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Original Article

Magnetic attachment improves the chewing ability of patients with dental defects after oral restoration

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Abstract: Objective: To investigate the effect and clinical value of magnetic attachments in oral restoration. Methods: Seventy-two cases of dental defects treated in Haishu District Stomatological Hospital from April 2018 to October 2019 were selected for retrospective analysis, of which 36 cases were treated with routine oral restoration (control group) and 34 cases with magnetic attachments (research group). The clinical efficacy, adverse reactions, masticatory efficiency and fixation force were compared between the two groups, and the treatment satisfaction was investigated at discharge. Subsequently, a one-year follow-up survey was conducted on the patients. The probing depth (PD) and alveolar bone height were re-examined at 6-month intervals, and the sulcus bleeding index (SBI), tooth loosening and plaque index (PLI) were recorded. Results: Compared with the control group, the total effective rate was higher in the research group, and the incidence of adverse reactions was lower ($P<0.05$). After the restoration treatment, the masticatory efficiency, fixation force, comfort and aesthetic outcome in the research group were higher than those in the control group (all $P<0.05$). The follow-up results showed that the SBI, PD, PLI and tooth loosening rate of the research group were lower while the alveolar bone height were higher, versus the control group (all $P<0.05$). Conclusions: Magnetic attachments can significantly improve the effect and safety of dental restoration as well as the masticatory efficiency, fixation, and periodontal rehabilitation of patients, which fully illustrates the clinical application value of magnetic attachments.

Keywords: Magnetic attachment, dental restoration, dental defect, masticatory efficiency, fixation

Introduction

In recent years, dental defects have become an extremely common oral condition in dentistry and periodontal diseases, and external trauma may give rise to dental defects to varying degrees [1]. According to statistics, 1 out of every 20-30 individuals may suffer from dental defects [2]. The most obvious result of dental defects is the destruction of the patient's appearance [3]. Patients with severe dental defects are more prone to facial bone collapse and change, ultimately leading to facial deformity [4]. In addition, dental defects are strongly linked to the masticatory function of patients, which is one of the crucial factors in nutrition intake [5]. They may also give rise to pathological changes such as dental caries and periodontal disease [6] that threatens the normal life of patients from many aspects. For the restoration of dental defects, the key is to reshape a tooth with complete function [7, 8]. However, the restoration process is complicated, and patients feel a strong foreign body sensation after the restoration [9]. Moreover, the implant-osseointegration process is time consuming, during which the masticatory force improvement of the patient is not ideal, and effective oral cleaning is unachievable [10]. Therefore, it is urgent to find a method to effectively address or make up for the shortcomings of the current dental restoration techniques.

Traditionally, dental restoration is mainly completed by rod attachments or cap attachments in actual practice, and its mechanism involves implementing the attachments based on the residual root canal in the mouth [11]. It can

effectively preserve the integrity of residual roots and the fullness of the alveolar ridge, but patients will have an obvious foreign body sensation after the procedure. Furthermore, its long-term application is likely to gather a large number of germs and debris, ultimately giving rise to periodontal diseases [12]. In recent years, the role of magnetic attachments in dental implant restoration has gained increasing attention [13]. Magnetic attachments make full use of the adsorption between the magnet at the abutment and the denture to significantly enhance the fixation of the implanted tooth through the closed magnetic field, thus improving the life quality of patients [14]. Magnetic attachments can help solve the problem of traditional implant clasps and reduce the foreign body sensation in the patient's mouth, thus improving the restoration feeling of patients. In addition, they can also lower the possibility of lateral movement of the implanted tooth through the axial force of magnetic adsorption [15]. We found that despite the advantages of magnetic attachment over conventional implants, doctors and patients still prefer implant treatment in clinical implant restorations. This is probably due to the fact that studies on the application of magnetic attachment are still rare and lacks reliable clinical reference and guidance. For the past few years, our hospital has advocated the application of magnetic attachments in dental prosthodontics and has achieved remarkable results. The research results are reported as follows, with the aim of providing a novel direction and guidance for future clinical implant restoration of patients with dental defects.

Methods

Data of patients

In this retrospective study, the clinical data of seventy-two patients with dental defects treated in Haishu District Stomatological Hospital from April 2018 to October 2019 were analyzed. Among them, 38 patients that received conventional dental restoration after admission were seen as the control group, while the other 34 patients that received magnetic attachment-based therapy were seen as the research group. The study was approved by the Ethics Committee of Haishu District Stomatological Hospital.

Inclusion and exclusion criteria

Inclusion criteria: Patients >18 years old; patients with a complete history of root canal treatment and obvious dental defects; patients with residual available root >8 mm; patients whose residual and broken roots were located in the site 0.5 mm above the gingiva or higher than the site 5 mm below the gingiva after removal of putrefaction; patients without other lesions around the root; patients who completed the treatment independently; and patients with complete medical history.

Exclusion criteria: Patients with coagulation or immune dysfunction; referred patients; patients allergic to drugs or materials used in this study; pregnant women or lactating women; patients with combined hypertension or diabetes mellitus; patients with mental illnesses that prevent communication; or patients with a history of oral restorative treatment or antibiotic treatment within half a year before admission.

Principles of treatment

As shown in **Figure 1**, the magnetic attachments were fixed by the absorption between magnetic materials or between magnetic materials and magnetic conductive materials, and the magnetic retainer embedded in the denture and the magnetic and magnetizable materials fixed in the root were used as the restorations of the retention devices.

Selection of magnetic materials

Currently, the magnetic materials that applicable to the human body include cobalt-platinum alloy, cobalt-rare earth alloy, and NdFeB permanent magnet alloy, among which NdFeB permanent magnet alloy is the magnetic material with the strongest magnetism and the best mechanical properties, making it the best choice for magnetic attachments.

Treatment method

Dental restoration was completed by senior dentists in our hospital. For the research group: Based on the retention of residual root canals in the oral cavity, the root surface was ground

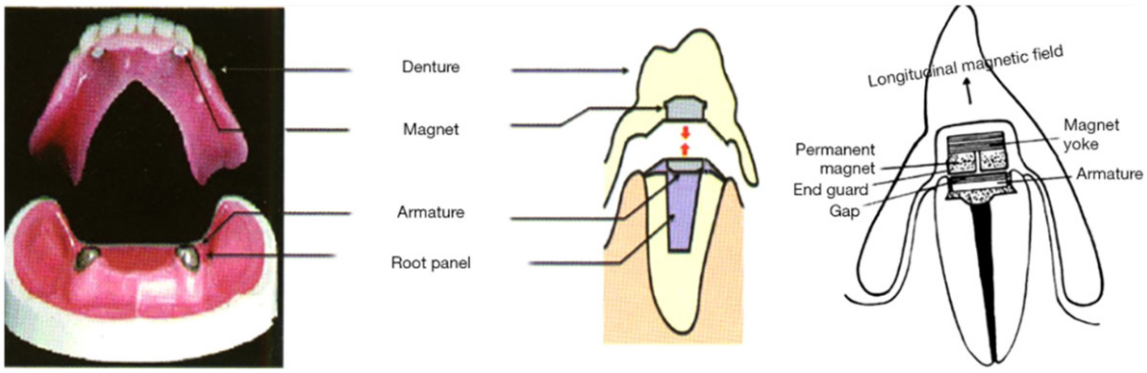

Figure 1. Therapeutic principle of magnetic attachments.

to the level of the gums within 1-2 weeks after root canal treatment, and a concave surface with a 1.0 mm edge and 45° width was established, with the root tip >4 mm retained. A silicone rubber impression was adopted to make an armature iron root cap. After confirmation of the size, the root cap was fixed on the abutment, and the denture was adsorbed by magnet. A 0.1 mm foil paper was placed between the magnet and the abutment. Then, self-setting greases were added, and the excess parts were removed after solidification. For the control group: With the conventional restoration mode, the clasp was retained at the abutment after root canal treatment. All dentures were purchased from Ivoclar Vivadent (Liechtenstein).

Follow-up of prognosis

Patients in the two groups were all followed up for 1 year. They were reminded to return to the hospital for reexamination by telephone at the 6^{th} and 12^{th} month during the prognosis period.

Outcome measures

Main indicators: In terms of clinical efficacy, markedly effective was defined as masticatory ability was completely restored, and the implant was stable; effective was defined as the patient's oral chewing ability after prosthetic treatment could satisfy daily life use; ineffective was defined as above criteria were not met [16]. Total effective rate = (the number of patients with markedly effective treatment + the number of patients with effective treatment)/the total number of patients × 100%. Adverse reactions from admission to discharge were calculated. Masticatory efficiency and fixation [17, 18]: Masticatory efficiency was detected by an ultraviolet spectrophotometer, and fixation by a fixation detector. In terms of tooth recovery, degree I tooth mobility was defined as tooth mobility range ≤1 mm; degree II tooth mobility was defined as 1 mm < tooth mobility range ≤2 mm; degree III tooth mobility was defined as tooth mobility range ≥2 mm. Mobility rate = degree I + degree II + degree III loosening incidence. In terms of plaque index, class I was defined as no visible dental plaque; class II was defined as no dental plaque under direct view but dental plaques on plaque indicator examination; class III was defined as a small amount of plaques with uneven distribution; class IV was defined as a large amount of plaques and soft scale [19].

Secondary indicators: Satisfaction: The Oral Impacts on Daily Performance (OIDP) scale was adopted for investigation of the satisfaction of patients in the two groups at discharge, mainly covering restoration comfort, appearance, and language function. Periodontal rehabilitation: Cone-beam computed tomography (CBCT) was used for the detection of the periodontal pocket depth and alveolar bone height, and the sulcus bleeding index (SBI) was recorded [20].

Statistical analyses

All data were processed via SPSS 22.0. Enumeration data, represented by (n/%), were compared between groups via the chi-square test. Measurement data conforming to a normal distribution were expressed as $\bar{x} \pm s$, and

Table 1. Comparison of baseline data

Variable	Research group	Control group	t or χ^2	P
Age	58.6±6.0	58.0±8.5	0.339	0.735
BMI (kg/cm^2)	21.7±3.6	21.6±5.0	0.096	0.924
Course of disease (years)	3.0±0.8	3.2±1.0	0.921	0.361
Gender			0.458	0.499
Male *vs.* female	21 *vs.* 13	25 *vs.* 11		
Family history of illness			0.187	0.666
Yes *vs.* no	6 *vs.* 28	5 *vs.* 31		
Living environment			0.697	0.404
Town *vs.* country	24 *vs.* 10	22 *vs.* 14		
Smoking			0.038	0.845
Yes *vs.* no	20 *vs.* 14	22 *vs.* 14		
Drinking			0.206	0.650
Yes *vs.* no	16 *vs.* 18	15 *vs.* 21		
Type of disease			0.701	0.704
Tooth defect *vs.* tooth loss *vs.* periodontal disease	15 *vs.* 12 *vs.* 7	14 *vs.* 15 *vs.* 5		

Table 2. Comparison of clinical efficacy

Variable	Markedly effective	Effective	Ineffective	Effective rate
The research group	24 (70.59)	9 (26.47)	1 (2.94)	97.06
The control group	18 (50.00)	11 (30.56)	7 (19.44)	80.56
χ^2				4.705
P				0.030

Table 3. Comparison of adverse reactions

Variable	Fracture of restoration	Gingivitis	Root caries	Falling off	The total incidence
The research group	1 (2.94)	2 (5.88)	0 (0.00)	0 (0.00)	8.82
The control group	3 (8.33)	4 (11.11)	1 (2.78)	2 (5.56)	27.78
χ^2					4.154
P					0.042

analyzed via the independent-samples T test. The comparison among multiple time points were conducted using one-way ANOVA followed with LSD test. The factors affecting restoration effect were analyzed by logistic regression. P<0.05 denoted a significant difference.

Results

Comparison of baseline data

The two groups were not significantly different in terms of clinical baseline data such as age, gender, and disease type (all P>0.05, **Table 1**).

Comparison of clinical efficacy

The total effective rate in the research group was 91.18%, which was higher than 80.56% in the control group (P<0.05, **Table 2**).

Comparison of adverse reactions

The research group showed a total incidence of adverse reactions of 8.82%, with 1 case of fracture of restoration and 2 cases of gingivitis, which was lower than 27.78% in the control group (P<0.05, **Table 3**).

Comparison of masticatory efficiency and fixation

Before restoration, the two groups were not significantly different in oral masticatory efficiency and fixation (both P>0.05). However, after fixation, the oral masticatory efficiency and fixation of both groups increased, with significantly higher levels in the research group than the control group (all P<0.05) (**Figure 2**).

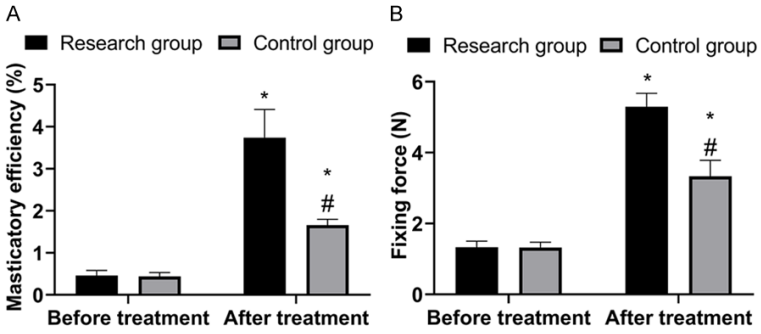

Figure 2. Comparison of masticatory efficiency and fixation. A. Comparison of masticatory efficiency. B. Comparison of fixation. *, P<0.05 *vs.* before restoration. #, P<0.05 *vs.* the research group.

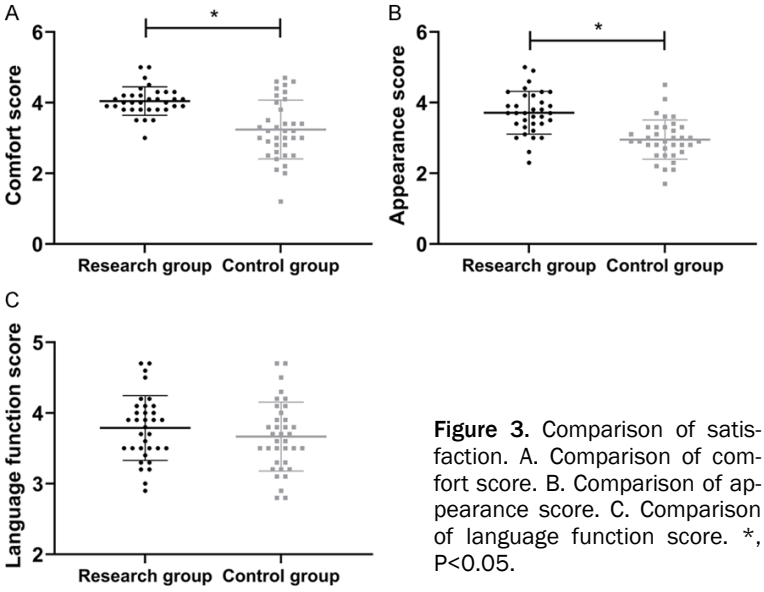

Figure 3. Comparison of satisfaction. A. Comparison of comfort score. B. Comparison of appearance score. C. Comparison of language function score. *, P<0.05.

Comparison of satisfaction

After restoration, the two groups were not significantly different in language function score (P>0.05), but both the comfort and appearance scores of the research group were higher than those of the control group (both P<0.05, **Figure 3**).

Comparison of periodontal rehabilitation

Before restoration, no notable difference was found between the two groups in the SBI, periodontal pocket depth, and alveolar bone height (all P>0.05). After restoration, the research group had no notable changes in periodontal indexes (all P>0.05), while in the control group, the SBI and periodontal pocket depth increased while alveolar bone height declined in a time-dependent manner (all P<0.05). After the restoration, the SBI and periodontal pocket depth were significantly less than those in the control group while the alveolar bone height was significantly more than that in the control group at the 6- and 12-month follow-up (all P< 0.05) (**Figure 4**).

Comparison of dental rehabilitation

The research group showed lower total tooth mobility than the control group (8.82% *vs.* 30.56%, P<0.05, **Table 4**).

Comparison of the plaque index

At 12 months after treatment, the plaque index of the research group was 0.62±0.22, the plaque index of the research group was significantly lower than that of the control group (P<0.05, **Figure 5**).

Univariate analysis of factors affecting prognosis of recovery

Patients with loose teeth were classified as the poor prognosis group (n = 14) and patients without loose teeth were classified as the good prognosis group (n = 56). As shown in **Table 5**, comparing the data of the two groups, the differences between the two groups in terms of gender and family history were not statistically significant (P>0.05), indicating that these indicators were not potential factors affecting the prognosis of patients. In contrast, the age and the number of people using conventional restorative treatment were higher in the poor prognosis group than in the good prognosis group (P<0.05), indicating that age and treatment modality were single factors influencing prognosis recovery.

Multifactorial analysis of the factors affecting prognosis of recovery

Logistic regression analysis was performed by assigning values to the above indicators (**Table**

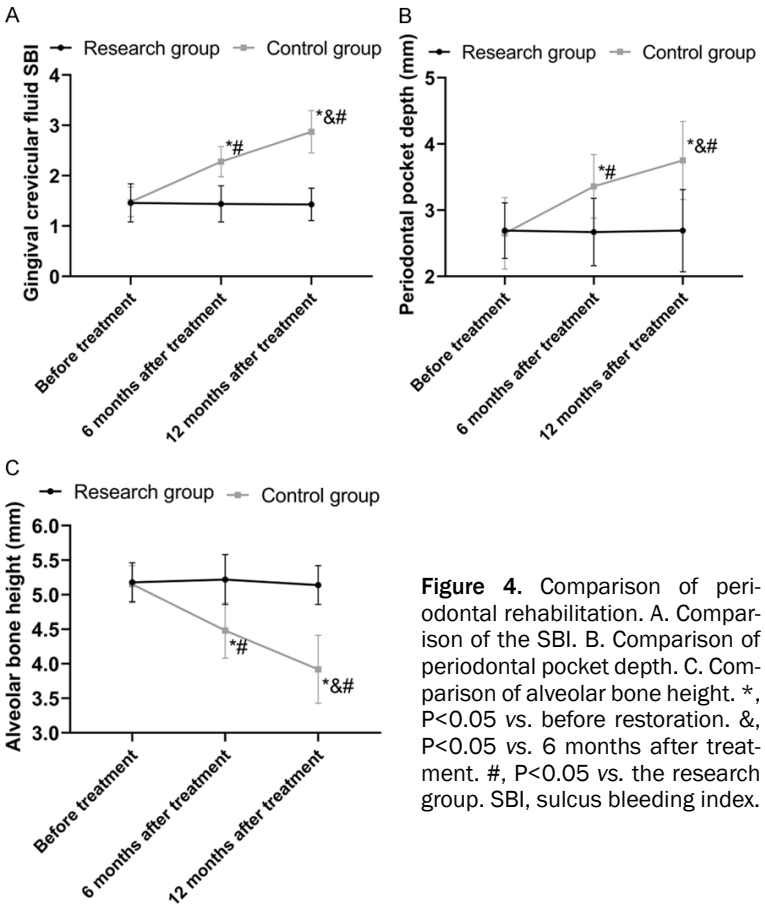

Figure 4. Comparison of periodontal rehabilitation. A. Comparison of the SBI. B. Comparison of periodontal pocket depth. C. Comparison of alveolar bone height. *, P<0.05 *vs.* before restoration. &, P<0.05 *vs.* 6 months after treatment. #, P<0.05 *vs.* the research group. SBI, sulcus bleeding index.

6) as oblique variables and using whether or not the patient experienced tooth loosening in prognosis as the independent variable, and the results are shown in **Table 7**, where age and treatment modality were all risk factors affecting the patient's prognosis for recovery (all P<0.05).

Discussion

Dental defects, a pervasive clinical disease, have great impact on patients' appearance and even psychological well-being [21]. Therefore, dental restoration has gained attention in the clinic for its importance and necessity [22].

Our study firstly evaluated the clinical efficacy and safety of restoration in the research group and control group. According to the results, the research group achieved a notably higher total effective rate and showed a lower incidence of adverse reactions compared with the control group, indicating the remarkable efficacy of magnetic attachments in dental restoration, which are consistent with the findings in a previous study [23]. Subsequently, we found notable improvements in the masticatory efficiency and fixation of the research group after restoration. During the follow-up, we found that both the SBI and periodontal pocket depth in the research group decreased, while alveolar bone height increased, which again verified the significant improvement and protective effect of magnetic attachments on periodontal tissue. The results are strongly linked to the structure of magnetic attachments. As the attachment adsorption force decreases with the increase of the distance between the magnet and the armature, the pressure on the abutment of the patient during the removal and wearing of the denture will greatly decline [24]. The results also suggest that the periodontal pocket depth and alveolar bone height after restoration with magnetic attachment will not change greatly. In a previous study [25], we also found no significant change in alveolar bone height in patients using magnetic attachment, which is consistent with our results. However, the clasp retention used in conventional restoration has a high and continuous pressure on the damaged abutment, which can promote the resorption of alveolar bone [26], thus lowering its height and greatly influencing the oral tissue of patients. The rehabilitation of teeth in the two groups also fully confirmed the obvious improvement of magnetic attachments on the stability of denture implantation. Based on the results of this study and related literature, we can preliminarily summarize the advantages of magnetic attachments as follows: (I) application of magnetic attachments to both sides of the dental arch can improve the balance of dentures and reduce the risk of denture fracture [14]; (II) the design of the magnetic attachment and armature realizes the gap sealing [27], and also reduces the incidence of dental

Table 4. Comparison of tooth mobility

Variable	Degree I	Degree II	Degree III	Mobility rate
The research group	2 (5.88)	1 (2.94)	0 (0.00)	8.82%
The control group	4 (11.11)	5 (13.89)	2 (5.56)	30.56%
χ^2				5.161
P				0.023

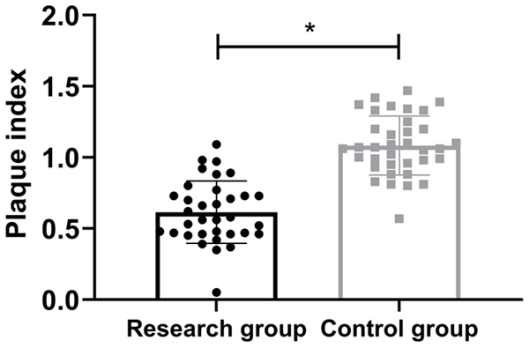

Figure 5. Comparison of the plaque index. *, P<0.05.

caries; (III) during chewing, traction caused by magnets can make the denture slightly float upwards, thus reducing the pressure on the oral cavity and improving the masticatory efficiency [28]; (IV) with the suction force between the armature and permanent magnet, the denture can be corrected to improve the retention and stability of denture restoration [29]. The satisfaction results of the two groups after dental restoration also fully illustrated the great application significance of magnetic attachments. Finally, the comparison results of dental rehabilitation and the dental plaque index between the two groups also showed that the application effect of magnetic attachments was notably superior to that of the control group, and the reason may be similar with above. In addition, dental plaques are a crucial outcome measure in prosthodontics and a pivotal factor reflecting the prognosis of patients with periodontitis [30]. In dental restoration, gingival retraction is an inevitable problem [31]. For this reason, a large number of bacteria can easily attach and grow in the retraction site [32]. In a 10-year long-term follow-up survey by Patil et al., we found that patients with tooth loss who underwent oral implant restoration could have a prognosis of approximately 2.8 SBI at 6-8 years [33]. However, magnetic attachments can completely prevent retraction [34], which greatly improves the cleanliness of teeth, reduce the plaque, thereby avoiding the possibility of periodontal disease. Again, this can be confirmed by the study of Xu et al. [35]. However, during the use of magnetic attachments, it should also be noted that since there is no support plate in the magnetic attachments, special attention should be paid to keep the gap between the two plates about 0.1 mm during restoration [36], so as to avoid the abutment teeth from being damaged by excessively concentrated bite force. Finally, we also found that age and treatment modality were independent factors affecting patient prognosis, which again validates our view and confirms the importance of magnetic attachment in restorative dental treatment. The influence of age may be due to the fact that older patients have a higher likelihood of tooth loosening because of their worse dental health status, which is also mentioned in a previous study [37].

However, due to limited conditions, the number of cases included in this study was small, and the study period was short, so it is impossible to judge the long-term prognosis of patients. We will follow up the subjects in this study for a longer period of time, expand the sample size, and perform a more in-depth and comprehensive analysis of the application of magnetic attachments in dental restoration.

Conclusions

Magnetic attachments can significantly improve the effect and safety of dental restoration as well as the masticatory efficiency, fixation, and periodontal rehabilitation of patients, which fully illustrates the clinical application value of magnetic attachments.

Disclosure of conflict of interest

None.

Table 5. Univariate analysis affecting prognosis of recovery

Variable	Good prognosis group	Poor prognosis group	t or χ^2	P
Age			5.833	0.016
<60 *vs.* ≥60	36 *vs.* 20	4 *vs.* 10		
BMI (kg/cm^2)			0.014	0.905
<21 *vs.* ≥21	27 *vs.* 29	7 *vs.* 7		
Course of disease (years)			0.060	0.807
<3 *vs.* ≥3	34 *vs.* 22	8 *vs.* 6		
Gender			0.016	0.900
Male *vs.* female	37 *vs.* 19	9 *vs.* 5		
Family history of illness			0.431	0.511
Yes *vs.* no	8 *vs.* 48	3 *vs.* 11		
Living environment			0.015	0.902
Town *vs.* country	35 *vs.* 21	9 *vs.* 5		
Smoking			0.134	0.714
Yes *vs.* no	33 *vs.* 23	9 *vs.* 5		
Drinking			0.232	0.630
Yes *vs.* no	24 *vs.* 32	7 *vs.* 7		
Type of disease			0.214	0.899
Tooth defect *vs.* tooth loss *vs.* periodontal disease	23 *vs.* 22 *vs.* 9	6 *vs.* 5 *vs.* 3		
Treatment modality			5.161	0.023
Magnetic attachment *vs.* conventional treatment	31 *vs.* 25	3 *vs.* 11		

Table 6. Assignment table

Variable	Assignment
Age	<60 = 0, ≥60 = 1
Treatment modality	Magnetic attachment = 0, Conventional treatment = 1
Prognosis	Good prognosis = 0, Poor prognosis = 1

Table 7. Multifactorial analysis of the factors influencing prognostic recovery

Variable	B	S.E.	Wald χ^2	P	OR	95% CI
Age	0.126	1.116	8.410	0.000	3.242	1.164-6.067
Treatment modality	0.542	1.842	12.064	0.000	4.871	2.206-7.185

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