatal area, and palatal volume.

Nonsurgical RME positively affected palatal morphology in adult patients, but this application could be performed in skeletally mature patients owing to increased molar tipping, taking into account the periodontal status and vertical dimensions.

Increased palatal area and palatal volume and less molar tipping obtained by SARME in adult individuals made us think that this approach would be more appropriate in maxillary transverse discrepancy where a greater skeletal effect is desired.

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