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Original Article

Stability and safety of mini-screw implant anchorage in the oral orthodontics

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Abstract: Objective: To investigate the stability and safety of the mini-screw implant anchorage in oral orthodontics. Methods: In this study, we retrospectively reviewed the clinical data of 120 patients who received the oral orthodontics. Among all these patients, 63 patients who implemented the surgery of the mini-screw implant anchorage were enrolled into the experimental group, and 57 patients who received the enhanced headgear anchorage into the control group. We observed the efficacy of dental orthodontics, complete closure time of the extraction space, inclination angle of the upper central incisor, convexity of the upper central incisor, displacement of the molar, bite force, chewing efficiency and the incidence of adverse reactions. Results: For all patients, the orthodontic success rate in the experimental group was significantly higher than that in the control group (χ^2=5.844, *P*=0.018); patients in the experimental group also suffered less due to the significantly shortened complete closure time of the extraction space in comparison with the control group (t=14.110, *P* < 0.001). Following treatment, the angle of inclination and the convexity of the upper central incisor in the experimental group were much larger than those in the control group (t=15.570 or 13.470, *P* < 0.001); but the recovery in the biting force and the chewing efficiency in the experimental group was superior to that in the control group (t=15.570, *P* < 0.001); while the incidence rate of the adverse reactions in the experimental group was significantly lower than that in the control group (χ^2=8.952, *P*=0.005). Conclusion: In comparison with the traditional orthodontics, mini-screw implant anchorage can increase the success rate and efficacy of oral orthodontics, with shorter complete closing time of extraction space, lower incidence rate of the postoperative adverse reactions and promising stability and safety.

Keywords: Mini-screw implant anchorage, oral orthodontics, stability, safety, oral surgery department

Introduction

With the improvement in the life quality, many people have chosen the oral orthodontics to alter the periodontal outlook and the facial morphology [1]. Oral orthodontics are a group of surgeries for teeth and jaw to exert the opposite and equivalent force on the teeth, called as the anchorage, so as to guarantee the migration angle of tooth and balance the facial skeleton, nerve muscle of the occlusalf surface and teeth [2]. Anchorage, instead of the targeted tooth, constitutes the basis of the orthodontic force, and is divided into the internal, external and intermaxillary anchorages [3].

Insufficient anchorage is a key factor altering the efficacy of oral treatment, while the direct load of skeletal anchorage may affect the biological force of the oral orthodontics; nevertheless, traditional methods, including face-bow, lip bumper, intermaxillary traction, hyoid arch and transpalatal arch, may fail due to the shortages like the difficulty in control, poor convenience and discomfort, as well as the susceptibility to the oral inflammation and soft tissue edema, severely influencing the recovery of the chewing efficiency and bite force of patients [4, 5]. With the development of oral implants, mini-screw implant anchorage has been extensively applied in the oral orthodontics, and different from the traditional methods, it mainly depends on the mechanical interblocking force between the implant and the bone for fixation to avert the migration of teeth, instead of binding to the bone firmly; moreover, it is also widely accepted and recognized by many researchers for its flexibility in selection of implantation site and simplicity in surgical methods [6].

To further figure out the efficacy of mini-screw implant anchorage in the oral orthodontics, we aimed to apply this method in the orthodontic surgery of patients to observe the stability and safety of this method in the oral orthodontics and the application value in the clinical practice of oral orthodontics.

Material and methods

General data

In this study, we retrospectively reviewed the clinical data of 120 patients who received the oral orthodontics. Among all these patients, 63 patients who implemented the surgery of the mini-screw implant anchorage were enrolled into the experimental group, and 57 patients who received the enhanced headgear anchorage into the control group. In the experimental group, there were 27 males and 36 females, aged between 14 and 27 years old, with an average age of (21.21±4.28) years old; there were 29 patients with anterior arch, 26 with lip incompetence and 8 with abnormal or dislocated teeth. In the control group, there were 23 males and 34 females, aged between 16 and 29 years old, with an average age of (22.78± 5.35) years old; there were 32 patients with anterior arch, 19 with lip incompetence and 6 with abnormal or dislocated teeth.

Inclusion and exclusion criteria

Inclusion criteria: patients aged between 14 and 30 years old; patients' dental anomalies meets the corrective guidelines and actively cooperates with the treatment. patients with perfect clinical data. Prior to the implementation, this study had been approved by the Ethic Committee of the hospital, and all subjects signed the written informed consents. Exclusion criteria: patients with periodontitis, gingivitis or other diseases of oral mucosa; patients with 1/2 absorbed alveolar bone and the oral hygiene is poor. Patients with the systemic diseases, autoimmune diseases or malignancies; patients with mental disorders; patients with severe dysfunctions in heart, lung or kidney; patients with poor compliance.

Treatment methods

Traditional oral orthodontics [7]: For patients in control group, they received the surgery of the enhanced face-bow anchorage. In brief, patients wore the Nance bow to tract from the teeth in flat alignment to the extraction space, with a force of about 350 g on one side. Patients were required to wear the bow for 9 h per day. Meanwhile, transpalatal arch was also utilized to cooperate with the treatment. For all patients, they were required to wear the Nance bow for 1 year, and undertake the re-examination once every month, with regular oral sanitation.

Mini-screw implant anchorage for the oral orthodontics [8]: In brief, chlorhexidine was used for oral sanitation, and focal anesthesia was sustained using the lidocaine. Then, according to the panoramic radiograph and root tip images using the Panoramic X-Ray Unit (Beijing Prolong Technique Co., Ltd.), the implant site, angle and depth were clarified. Then, according to the X-ray image, implant teeth were separated by the brass wire to isolate the oral mucosa in the implant site, and then the micro-titanium nail was inserted in the angle perpendicular to the bone surface. Following implantation, root tip was photographed to clarify the correlation between the structure of mini-screw implant and the root. Patients were later advised to sustain the oral sanitation and prevent the postoperative infection using the chlorhexidine and antibiotics, and required to take re-examination once per month. One year later, the brass wire was fixed on the top of micro-titanium nail, and the mini-screw implant was removed by contrarotation.

Observation indexes

Following operation, we observed the efficacy of oral orthodontics of patients in two groups [9]. Excellence: Following the oral orthodontics, teeth were well fixed in alignment, and patients were satisfied towards the outcome. Improvement: Following the oral orthodontics, teeth was fixed in alignment, and patients were basically satisfied towards the outcome. Failure: Following oral orthodontics, tooth deformity had no significant alteration, and patients were not satisfied towards the outcome. Success rate of oral orthodontics = (Excellence + Improvement)/Total × 100%. Following surgery, we observed the complete closure time of the extraction space, angle of inclination of the upper central incisor, convexity of the upper central incisor, displacement of the molar, bite force, chewing efficiency. Closure time: The extraction space of two groups were measured with vernier calipers [10] and no observed gaps

indicated complete closure, and the time of complete closure of the interdental spaces was recorded. The angle of the upper central incisors, convexity of upper incisor, and the displacement of the molars were measured by a panoramic dental X-ray machine; After 30 days of treatment, the bite force was measured using an Ai Bite Force Analyzer (Aidong Group Flexible Sensor Co., Ltd., Jiangsu, China) [11]. The occlusal test materials was placed under the first molar of the mandible, and teeth bite 10 times at a frequency of 1/2 s. Three of the largest data were selected and the average value was calculated as the bite force; Chewing efficiency: 2 g of peanuts was chewed by the left and right sides 20 times respectively. The patient was then asked to spit out the remaining fragments in a bowl covered with special sieve. Theparticles sticking to the teeth were rinsed off with water and collected in the same bowl. The particles remaining in the oral cavity were collected in the same bowl. The collected fragments were stirred with distilled water and filtered with sieved (200 eyes), and the residue obtained by filtration was dried and weighed, and the chewing efficiency was calculated according to the difference in weight before and after chewing/weight before chewing × 100% [12]. The incidence of adverse reactions, mainly including the discomfort, oral infection, oral inflammation and mild edema of soft tissues, etc.

Statistical methods

SPSS 19.0 software (SPSS Inc., Chicago, IL, USA) was utilized for the statistical analysis of this study. Measurement data, in form of means±standard deviation ($\bar{x} \pm s$), were compared using *t* test between two groups, while enumeration data, in form of n (%), using the chi-square test. $P < 0.05$ suggested that the difference had statistical significance.

Results

Baseline data

Comparisons of the baseline data, including gender, age, body mass index (BMI), deformity types, smoking status, drinking status, level of blood glucose (Glu), alanine transaminase (ALT) and aspartate aminotransferase (AST), between two groups showed that differences had no statistical significance ($P > 0.05$) (**Table 1**).

Mini-screw implant anchorage improve orthodontic success rates

In the experimental group, 40 patients had the outcome of excellence (63.49%), 17 had the outcome of improvement (26.98%) and 6 had the outcome of failure (9.52%), with an orthodontics success rate of 90.48%. In the control group, 22 patients had the outcome of excellence (38.60%), 20 had the outcome of improvement (35.09%) and 15 had the outcome of failure (26.32%), with an orthodontics success rate of 73.68%. Thus, the success rate in the experimental group was significantly higher than that in the control group ($\chi^2=5.844$, $P=0.018$) (**Table 2**).

Mini-screw implant anchorage shorten complete closure time of the extraction space

In the experimental group, the complete closure time of the extraction space was (7.6±1.1) months, significantly shorter than (10.1±0.8) months in the control group (t=14.110, $P < 0.001$) (**Figure 1**).

Mini-screw implant anchorage improve angle of inclination of the upper central incisor, convexity of the upper central incisor and displacement of the molar

Following operation, in the experimental group and the control group, the angles of inclination of the upper central incisor were (25.34±2.13)° and (14.18±5.23)°, the convexities of the upper central incisor were (4.39±0.95) mm and (2.57±0.39) mm, and the displacements of the molar were (3.23±0.20) mm and (6.43±0.57) mm, respectively. From data above, we found that in the experiment group, patients had larger angles of inclination of the upper central incisor and the convexities of the upper central incisor than those in the control group (*t*= 15.570 or 13.470, all $P < 0.001$), with a significantly smaller displacement of the molar (*t*=41.820, $P < 0.001$) (**Figure 2**).

Mini-screw implant anchorage improve enhances the bite force and chewing efficiency

Following operation, in the experimental group and the control group, the bite forces were (131.85±15.69) lbs and (112.63±14.96) lbs, while the chewing efficiencies were (89.57± 11.24)% and (72.49±8.46)%, respectively. Thus, both of the bite force and chewing efficiency

Table 1. Baseline data of experimental group and control group [n (%)] ($\bar{x} \pm sd$)

Category	Experimental group (n=63)	Control group (n=57)	t/χ^2	P
Gender			0.077	0.854
Male	27 (42.86)	23 (40.35)		
Female	36 (57.14)	34 (59.65)		
Age	21.21±4.28	22.78±5.35	1.783	0.077
BMI (kg/m^2)	26.37±3.56	26.89±3.28	0.829	0.408
Malformation type			1.225	0.541
Anterior arch	29 (46.03)	32 (56.14)		
Lip incompetence	26 (41.27)	19 (33.33)		
Abnormal or dislocated teeth	8 (12.70)	6 (10.53)		
Smoking status			0.540	0.520
Yes	13 (20.63)	15 (26.32)		
No	50 (79.37)	42 (73.68)		
Drinking status			0.278	0.675
Yes	17 (26.98)	13 (22.81)		
No	46 (73.02)	44 (77.19)		
Glu (mmol/L)	6.02±0.56	5.83±0.72	1.622	0.107
ALT (U/L)	10.58±5.78	12.41±6.37	1.650	0.101
AST (U/L)	29.37±7.22	31.06±8.19	1.201	0.232

Table 2. Comparison of orthodontic success rate between experimental group and control group [n (%)]

Group	n	Excellence	Improvement	Failure	Success rate (%)
Experimental group	63	40 (63.49)	17 (26.98)	6 (9.52)	90.48
Control group	57	22 (38.60)	20 (35.09)	15 (26.32)	73.68
χ^2	-	-	-	-	5.844
P	-	-	-	-	0.018

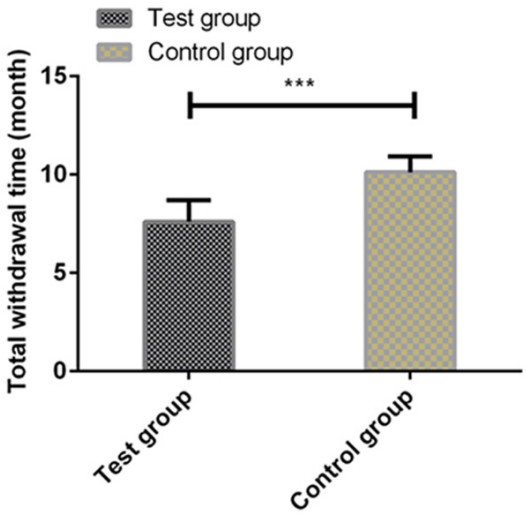

Figure 1. The complete closure time of the extraction space between the experimental group and the control group. The complete closure time of the extraction space in the experimental group was significantly lower than that of the control group (t=14.110, $P < 0.001$). Note: ***$P < 0.001$ compared with the control group.

of patients in the experimental group were significantly higher than those in the control group (t=15.570, $P < 0.001$) (**Figure 3**).

Mini-screw implant anchorage reduce adverse reactions

Following operation, in the experimental group, there were 2 patients with oral discomfort (3.17%), 1 with oral inflammation (1.59%) and 1 with mild edema of soft tissues (1.59%), and the incidence rate of adverse reaction was 6.35%; in the control group, there were 5 patients with oral discomfort (7.94%), 6 with oral infection (9.52%), 2 with oral inflammation (3.17%) and 2 with mild edema of soft tissues (3.17%), and the incidence rate of adverse reaction was 23.81%. Thus, patients in the experimental group suffered less from the adverse reactions in comparison with their counterparts in the control group (χ^2= 8.952, P=0.005) (**Table 3**).

Discussion

With the social development, more and more people focus on their facial morphology, oral health and periodontal outlook, and any periodontal diseases, without timely intervention, may induce the advanced loss of the tooth function [13]. Oral orthodontics refers to a orthopedic method through providing persistent pressure on the targeted teeth [14]. Anchorage design is a key factor affecting the efficacy of oral orthodontics, and a stable anchorage can positively enhance the efficacy of the oral orthodontic protocol. Thus, a promising proto-

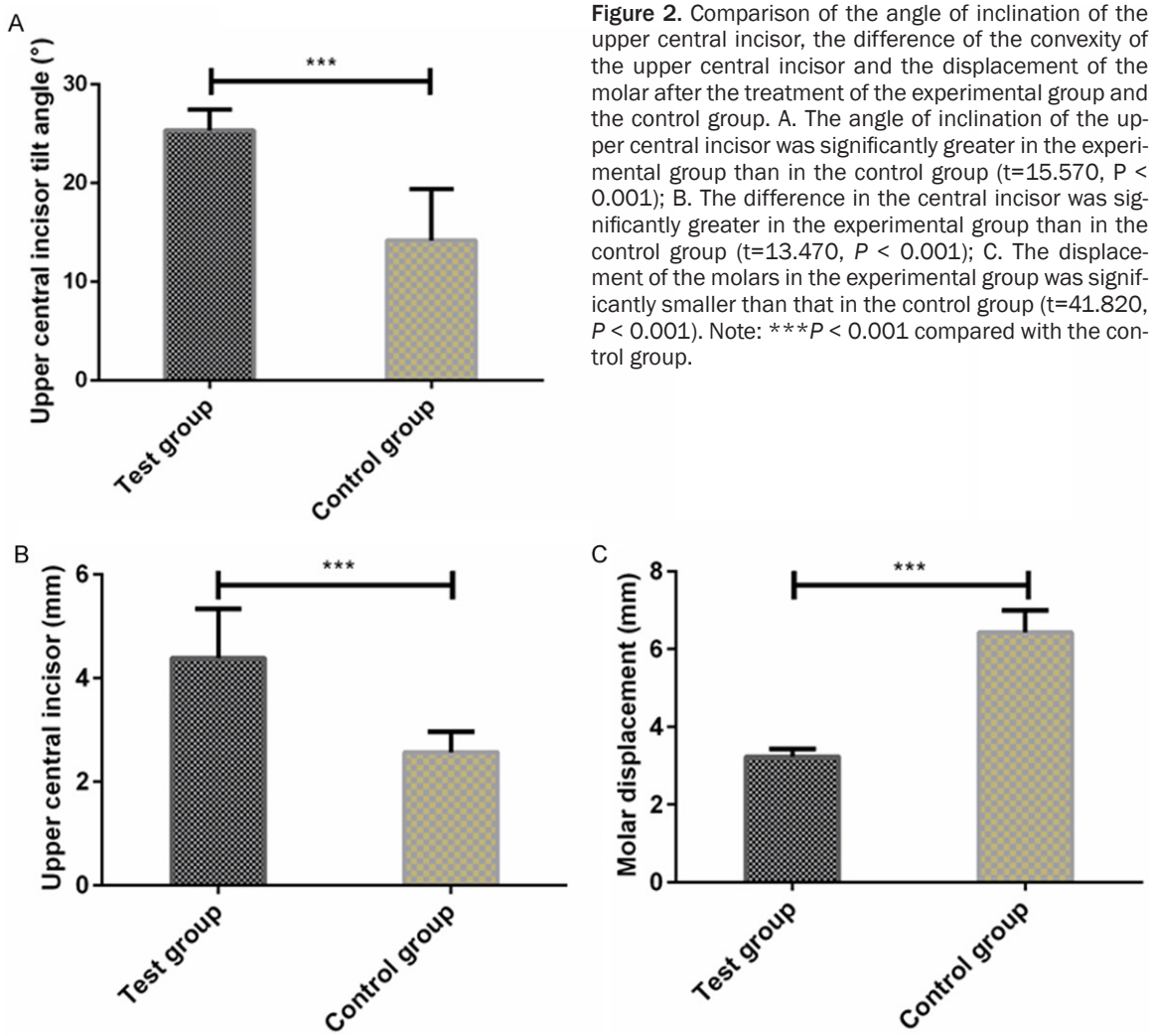

Figure 2. Comparison of the angle of inclination of the upper central incisor, the difference of the convexity of the upper central incisor and the displacement of the molar after the treatment of the experimental group and the control group. A. The angle of inclination of the upper central incisor was significantly greater in the experimental group than in the control group (t=15.570, P < 0.001); B. The difference in the central incisor was significantly greater in the experimental group than in the control group (t=13.470, *P* < 0.001); C. The displacement of the molars in the experimental group was significantly smaller than that in the control group (t=41.820, *P* < 0.001). Note: ***$P < 0.001$ compared with the control group.

col of anchorage always results in the good clinical outcome [15].

Traditional anchorages, including the intermaxillary traction and face-bow, are designed to perform the traction treatment for targeted teeth using the active or fixed headgear, and its efficacy has been proved in clinical practice. However, due to the lack of promising stability, patients suffer from the rotation of targeted teeth, which may affect the efficacy of oral orthodontics and further the physical and psychological health [16, 17]. According to the previous literature, among the traditional treatment methods using the anchorage, patients usually gain poor efficacy, but also suffer from the extremely high recurrence rate, let alone the attaining the anticipated outcome [18]. Mini-screw implant anchorage is made up by the titanium in small diameter, and the part that is embedded in the bone is designed in the screw shape, which endow the anchorage the ability to reach in the root of teeth [19, 20]. The results of this study showed that the success rate of orthodontics in the experimental group was significantly higher than that in the control group; the complete closure time of the extraction space in the experimental group was significantly lower than that in the control group, suggesting that the micro-implant anchorage can improve the success rate of orthodontic treatment and shorten the closure time.

Research by Magkavali-Trikka et al. shows mini-screw implant anchorage is also characterized by the promising stability, minimal invasion and the ability to bear the large orthodontic force [21], which is similar to the result of our study. The reason may be that bones act as the role to bear the force of anchorage, and for the mini-

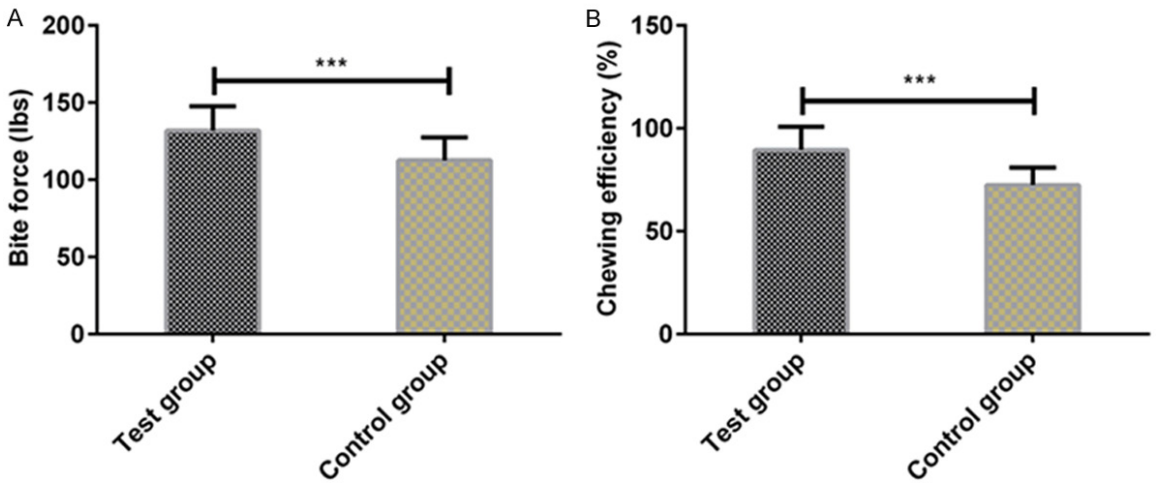

Figure 3. Comparison of the results of bite force and chewing efficiency between the experimental group and the control group. A: The bite force of the experimental group was significantly higher than that of the control group (t=15.570, $P < 0.001$); B: The chewing efficiency of the experimental group was significantly higher than that of the control group (t=15.570, $P < 0.001$). Note: ***$P < 0.001$ compared with the control group.

Table 3. Comparison of the incidence of adverse reactions after treatment in the experimental group and the control group [n (%)]

Group	n	Discomfort	Oral infection	Oral inflammation	Soft tissue mild edema	The incidence of adverse reactions (%)
Experimental group	63	2 (3.17)	0 (0.00)	1 (1.59)	1 (1.59)	6.35
Control group	57	5 (7.94)	6 (9.52)	2 (3.17)	2 (3.17)	23.81
χ^2	-	-	-	-	-	8.952
P	-	-	-	-	-	0.005

screw implant anchorage, the counterforce of the orthodontic force is transferred to the jaw, so as to avert the force generated from the tooth migration. Therefore, micro-implant anchorage can get better results that hardly gained in the traditional anchorage. The micro-implant anchorage can maximize the use of the extraction space and restore the anterior teeth, which can improve the relationship between the facial shape and the molars, thus achieving the ideal anchorage control [22]. Zhang reported that micro-implant anchorage and extraoral anchorage headgear can achieve the desired clinical results [23]. By further analyzing the stability of micro-implant anchorage, the results showed that the angle and convexity of the upper incisor were significantly bigger in the experimental group than in the control group. The displacement of the molar was significantly smaller than that in the control group. After treatment, the bite force and chewing efficiency are significantly higher in the experimental group than the control group, so the micro-implant anchorage is more stable than the traditional orthodontic treatment, and has better load-resistance.

Previous studies have shown that due to the insufficient distance between the roots of teeth, patients are more susceptible to the mechanical damage to the root during the orthodontic surgery, which gives rise to the discomfort and aches in root; particularly, patients in some severe cases may suffer from the infections or inflammations, and in some cases, patients with sensitive oral mucosa may also experience the adverse reactions like edema or vague words [24]. Wahabuddin et al. [25] reported that micro-implants have shorter diameters and are available in a variety of lengths. The screws are small in diameter and can be placed in any desired position without osseointegration and can be easily removed.The inci-

dence rate of the adverse reactions in the experimental group was significantly lower than that in the control group, indicating that the mini-screw implant anchorage can reduce the incidence rate of adverse reactions of patients. The underlying reason may be that the small size of implant brings about less damage to the oral cavity, and the removal of implant can be easily by direct rotation following the oral sanitation, with no pains, while the cavity would be quickly placed by the blood clot that is conducive to the wound healing and decrease of the infection rate [26]. However, we found that even for mini-screw implant anchorage in the orthodontic surgery, patients still suffer from the ineffectiveness of orthodontics and adverse reactions. Thus, we will focus on the development of more promising orthodontic methods using the anchorage in the future studies.

In conclusion, compared to the traditional orthodontics, mini-screw implant anchorage can increase the success rate and efficacy of oral orthodontics, with shorter complete closing time of extraction space, lower incidence rate of the postoperative adverse reactions and promising stability and safety.

Disclosure of conflict of interest

None.

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