Review Article

Evaluation of Bite Force After Open Reduction and Internal Fixation Using Microplates

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Abstract

The primary aim of this study is to determine maximum bite force in molar and incisor regions of healthy individuals, to evaluate the bite force after open reduction and internal fixation of mandibular fractures using micro plates, for a period of up to 6 weeks and to determine the rate of recovery of maximum bite force in an Indian population.

Key Words: Bite Force Evaluation, Microplates, Open Reduction, Internal Fixation.

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INTRODUCTION

The advantages of using microplates are: (a) avoiding an external incision, (b) eliminating potential nerve damage, (c) simultaneous surveillance of fractured line reduction and occlusal relationships, (d) eliminating the need for intermaxillary fixation (IMF) during the 4 to 8-week-period and its complications.

A person with a complete dentition and good occlusal relationship will probably demonstrate better masticatory performance than someone with fewer occlusal contacts. Likewise, someone who generates higher force during mastication might have a better masticatory performance. Someone with carious, painful teeth will unconsciously avoid those teeth during mastication, reducing the performance of mastication. If there is a correlation between masticatory performance and bite forces, then bite forces could be used as a clinical indicator of masticatory performance.

Previous studies have addressed bite force in human beings, in the attempt to evaluate and understand masticatory system function, considering that bite force is a component of the chewing function. The chewing function is exerted by mandibular elevator muscles and regulated by nervous, muscular, skeletal systems and dental conditions.

Since the biting force is an important parameter in assessing the masticatory function, the aim of this study was to evaluate the maximum bite force in patients with mandibular fractures treated with a microplate osteosynthesis and also to determine the rate of recovery of the bite force.

MATHERIALS AND METHODS

The materials used in this study were:
Bite Force Displacement Appliance
Digital Vernier Caliper
Tensile Testing Machine
Load vs Displacement Calibration Chart
Disposable Rubber Occlusal Pads

Formulation and Calculation of Bite Force:

The maximal bite force of the control group between the incisors was approximately 185 N. For the molars, the force was about 325 N. So to be on the safe side, we chose a spring with a resistance of 50kg (1kg = 9.81 Newton) as studied by Erickson et al. [1], giving us a range of 490.5 N, which was well above the range measured by Gerlach et al. [2]. The appliance was fabricated on a simple lever-spring principle, as was described by Howell et al. [3].

According to Principles of First Order Lever stated by Ugural et al, [4] we know that:

$$\boldsymbol{BF \times a = SF \times b}$$

Where BF = bite force; SF = spring resistance; a = load arm; and b = spring arm.
Therefore, BF $\propto$ SF.
In addition, from Hooke's law we know that SF $\propto \delta L$.
Where SF = spring resistance; and δL = change in the length of the spring.
Therefore, BF $\propto \delta L$.
From the above equation, we can conclude that any change in the bite force will cause a direct change in the length of the spring. In this study, we used this conclusion to determine the amount of bite force generated when there was a change in the length of the spring.
The maximum biting force was measured by a hand-held occlusal force meter based on the requirements of the study, according to Kriztina Márton et al. (2005), [5]. The device was constructed of two parts: the metal gauge and the display. The working end piece of the gauge was formed to be suitable for measurements at the front and at the molar regions as well. This part was covered with disposable rubber pads in order to prevent decrease of the masticatory force experienced on metal sensation. The opposing endpiece contained a resistance spring that was sensitive to the deformation of the gauge. The sensed deformation or displacement was then recorded using a Vernier Caliper.
After fabrication of the appliance, it was calibrated using a tensile testing machine at IIT Madras. The machine was used to apply known loads to the appliance that was matched against the corresponding displacement measured by the Vernier Caliper. Three sets of trials were done, starting from loads of 0 kg to 50 kg. The trial readings were then averaged out and a calibration chart was prepared using the mean values.
The study group consisted of 10 patients who were treated for mandibular fractures by open reduction and internal fixation. A control group of 10 adults was also selected, for comparison with the study group. A set of inclusion and exclusion criteria was determined that helped in the final selection of the samples.

Inclusion Criteria:

Adequate dentition to perform bite force measurements
Absent or minimal dental restorations
No sensitivity to percussion on the teeth to be tested
Willing individuals with an informed consent
Exclusion Criteria:
Unwillingness for participating in the study
Presence of neurosensory defects
Unwillingness for a long follow-up
Presence of mobile or sensitive teeth
The study and the control samples were divided into four subgroups; namely, the male control, female control, male patient and female patient.
All bite force measurements were performed using a custom bite force displacement appli-

ance consisting of nose pliers, a 50kg spring load attached to a digital vernier caliper. The flattened beaks of the pliers were covered with rubber pads and were adjusted to an opening of 15 mm. Load changes on the biting end produced a measurable displacement change across the resistance end, determined by the digital vernier caliper.

All measurements were made with the subject seated with the head upright, looking forward, and in an unsupported natural head position. The subject was asked to remain in this position throughout the trials and to refrain from extraneous movements as mentioned by Vivek Shetty [6]. Bite forces were measured at the incisor and right and left molar regions [1]. The subject was instructed to bite on the pads of the bite force gauge to the maximum level. This was accomplished by instructing the subject to bite as forcefully as possible.

Each subject was asked to bite the device three times with maximal effort, with a 2-min rest between trials. Bite force displacement was recorded in mm and displayed on the screen of the digital vernier caliper for further analysis. The highest value among the three trials was considered as the subject's maximum bite force displacement.

The bite force displacement values were then analyzed and the force generated was determined using the load versus displacement chart provided along with the appliance. All the readings were then stored in the computer for statistical analysis.

Statistical Analysis:

The obtained data was fed into a personal computer and statistical analysis was performed using SPSS 10.0 software for Windows (SPSS Inc., Chicago, Illinois, USA) and analyzed accordingly. The 10 patients and 10 controls were considered as separate groups:

A – Control Group

B – Patient Group

The readings for the controls, recorded in a single sitting are tabulated in Table 1.

The readings for the patients were recorded in weekly sittings, over six weeks, for each subject as given in Tables 2a to 2f.

RESULTS

Table 1 represents force-displacement values of the control group. The recorded displacement is mentioned in 'mm' and the conversion of this displacement into force is mentioned in 'Newton', based on the calibration chart. The highest bite force generated by the control group is 421 Newtons on the right molar side, 394 Newtons on the left molar side, and 208 Newtons in the anterior region. The range varies from 334-421 Newtons, 323-398 Newtons, and 168-208 Newtons for right molars, left molars, and incisors, respectively.

Table 2 represents the mean and standard deviation (SD) of the displacement values in the control group. Table 3 represents the mean and standard deviation of the bite force values in the control group. Table 4 represents the mean and standard deviation of the displacement values in the patient group for weeks 1 to 6. The mean and SD of bite force for the patient group for weeks 1 to 6 is shown in Table 5.

DISCUSSION

One of the main advantages of using a microplate for the treatment of mandibular fracture is the early return to normal function, as there is no requirement for IMF [7]. Maximum occlusal force is a parameter of masticatory function that is relatively easy to measure. In addition, maximum occlusal force is reduced with fractures within the masticatory system [8,9]. So, to measure the effectiveness of the microplates after surgery, estimation of the occlusal force will give a good view of the masticatory function.

Thus, the aim of this study was to determine the bite forces of patients treated for fractures of the mandible by open reduction and internal fixation using microplates to compare these readings with those of normal individuals, and

Table 1. Force-Displacement Readings of the Control Group

S N	Control	Right Molar		Incisor		Left Molar	
		Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)
1	A	21.13	421	6.46	174	20.08	394
2	B	19.81	389	5.34	155	17.47	344
3	C	19.39	381	5.81	161	19.63	386
4	D	18.74	368	6.35	172	19.51	383
5	E	18.96	371	4.42	143	16.32	324
6	F	21.04	419	7.17	183	19.79	388
7	G	17.72	349	5.29	154	18.43	361
8	H	19.32	379	4.82	146	17.98	354
9	I	16.90	334	4.03	134	16.25	323
10	J	18.67	365	5.18	152	17.96	353

Table 2a. Week 1 Readings of Patient Group

S N	Patient	Week 1					
		Right Molar		Incisor		Left Molar	
		Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)
1	a	2.48	116	1.34	30	2.56	116
2	b	2.35	112	1.38	46	2.47	116
3	c	2.10	109	1.35	35	2.18	111
4	d	2.42	113	1.42	51	2.26	112
5	e	2.70	117	1.48	64	2.37	113
6	f	1.98	103	1.34	30	2.08	109
7	g	2.13	110	1.40	49	2.32	112
8	H	2.16	111	1.37	45	2.10	109
9	I	2.30	112	1.34	30	2.45	115
10	J	2.63	117	1.46	60	2.52	116

Table 2b. Week 2 Readings of Patient Group

S N	Patient	Week 2					
		Right Molar		Incisor		Left Molar	
		Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)
1	A	3.41	127	1.34	30	3.56	130
2	B	3.83	135	1.42	53	3.72	131
3	C	3.74	132	1.56	80	3.40	127
4	D	3.90	137	1.37	44	3.58	130
5	E	3.24	126	1.48	64	2.80	121
6	F	2.87	121	1.38	45	3.06	121
7	G	3.61	131	1.60	87	3.47	127
8	H	3.54	130	1.35	35	3.63	131
9	I	2.96	127	1.44	57	3.35	128
10	J	3.32	128	1.53	75	3.18	125

Table 2c. Week 3 Readings of Patient Group

S N	Patient	Week 3					
		Right Molar		Incisor		Left Molar	
		Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)
1	A	4.28	142	1.36	40	4.64	147
2	B	4.10	137	1.47	62	4.60	146
3	C	5.72	161	1.62	90	5.28	153
4	D	5.24	152	2.10	108	4.96	151
5	E	5.18	151	1.35	35	5.59	158
6	F	4.84	147	1.94	102	5.88	163
7	G	5.36	156	2.16	111	5.75	161
8	H	5.80	162	1.39	47	5.04	151
9	I	6.34	172	1.90	98	5.93	164
10	J	5.53	157	1.68	100	4.86	147

Table 2d. Week 4 Readings of Patient Group

S N	Patient	Week 4					
		Right Molar		Incisor		Left Molar	
		Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)
1	a	5.35	155	1.39	47	6.81	178
2	b	4.92	150	1.68	100	5.38	156
3	c	6.27	170	1.98	102	5.62	160
4	d	5.85	163	2.71	117	5.47	157
5	e	5.72	162	1.46	60	6.28	170
6	f	5.64	160	2.74	118	7.20	182
7	g	6.10	167	2.79	121	6.31	170
8	h	6.83	178	1.69	101	5.94	165
9	i	8.26	197	2.45	115	7.82	190
10	j	6.76	176	2.16	111	5.30	153

Table 2e. Week 5 Readings of Patient Group

S N	Patient	Week 5					
		Right Molar		Incisor		Left Molar	
		Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)
1	A	8.28	197	1.48	65	8.92	204
2	B	9.17	208	2.24	116	10.03	225
3	C	9.53	219	2.57	119	9.10	208
4	D	9.71	223	2.91	126	9.46	216
5	E	10.48	233	2.59	120	10.93	241
6	F	9.41	215	2.63	122	10.18	228
7	G	9.57	220	2.87	124	9.87	224
8	H	10.84	239	2.19	113	10.09	226
9	I	11.42	248	2.65	123	10.93	241
10	J	8.24	196	2.10	108	7.85	191

Table 2f. Week 6 readings of patient group

S N	Patient	Week 6					
		Right Molar		Incisor		Left Molar	
		Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)	Displacement (mm)	Force (Newton)
1	A	10.52	234	2.74	123	11.31	246
2	B	12.91	268	3.81	134	13.04	271
3	C	11.16	244	3.15	124	10.92	241
4	D	11.63	249	3.98	136	11.48	250
5	E	13.27	276	3.76	132	13.87	284
6	F	10.89	240	3.27	128	11.38	247
7	G	10.43	232	2.90	126	11.10	242
8	H	11.76	252	2.83	124	11.27	245
9	I	12.84	267	3.39	129	12.56	262
10	J	9.41	216	2.62	122	9.38	215

Table 3. Summary of Results for the Patient Group

Week	Bite Force Displacement of the Control Group		
	Right Molar	Left Molar	Anterior Region
	(Max/ [Range]) Newton	(Max/ [Range]) Newton	(Max/ [Range]) Newton
Week 1	117, [103-117]	116, [109-116]	44, [30-44]
Week 2	137, [121-137]	131, [121-131]	87, [30-87]
Week 3	172, [137-172]	164, [146-164]	111, [35-111]
Week 4	197, [150-197]	190, [153-190]	121, [47-121]
Week 5	248, [196-248]	241, [191-241]	126, [65-126]
Week 6	276, [216-276]	284, [215-284]	136, [122-136]

Table 4. Mean & Standard Deviation of the Control Group (Displacement)

Week	Patient Group (Displacement)					
	Right Molar		Incisor		Left Molar	
	MEAN	SD	MEAN	SD	MEAN	SD
1	19.168	1.315	9.487	0.971	18.342	1.400

Table 5. Mean & Standard Deviation of the Control Group (Force)

Week	Patient Group (Force)					
	Right Molar		Incisor		Left Molar	
	MEAN	SD	MEAN	MEAN	SD	MEAN
1	377.600	27.395	186.800	12.665	361.000	26.124

Table 6. Mean & Standard Deviation of the Patient Group (Displacement)

Week	Patient Group (Displacement)					
	Right Molar		Incisor		Left Molar	
	MEAN	SD	MEAN	MEAN	SD	MEAN
1	2.325	0.236	1.388	0.051	2.331	0.172
2	3.442	0.350	1.447	0.092	3.375	0.286
3	5.239	0.686	1.697	0.310	5.253	0.506
4	6.170	0.942	2.105	0.543	6.213	0.845
5	9.665	1.023	2.423	0.430	9.736	0.942
6	11.482	1.245	3.245	0.482	11.631	1.249

Table 7. Mean & Standard Deviation of the Patient Group (Force)

Week	Patient Group (Force)					
	Right Molar		Incisor		Left Molar	
	MEAN	SD	MEAN	MEAN	SD	MEAN
1	112.0	4.243	44	12.490	112.9	2.767
2	129.4	4.648	57	19.276	127.1	3.755
3	153.7	10.242	79.3	29.974	154.1	6.887
4	167.8	13.448	99.2	25.403	168.1	12.252
5	219.8	16.989	113.6	17.921	220.4	15.911
6	247.8	18.612	127.8	4.872	250.3	18.738

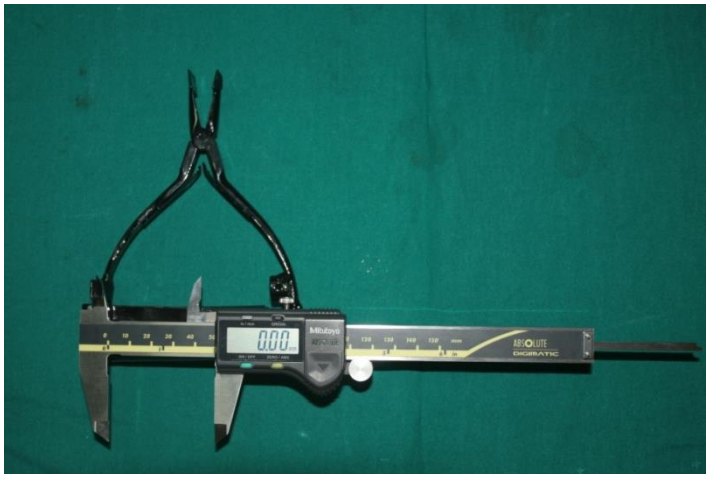

Fig 1. Bite Force Displacement Appliance

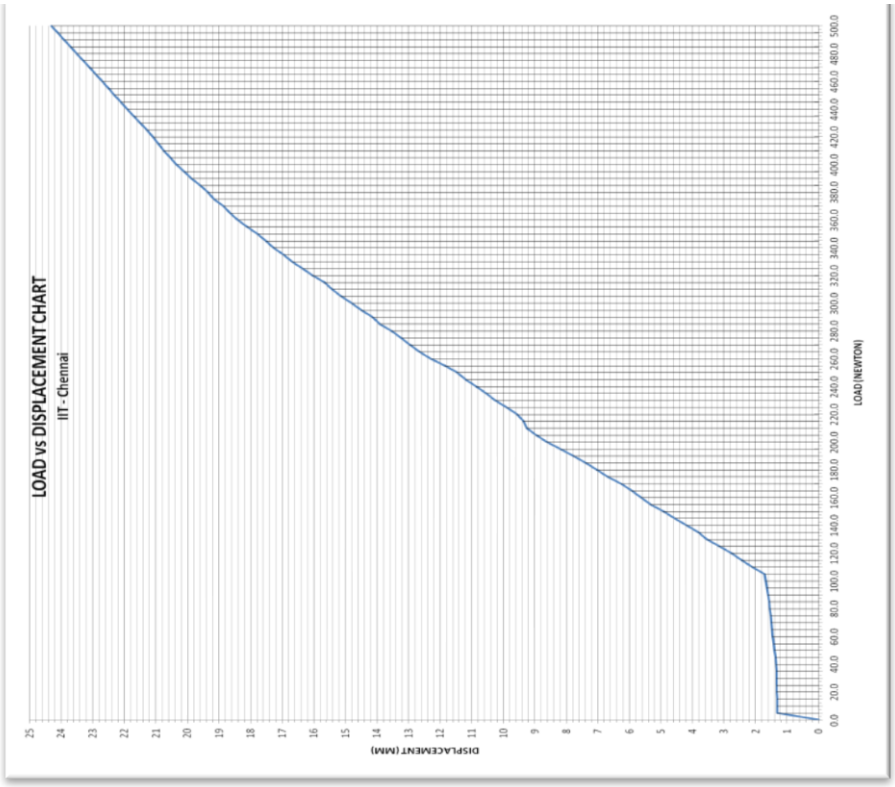

Fig 2. Load versus Displacement Chart

to determine the time taken for the bite forces to return to a normal functional range.

The bite force measurements in this study were recorded with a custom-made bite force displacement appliance shown in Fig 1.

The readings were taken in three areas – the right molar region, incisor region and the left molar region.

A control group of 10 male individuals were selected and the bite force measurements were

taken in one sitting. Each subject was asked to bite the device three times with maximal effort, with a 2-minute rest between trials. The highest value among three trials was considered the subject's maximum bite force as illustrated by Simone et al. [10]. Bite displacement was recorded in mm as was displayed on the screen of a Vernier caliper. Similarly, the bite force readings were recorded for the study group of 10 male patients weekly for a period of six weeks.This measured displacement was then calibrated with the load versus displacement chart as shown in Fig 2 and the amount of force generated was determined up to the nearest Newton.

The week 1 bite forces of the patient group accounted for only 23% of the control group values. These values rose to 30% in week 2, 40% in week 3, 44% in week 4, 58% in week 5, and 66% at the end of week 6.

The bite force measurements recorded in this study showed a significant reduction in values at the first post-op week in the study group when compared to the normal vales of the control group. This finding was in accordance with the findings of the studies conducted by Erickson et al. and Gerlach et al. [1,2].

The measurements on the 2nd, 3rd, 4th, 5th and 6th weeks showed a steady increase in the maximum bite force. These findings were consistent with studies carried out by Ellis and Throckmorton [8] and Dal Santo et al. [9]. There were discrepancies seen in the findings compared to the finding of other authors.

In our study, force measurements were taken for a period of 6 weeks, whereas Frank et al. performed the readings for up to 4 weeks only [9]. In addition, they conducted a study on patients with zygomatic complex fractures; whereas, this study was carried out for patients with mandible fractures only.

The study conducted by Erickson [1] included all male samples treated for fractures of the mandible angle only. Where as in this study, we have taken into account all the mandible fractures, and not just the angle alone.

Ellis et al. carried out readings starting on the 6th week, then 6 months, 1 year, 2 years and 3 years [8]. In this study, the readings were taken weekly for up to 6 weeks only. The 6th week reading of this study showed values similar to the 6th week reading in the study for bite forces after treatment of condylar fractures by open or closed methods. In this study, two cases were subcondylar fractures, both of which were treated by open reduction, internal fixation, without IMF.

The study by Gerlach et al. [2] also considers mandible angle fractures only, as compared to fractures of different areas of the mandible in this study. In their study, there was also a sharp decline in the bite forces on the 5th post-op week followed again by an increase on the 6th week. This was not seen in the present study, where the bite forces only showed a steady increase over the 6 weeks.

The mean bite forces of the control group in this study were 377.6 N in the right molar region, 361 N in the left molar region and 186.8 N in the incisor region. These findings were close to the findings of Nishigawa et al. and Yoshinori et al. [11, 12]. But these values were much less than the values reported by Kawai et al. [13]. Biting forces between the molars in the present study amounted to 90 N at 1 week after operation and 148 N at 6 weeks after operation. The reason for reduced bite forces after surgery can be attributed to the protective neuromuscular mechanisms present throughout the body. For instance, one of the first protective mechanisms seen when a fracture of a long bone occurs is muscle splinting, where selective components of the neuromuscular system are activated or deactivated to take forces off the damaged skeleton [1]. Similar muscle activation or de-activation can be seen in mandibular fracture, leading to reduction in the amount of generated force.

The significance of the findings of this study is that fixation requirements based on maximum voluntary bite forces in non-injured subjects are grossly inflated.

The amount of force subjects with fractures can generate is much less. It should be considered that the maximum voluntary bite force is the most the individual could voluntarily generate. The amount of the force used during functional activities is much less.

The microplate technique is performed with minimal effort, more convenient access and less stripping of the surrounding periosteum especially on the lingual aspect than necessary for traditional superior border wire, because this is a monocortical technique, there is less chance for iatrogenic damage to adjacent teeth by misdirected wire passing burs. Most importantly less manipulation of the fracture segment is required to provide stabilization leading to a lower probability of neurovascular injury. Less post-operative paresthesia and heamotoma formation are likely to occur. The used microscrew/microplate system is low profile less than 0.75mm. It is fabricated from titanium. It is extremely biocompatible, non-allergic, light-weighted, corrosion resistant, and does not interfere with current imaging modalities such as radiography, magnetic resonance imaging or computed axial tomography [14].

The microplate as well as the screws are comparatively expensive.

The length of the screw of the miniplate and microplate is identical, but the microplate screws are smaller in diameter and the risk of injuring the dental root or mandibular nerve is reduced by 25%. The risk of injuring the inferior alveolar nerve as a result of osteosynthesis should be kept as low as possible. Feller et al. has reported that it is difficult to calculate the extent to which a reduction of the total amount of titanium used will decrease deposition of metal ions in the peripheral organs [15].

CONCLUSION

In conclusion, in our study, the bite force loading capacity was 225N. A masticatory load exceeding 200N on the plates occurs only 3 months after osteosynthesis. At that time, the fracture is largely consolidated.

The torsional strength of the microplate was similar to that of the miniplate. According to Champy, the rotational force in the anterior region is approximately 1000Nm and needs to be withstood by the osteosynthesis material. Our results suggest that the treatment of fracture in the interforaminal region with a microplate will be stable enough for early mobilization.

The maximum bite force in molar and incisor regions of healthy individuals is 377.6 ± 27.395 for the right molars, 361.0 ± 26.124 for the left molars, and 186.8 ± 12.665 for the incisors. The bite force after open reduction and internal fixation of mandibular fractures, for a period of up to 6 weeks increases steadily from 112.0 ± 2.243, 44.0 ± 12.490, and 112.9 ± 2.767 for the right molar, incisors, and left molar, respectively, in the first week. 247.8 ± 18.612, 127.8 ± 4.8717, and 250.3 ± 18.738 for the right molar, incisors, and left molar, respectively, for week 6. The rate of recovery of maximum bite force in a patient with a treated mandible fracture is steady over a 6-week period, but not completely normal.

The early functional load the patient can generate for mastication of normal food items is reached at the end of week 1.

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