TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2022.20143

Original Article

The Effects of Increased Maxillary Canine Bracket Angulation on Tooth Movement and Alignment Efficiency: A Prospective Clinical Study

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Cite this article as: Türedi M, Yazıcıoğlu S. The effects of increased maxillary canine bracket angulation on tooth movement and alignment efficiency: A prospective clinical study. *Turk J Orthod.* 2022;35(1):33-38.

Main Points

- Orthodontic bracket prescription was significant for the direction and amount of tooth movement.
- The distal movement of the canine was significantly higher in the control group than in the study group in treatment involving premolar extraction.
- Different canine bracket angulations had similar effects on crowding correction.

ABSTRACT

Objective: This study aimed to evaluate the effects of a 10° angulation of a maxillary canine (Mx3) bracket on Mx3 and maxillary central incisor (Mx1) tooth movements and alignment efficiency in treatments involving maxillary premolar extraction.

Methods: This split-mouth study included 29 individuals in a +10° angulation study group and a 0° angulation control group. The initial (T0) and 12th week (T1) orthodontic models were prepared and digitized with a three-dimensional scanner and superimposed using the OrthoAnalyzer analysis program. The movements of Mx3 and Mx1 were measured, and the alignment efficiency was assessed using Little's Irregularity Index. The Shapiro–Wilk test was used to test the data for a normal distribution. T1 and T0 measurements within the group and T1 and T0 differences between groups were compared using a paired samples *t*-test. The significance level was set to $P < .05$.

Results: The linear movements of Mx3 in the distal direction significantly increased, and Little's Irregularity Index values statistically significantly decreased in both groups. Distal movements of Mx3 were significantly higher in the control group than in the study group ($P < 0.01$ and $P < 0.05$). The movements of Mx1 and Little's Irregularity Index measurements did not show statistically significant differences between the groups ($P > 0.05$).

Conclusion: A +10° Mx3 bracket angulation increased the inclination of Mx3 to the mesial, but it decreased the Mx3 distal linear movement and the retraction of Mx1, with no difference in terms of alignment efficiency between the + 10° and 0° Mx3 bracket angulations.

Keywords: Maxillary canine, bracket angulation, alignment, tooth movement

INTRODUCTION

Over the years, clinicians have worked on bracket design to achieve the optimum aesthetics and functionality goals of orthodontic treatment.[1] In 1972, Andrews introduced the straight-wire technique with pre-adjusted brackets that included angulation, inclination, and in–out values in the bracket design.[2] Slot angulation is an important component for obtaining dental positions suitable for Andrews' 6 keys to normal occlusion.[3] Since then, different straight-wire bracket prescriptions have been introduced by Roth,[4] Alexander,[5] McLaughlin, Bennett and Trevisi (MBT),[6] and Capelozza.[7] These prescriptions have different angulation values for the maxillary

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Received: November 6, 2020
Accepted: August 15, 2021

canine (Mx3) brackets. The Mx3 angulation was 11° in Andrews' prescription[2] and 10° in Alexander's prescription.[5] In Roth's system, the Mx3 angulation was increased to 13° to facilitate canine guidance.[4] The MBT[6] and Capelozza[7] procedures used an Mx3 bracket angulation of 8° to achieve a more favorable relationship between Mx3 and the first premolar roots.[7,8]

Protrusive incisors and anterior crowding due to lack of space are the main indications for orthodontic treatment with first premolar extraction.[5] In previous studies, different Mx3 bracket angulations were evaluated for anchorage loss,[9] anterior tooth positions,[1,10] and dental arch perimeter.[11] Based on these studies, changes in the amount of tooth movement and position caused by different bracket angulations were considered to increase the alignment efficiency, which is related to the features of the pre-adjusted appliances.[3] Therefore, the present study evaluated the effects of Mx3 bracket angulation of 10° on Mx3 and maxillary central incisor (Mx1) tooth movements and alignment efficiency, in treatments involving maxillary first premolar extraction.

METHODS

The study protocol was reviewed and approved by the ethics review board of the Ondokuz Mayıs University Clinical Research Ethics Committee, resolution number OMÜ KAEK—2016/336. This was a single-center prospective clinical study, with a single operator (MT) participating in the orthodontic treatment of the patients. A signed informed patient consent form was obtained from all patients. The individuals included in the study had the following conditions:

- Patients with maxillary anterior crowding due to lack of space
- Indication of fixed orthodontic treatment with moderate anchorage in the upper dental arch and extraction of the maxillary right–left 1st premolars
- Both with and without an indication for extraction of mandibular right–left 1st premolars
- In permanent dentition
- No missing teeth
- No systemic diseases
- Not on any medication
- Good oral hygiene

The average age of the 29 participants (20 females and 9 males) was 15 years and 3 months (13 years and 8 months to 17 years and 10 months) (Table 1). The study groups were formed using the split-mouth method used in many studies,[12,13,14] as it produces more reliable data than those generated by comparing the variables on different patients. This design eliminated the differences due to gender, age, and other individual characteristics in the study participants. All individuals were bonded with Mx3 brackets with a +10° angulation in one-half of the upper dental arch (study group) and a 0° angulation in the other half of the upper dental arch (control group). The right–left direction distribution of the groups was conducted through simple randomization, including the use of a shuffled deck of bracket prescription cards. Prescription 1, with 0º in the left Mx3 bracket angulation and +10° in the right Mx3 bracket angulation; and prescription 2, with +10° in the left Mx3 bracket angulation and 0º in the right Mx3 bracket angulation were prepared. Fifteen patients were bonded with 0º in the left half of the dental arch and +10° in the right half of the dental arch, and equalized with 14 patients with +10° in the left-half of the dental arch and 0º in the right-half of the dental arch. Figure 1 presents the flowchart of this study.

The brackets used in this study were the 0.018-inch slot Level Arch Modern prescription Mini Diamond Twin® (Ormco, Glendora, CA, USA) metal brackets and Accent™ (Ormco, Glendora, CA, USA) maxillary first molar tubes. The bracket prescriptions used for the study and control groups are shown in Table 2. The bracket selection criteria were the same angulation and torque values for all symmetrical teeth, with only the Mx3 teeth having a different angulation alternative. The 0.018-inch slot Level Arch Modern prescription Mini Diamond

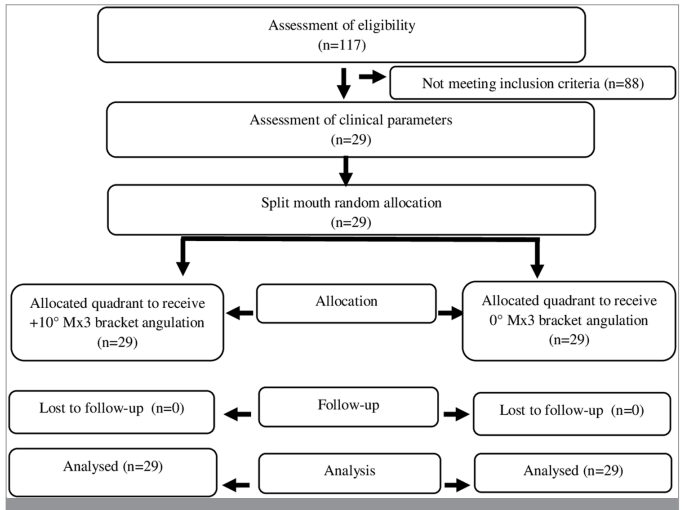

Figure 1. Flowchart of this study

Table 1. Mean values for age, arch/tooth size discrepancy and skeletal relationship of individuals included in this study

Measurements	Mean ± SD
Age	15.3 ± 1.65
Arch/tooth size discrepancy (mm)	5.96 ± 1.84
Palatal Plane—Mx1Angle (°)	113.92 ± 6.50
ANB Angle (°)	3.90 ± 2.03
SnGoGn Angle (°)	35.71 ± 5.53

Table 2. The angular values of the brackets used for the study and control groups

Brackets and tube (Maxillary)	Groups			
	Study		Control	
	Angulation	Torque	Angulation	Torque
Central	+5°	+14°	+5°	+14°
Canine	+10°	0°	0°	0°
First molar	+15° (distal offset)	−10°	+15° (distal offset)	−10°

Twin® (Ormco, Glendora, CA, USA) metal bracket was preferred because they met the criteria.

The initial arch wire was a 0.017 inch × 0.025 inch Turbo Wire (Ormco Corp., Orange, CA, USA). This wire is a nine-strand, rectangular, braided NiTi with low stiffness and great flexibility.[15] It can also be used as an initial arch wire in severe malocclusions.[16]

The brackets were bonded to Mx1, Mx3 and maxillary first molar teeth as measurement references. The upper orthodontic model (T0) was then prepared. Bonding in the upper arch was completed without the inclusion of the maxillary right–left first premolars and maxillary second molars (Mx7). The anchorage was prepared moderately. The maxillary right–left second premolars and maxillary right–left first molars were the anchorage segment, and the maxillary anterior teeth were the active segment. After the extraction of the premolars, lacebacks were applied to the Mx3 teeth during the same session using a 0.010-inch-long ligature wire and a Turbo Wire® arch, with the arch wire inserted into the brackets. The frequency of the control sessions was 4 weeks. In the fourth and eighth weeks of the control sessions, the arch wire was removed, and the laceback application was repeated with a new ligature wire. On the 12th week of the control sessions, a second upper orthodontic model (T1) was prepared. The T0 and T1 models were digitized with a three-dimensional scanner (3Shape R-700 Desktop Orthodontic Scanner, Copenhagen, Denmark) and superimposed using the OrthoAnalyzer (3Shape, Copenhagen, Denmark) analysis program. The medial and lateral points of the third palatal rugae and the medial point of the first palatal rugae were used as references for superimposition[17,18] (Figure 2). Sagittal and horizontal planes were formed in this model. The sagittal plane was created using the medial points of the first, second, and third palatal rugae on the medial palatal suture. The horizontal plane was formed perpendicular to the sagittal plane by passing through the medial point of the third palatal rugae on the right side and the lateral points of the right and left third palatal rugae.

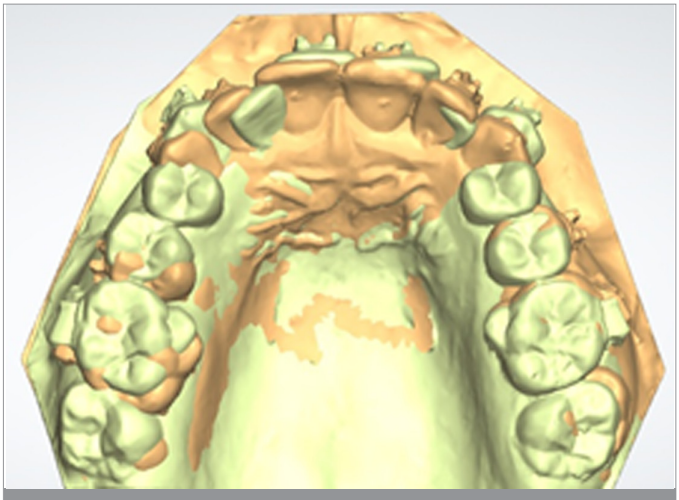

Figure 2. The superimposition model

Measurements

Mx3 millimeter (Mx3 mm): The distance between the tip of Mx3 and the tip of the Mx7 mesiobuccal cusp on the x-axis of the sagittal plane.

Mx1 millimeter (Mx1 mm): The distance between the tip of Mx1 and the tip of the Mx7 mesiobuccal cusp on the x-axis of the sagittal plane.

Mx3 degree (Mx3, °): The disto-occlusal angle between the line passing the disto-occlusal corner of the Mx3 bracket and the tip of the tooth and the line passing parallel to the bracket base.

Mx1 degree (Mx1, °): The disto-incisal angle between the line passing the disto-incisal corner of the Mx1 bracket and the tip of the tooth and the line passing parallel to the bracket base.

Linear and angular measurements are shown in Figure 3 and Figure 4, respectively.

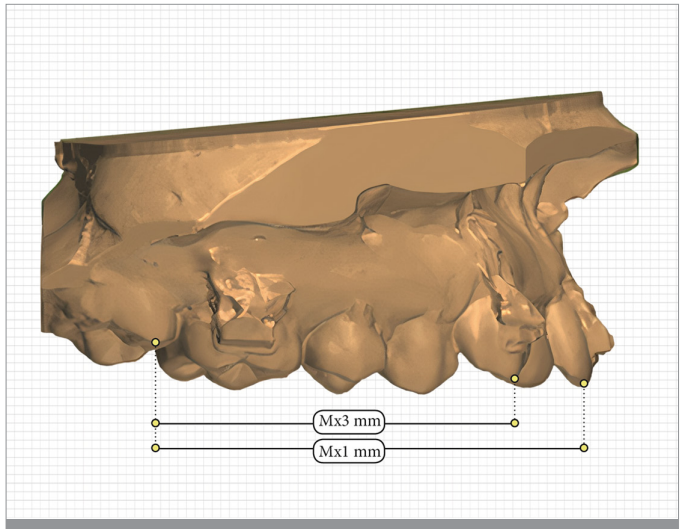

Figure 3. Mx3 and Mx1 linear measurements

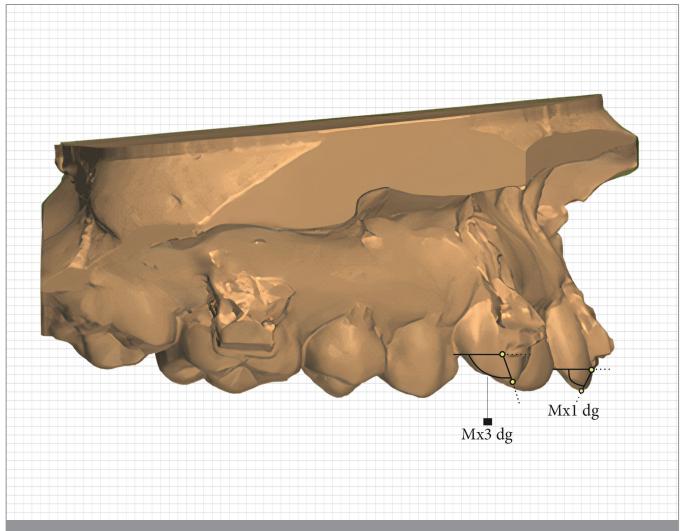

Figure 4. Mx3 and Mx1 angular measurements

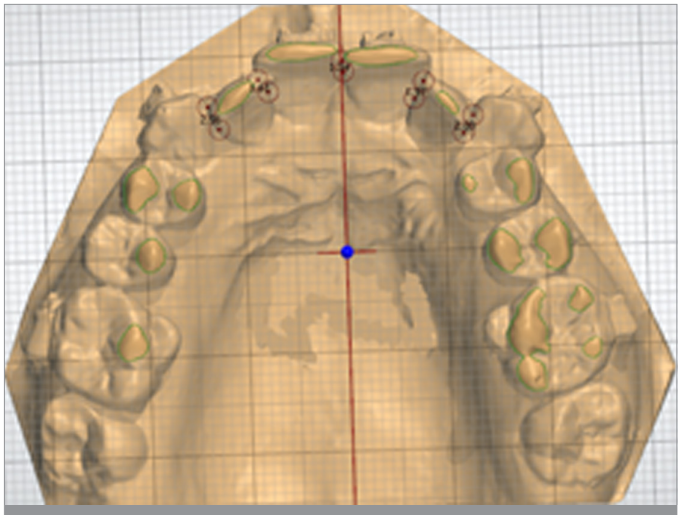

Figure 5. Little's Irregularity Index measurement

Little's Irregularity Index was calculated as the sum of the linear measurements of the distance between the tooth's respective anatomic contact points and the adjacent anatomic contact points in the upper jaw anterior region (Figure 5). Since this study had a split-mouth design, the current degree of crowding in the midline was evenly divided into 2 sides when calculating the Irregularity Index.

Statistical Analysis

The dataset consisted of measurements performed on 58 upper jaw digital orthodontic models of 29 patients. The margin of error in the measurements was calculated from 14 measurements repeated by the same researcher on 20 orthodontic models after 6 weeks. According to the Dahlberg formula,[19] the margin of error was calculated to not exceed 1.2° for the angular measurements and 0.4 mm for the linear measurements.

The data were analyzed with IBM SPSS V23, and the Shapiro–Wilk test was used to test the data for a normal distribution. Intragroup comparisons between the T0 and T1 stages and intergroup comparisons for T1–T0 difference values were made using a paired samples *t*-test. The results were presented as mean ± standard deviation, and the significance level was set to $P < .05$.

RESULTS

Intragroup Comparisons

The amount of linear movements of Mx3 in the distal direction significantly increased in both groups ($P < .001$). However, the angular movements of the Mx3 teeth did not show a statistically significant difference in either the study or the control groups ($P > .05$).

The Mx1s showed statistically significant retrusion in the control group ($P < .01$), but no statistically significant retrusion in the study group ($P > .05$).

Little's Index values showed statistically significant decreases in both the study ($P < .001$) and control ($P < .001$) groups.

Intragroup comparisons are shown in Table 3.

Intergroup Comparisons

The linear movement of the Mx3 in the distal direction was significantly higher in the control group than in the study group ($P < .01$). The Mx3 angulation showed a statistically significant difference ($P < .05$) between the study and control groups. The Mx3 inclined mesially in the study group and distally in the control group.

The linear movements of the Mx1s and the amount of change in the Little's Index measurements did not show any statistically significant differences between the groups ($P > .05$).

Intergroup comparisons are shown in Table 4.

Table 3. Paired samples *t*-test results for intragroup comparisons

		Measurement Value		
Measurement	Group	Bonding (T0) Mean ± SD	12th week (T1) Mean ± SD	*P*-value
Mx3 (°) (Angular)	Study	105.6 ± 24.2	110.1 ± 12.7	.225
	Control	113.5 ± 14.1	106 ± 21.1	.076
Mx3 (mm) (Linear)	Study	31.7 ± 1.7	29.4 ± 2.2	<.001***
	Control	31.7 ± 1.8	28.8 ± 1.7	<.001***
Mx1 (°) (Angular)	Study	88.4 ± 19.5	85.5 ± 11.4	.148
	Control	87.5 ± 13.8	83.2 ± 11.0	.009**
Mx1 (mm) (Linear)	Study	39.7 ± 2.9	39.2 ± 2.4	.105
	Control	39.5 ± 3.2	38.7 ± 2.4	.007**
Little index value	Study	4.46 ± 2.33	–0.49 ± 0.61	<.001***
	Control	4.78 ± 1.687	–0.59 ± 0.742	<.001***

**Statistically significant difference ($P < .01$).
***Statistically significant difference ($P < .001$).
Mx3, Maxillary canine tooth; Mx1, Maxillary central incisor tooth; SD, standard deviation.

Table 4. Paired samples *t*-test results for intergroup comparisons

Measurement	Group	Measurement (T1-T0) Mean ± SD	*P*
Mx3 (°) (Angular)	Study	4.46 ± 19.38	.015*
	Control	−7.52 ± 21.97	
Mx3 (mm) (Linear)	Study	−2.26 ± 1.12	.007**
	Control	−2.9 ± 1.09	
Mx1 (°) (Angular)	Study	−2.87 ± 10.39	.553
	Control	−4.35 ± 8.33	
Mx1 (mm) (Linear)	Study	−0.54 ± 1.73	.556
	Control	−0.74 ± 1.36	
Little index value	Study	−4.95 ± 2.13	.417
	Control	−5.37 ± 1.63	

*Statistically significant difference ($P < .05$)
**Statistically significant difference ($P < .01$)
Mx3, Maxillary canine tooth; Mx1, Maxillary central incisor tooth; SD, standard deviation.

DISCUSSION

In this study, treatment involving the maxillary first premolar extraction during the first 12 weeks was evaluated. During this period, a single arch wire was used to counteract the effects of arch wire change. Therefore, a 0.017 × 0.025 Turbo Wire was chosen as arch wire for increased breakage resistance. This arch wire was introduced as an initial arch wire by the manufacturer. The possible torque effect of the rectangular arch wire on Mx3 was eliminated by choosing 0° as the torque value of the Mx3 brackets in both groups.

The data set of this study was obtained by measuring the amount of tooth movement and crowding in digital models. Previous studies have also used digital jaw models for the three-dimensional analysis of orthodontic tooth movement[20] and for the calculation of Little's Irregularity Index.[21] The results of this study showed that Mx3 of the study group exhibited angular changes in the mesial direction while moving linearly in the distal direction. By contrast, the control group showed both angular and linear movements of Mx3 in the distal direction.

A comparison of the 2 groups revealed that the amount of linear and angular movements in the distal direction was significantly higher in the control group than in the study group. This result is consistent with the angulations of the Mx3 brackets, as increases in the angulation of the bracket were accompanied by increases in the angulation of the tooth in the mesial direction and with decreases in the amount of linear motion in the distal direction. In orthodontic treatment involving premolar extraction, excessive distal tipping of the canines can lead to posterior bite opening and prolong the total treatment time.[6] For this reason, the Mx3 movement observed in the study group was considered more desirable in the initial phase of the treatment with extraction.

In this study, a statistically significant retrusion was measured in the Mx1s in the control group, but no statistically significant retrusion occurred in the study group. Therefore, increases in the Mx3 bracket angulation were accompanied by a decrease in the amount of movement of Mx1 in the palatinal direction. According to Pontes et al.,[11] the upper dental arch length increased with increasing angulation in the 6 anterior maxillary teeth when using a straight-wire bracket. Although these previous researchers obtained this result from cases with no tooth loss in the upper dental arch, their finding is consistent with that which we obtained in our cases with premolar extraction.

In the present study, the amount of reduction in maxillary anterior crowding at the end of 12 weeks was defined as alignment efficiency. Here, Little's Irregularity Index was used to evaluate the effect of Mx3 bracket angulation on alignment efficiency, as this index has been used in many studies to evaluate the efficiency of crowding treatments.[22,23,24] This index has also been used to assess the performance of the arch and orthodontic bracket systems, orthodontic stability, retention of the upper jaw, and measurements of the lower jaw over time.[25,26]

However, in the present split-mouth study, the amount of crowding present in the midline was equally distributed on both sides according to Little's Irregularity Index calculations for each group. Specifically, the index value decreased from +4.78 mm to −0.59 mm in the control group and from +4.46 mm to −0.49 mm in the study group. Therefore, the decrease in anterior crowding did not exhibit a statistically significant difference between the 2 groups. Although the amount and angle of movement of Mx3 in the distal direction showed significant differences between the 2 groups, their alignment efficiencies were similar. This result is related to the effects of the Mx3 bracket angulations on the retrusion of Mx1. Increases in the Mx3 bracket angulation led to decreases in the distal canine tooth movement and in the retrusion of Mx1. The opposite was true for the control group. Therefore, the alignment activity, which is the total result of these tooth movements, did not differ between the groups. However, the differences measured for the individual movements of Mx3 and Mx1 were statistically significant.

The limitation of this study is that tooth movement was evaluated only at the crown level. The movement of the tooth root should also be measured by radiological assessment. Nevertheless, this prospective clinical study can serve as a reference for clinicians when choosing a bracket prescription appropriate for the Mx1 and Mx3 positions in a treatment involving premolar extraction. Future studies could examine the effects of different Mx3 bracket angulations and bracket torque combinations on tooth movement and alignment efficiency.

CONCLUSION

In this study, the following results were obtained:

- The +10° Mx3 bracket angulation caused an increase in the inclination of the canine tooth in the mesial direction and a decrease in the distal linear movement of Mx3 compared with the 0° Mx3 bracket angulation.
- The +10° Mx3 bracket angulation caused a decrease in the Mx1 retraction compared with the 0° Mx3 bracket angulation.
- No significant difference was found between the +10° Mx3 bracket angulation and the 0° Mx3 bracket angulation in terms of alignment efficiency in a treatment involving maxillary first premolar extraction.

Ethics Committee Approval: The study protocol was reviewed and approved by the ethics review board of the Ondokuz Mayıs University Clinical Research Ethics Committee, resolution number OMÜ KAEK —2016/336.

Informed Consent: A signed informed patient consent form was obtained from all patients.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - S.Y.; Design - S.Y.; Supervision - S.Y.; Fundings – M.T.; Materials - M.T.; Data Collection and/or Processing - M.T.; Analysis and/or Interpretation - M.T., S.Y.; Literature Review - M.T.; Writing - M.T., S.Y.; Critical Review - S.Y.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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