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ORIGINAL ARTICLE

Prospective Study

Orthodontic treatment combined with 3D printing guide plate implant restoration for edentulism and its influence on mastication and phonic function

Li-Bo Yan, Yu-Chao Zhou, Yang Wang, Li-Xin Li

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Abstract

BACKGROUND

Dentition defect, a common clinical oral disease developed in humans, not only causes masticatory dysfunction and articulation difficulties but also affects facial appearance and increases the burden on the intestinal tract. Restorative treatment is the primary option for this disease. However, traditional restorations have many drawbacks, such as mismatch with the body, low reliability, and incomplete occlusal function recovery.

AIM

to analyze the efficacy of orthodontics combined with 3D printing guide plate implant restoration in treating patients with dentition defects and its influence on masticatory and phonic functions.

METHODS

A prospective study was carried out in 86 patients with dentition defects who received implant prosthesis after orthodontic treatment in our hospital between January 2018 and January 2019. Those patients were divided into a control group and an intervention group with 43 patients in each group using a random number table. The control group received traditional implant restoration, whereas the intervention group received 3D printing guide plate implant restoration. Treatment outcomes, cosmetic appearance, dental function, implant deviation, and quality of life were compared between the two groups.

RESULTS

The overall response rate in the intervention group was significantly higher than

that in the control group (95.35% *vs* 81.40%, χ^2 = 4.071, P = 0.044). The number of cases with neatly trimmed cosmetic appearance (χ^2 = 4.497, P = 0.034), complete coverage (χ^2 = 4.170, P = 0.041), and normal occlusion (χ^2 = 5.512, P = 0.019) in the intervention group was higher than that in the control group. After treatment, mastication, swallowing, and articulation were significantly improved in both groups. Masticatory (t = 2.980, P = 0.004), swallowing (t = 2.199, P = 0.031), and phonic functions (t = 3.950, P = 0.004) were better in the intervention group than those in the control group. The deviation value and the deviation angle (t = 5.440, P = 0.000) at the top (t = 6.320, P = 0.000) and middle parts of the implants (t = 22.295, P = 0.000) in the intervention group were lower than those in the control group after treatment. Functional limitations, psychosocial and physical pain and discomfort, and total scores decreased in both groups. The functional limitation (t = 2.379, P = 0.020), psychosocial (t = 2.420, P = 0.000), physical pain and discomfort (t = 6.581, P = 0.000), and total scores (t = 2.140, P = 0.035) were lower in the intervention group than those in the control group.

CONCLUSION

Orthodontic treatment combined with 3D printing guide plate implant restoration can significantly improve the masticatory and phonic functions, quality of life, and psychological health of patients with dentition defects. Therefore, it is highly recommended in clinic application.

Key Words: Dentition defect; Orthodontics; 3D printing guide plate implant restoration; Masticatory function; Phonic function

Core Tip: In the present prospective study, we included 86 patients with dentition defects who underwent implant restoration after orthodontic treatment at our hospital between January 2018 and 2019. The patients were divided into two groups using a random number table: the patients in the control group were treated with implant prosthesis, and those in the intervention group were treated with 3D printing guide plate implantation. In terms of oral function after treatment, the patients in the intervention group had significantly better chewing, swallowing, and phonic functions than those in the control group. The above results demonstrate that the consistency of the implant with the body was significantly improved after 3D printing guide plate implantation, which had a positive effect on muscle strength recovery at the local lesions. The results of the present study support 3D printing guide plate implantation in routine clinical use.

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INTRODUCTION

Dentition defects is one of the most common oral diseases in clinical practice. Progression of this disease causes not only masticatory dysfunction and articulation difficulties but also aesthetic damage, seriously disturbing people's quality of life[1]. Furthermore, the ability to chew foods at the lesions is markedly reduced, which increases the intestinal burden among patients[2]. Long-term dentition defects also leads to compensatory ptosis of the corner of the mouth, deepening of wrinkles, and other marked changes in appearance. Currently, restorative treatment is the primary method used to fix dentition defects. Through such treatment, oral function and aesthetics of patients can be effectively improved. However, there is a gap between the conventional implant prosthesis and the receptor, resulting in lower reliability of the prosthesis[3] impeding the occlusal recovery of the body[4]. Moreover, in patients with long-term edentulism, the adjacent teeth on both sides tilt to a certain extent, thereby presenting challenges to the denture repair. A study found that implantation aided by 3D printing guide plate can improve the reliability of prosthesis[5]. This study analyzed the effect of orthodontic treatment combined with 3D printing guide plate implantation in dentition defects in an effort to provide scientific verification for its clinical application.

MATERIALS AND METHODS

Clinical data

This prospective study enrolled 86 patients with dentition defects who underwent implant restoration after orthodontic treatment at our hospital between January 2018 and 2019.

The inclusion criteria were as follows: (1) receiving treatment with orthodontics and desire for a fixed denture restoration; (2) no retention value among all residual teeth in the dentition defects; and (3) signing the informed consent. The exclusion criteria were as follows: (1) severe cardiovascular and cerebrovascular diseases; (2) cognitive dysfunction; (3) inability to perform in this study; and (4) intolerance to the implants or restorations used in this study. This study was approved by the Ethics Committee of our institution.

Methods

All patients were given an oral health examination. According to the imaging data, orthodontic treatment was adopted, and straight-wire technique or edgewise archwire fixation technique was opted for treatment. By observing the dislocation and inclination of teeth, the tooth space was adjusted in time to correct the lesion occlusion relationship. The patients in the control group received implant restoration: it was carried out in time based on the severity of dentition defects. Before operation, their oral cavity and surrounding skin were disinfected, sterile swabs were laid, and lidocaine (2% concentration) was administered for local anesthesia. Under the action of the guide plate, L-shaped or H-shaped incision was made on the periosteum and bone surface at the implantation point. After fully exposing the alveolar bone, drilling on the top of the alveolar ridge was performed, and the implant restoration was carried out by the imaging characteristics. After the operation, normal saline was used to clean the lesion and bleeding is stopped. After placing appropriate screws, soft tissues were sutured. Patients were given antibiotics routinely after operation, and the sutures were removed 7-10 d after operation.

Patients in the intervention group were treated with 3D printing guide plate implant restoration. Their lesions were scanned with computed tomography (CT) before operation. The model data of the patients were obtained using a 3Shape D700 series scanners from the United States. The occlusal relationship was simultaneously recorded using cone-beam CT and rubber molding. Occlusal rim was adopted for patients without malocclusion. After the relationship between the length, direction, and position of the implant was clear, the aforementioned data were imported into the 3D tool again for 3D reconstruction, and the preoperative plaster cast was confirmed using a laser scanner. The implant guide plate was prepared simultaneously based on real-time data registration during data reconstruction. Thereafter, the implant restoration was completed. Routine antibiotic treatment was administered postoperatively.

Outcome measures

Efficacy: The efficacy was compared in the two groups after surgery. When the dentition defect was repaired and there was no difference in the physiological function and color between the local lesions and normal tooth condition, the treatment was considered significantly effective. When the dentition defect was roughly repaired and there was a slight difference in the physiological function and color between the local lesions and normal tooth condition, the treatment was considered effective. When the dentition defect was not effectively repaired and there was a significant difference in the physiological function and color between the local lesions and normal tooth condition, the treatment was considered ineffective. The overall response rate was calculated as follows: (effective + significantly effective)/(total number of cases)[6].

Cosmetic appearance: Alignment, complete coverage, and occlusal normality after treatment were compared between the two groups.

Dental function: The masticatory, swallowing, and phonic functions were compared between the two groups before and six months after treatment. These variables were rated using a 5-level Likert scale, with higher scores indicating better outcomes[7].

Implant deviations in the 3D plane: Six months after treatment, CT was performed in both groups, and the data were inputted into the 3D tool for 3D reconstruction. The deviation values and the deviation angles at the top and middle parts of the implants were compared between the two groups.

Quality of life: The quality of life of patients was evaluated before and 6 mo after treatment using the Oral Health Impact Profile for Supported Partial Prostheses[8]. It was rated through the evaluation of the functional limitation, social interaction, and physical pain and discomfort of the patients. Higher scores it obtained, worse quality of life was among patients.

Statistical analysis

Data was analyzed using the SPSS 19.0 in this study, in which measurement data were measured as

Table 1 Comparison of the general data between the groups

Group	Sex (male/female)	Dentition defects (full mouth/upper/lower)	Body mass index (kg/m^2)	Age (yr)
Control group (n = 43)	20/23	8/12/23	24.83 ± 2.24	45.60 ± 3.26
Intervention group (n = 43)	22/21	9/18/16	24.97 ± 2.22	45.74 ± 4.37
χ^2/t value	0.186	2.515	0.291	0.168
P value	0.667	0.284	0.772	0.867

mean ± SD. An independent sample t-test was also conducted. Enumeration data were expressed as n (%), and comparison between groups were made by χ^2 test. $P < 0.05$ indicated statistical significance.

RESULTS

General data

There were 44 women and 42 men aged 36-61 years (average age: 45.67 ± 3.83 years). The average body mass index (BMI) was 24.90 ± 2.22 kg/m^2. Seventeen patients had complete perioral dentition defect, 30 had lower tooth losses, and 39 had upper tooth losses. The patients were divided into two groups using a random number table; each group included 43 patients, and there was no significant difference in the types of dentition defect, sex, age, or BMI between the groups ($P > 0.05$) (Table 1).

Treatment effects

The overall response rate of the intervention group was significantly higher than that of the control group (95.35% *vs* 81.40%, $\chi^2 = 4.071$, $P = 0.044$). Further details are provided in Table 2. Pictures of typical cases are shown in Figure 1.

Cosmetic appearance

The number of cases with neatly arranged cosmetic appearance ($\chi^2 = 4.497$, $P = 0.034$), complete coverage ($\chi^2 = 4.170$, $P = 0.041$), and normal occlusion ($\chi^2 = 5.512$, $P = 0.019$) was significantly higher in the intervention group than that in the control group. Further details are provided in Table 3.

Dental function

Before treatment, swallowing, masticatory, and phonic functions did not significantly differ between the groups ($P > 0.05$). After treatment, masticatory, swallowing, and phonic functions significantly improved in both groups. The masticatory ($t = 2.980$, $P = 0.004$), swallowing ($t = 2.199$, $P = 0.031$), and phonic functions ($t = 3.950$, $P = 0.004$) were significantly better in the intervention group than those in the control group. Further details are provided in Table 4.

Implant deviations in the 3D plane

The deviation values and the deviation angle ($t = 5.440$, $P = 0.000$) at the top ($t = 6.320$, $P = 0.000$) and middle parts of the implants ($t = 22.295$, $P = 0.000$) in the intervention group were significantly lower than those in the control group (Table 5).

Quality of life

Before treatment, functional limitation, psychosocial and physical pain and discomfort, and total scores did not significantly differ between the groups ($P > 0.05$). After treatment, functional limitation, psychosocial and physical pain and discomfort, and total scores decreased in both groups. Functional limitations ($t = 2.379$, $P = 0.020$), psychosocial ($t = 2.420$, $P = 0.000$), physical pain and discomfort ($t = 6.581$, $P = 0.000$), and total scores ($t = 2.140$, $P = 0.035$) were significantly lower in the intervention group than in the control group. Further details are provided in Table 6.

DISCUSSION

Dentition defect is a prevalent oral disease, and related research has found that nearly 60% of the patients with such disease will develop dental malformation, aggravating the case, which can cause a vicious spiral[9]. Orthodontic treatment before implantation can alleviate malocclusion and jaw malformation, make the mouth more desirable, and maintain the normal physiological alignment between the implant and the normal teeth in the mouth for a longer time. However, implants can only repair dentures, which makes it difficult to improve the beauty and function of teeth in the mouth. If

Table 2 Comparison of the treatment effect between the groups, *n* (%)

Group	Significantly effective	Effective	Ineffective	Overall response rate
Control group (n = 43)	15 (34.88)	20 (46.51)	8 (18.60)	35 (81.40)
Intervention group (n = 43)	25 (58.14)	16 (37.21)	2 (4.65)	41 (95.35)
χ^2/U value	2.391			4.071
P value	0.014			0.044

Table 3 Comparison of the cosmetic appearance between the groups, *n* (%)

Group	Neatly trimmed cosmetic appearance	Complete coverage	Normal occlusion
Control group (n = 43)	30 (69.77)	29 (67.44)	25 (58.14)
Intervention group (n = 43)	38 (88.37)	37 (86.05)	35 (81.40)
χ^2 value	4.497	4.170	5.512
P value	0.034	0.041	0.019

Table 4 Comparison of the dental function between the groups (mean ± SD)

Group	Masticatory function		Swallowing function		Phonic function	
	Before	After	Before	After	Before	After
Control group (n = 43)	1.91 ± 0.29	3.09 ± 0.43	2.65 ± 0.48	3.63 ± 0.54	2.56 ± 0.98	3.26 ± 0.98
Intervention group (n = 43)	1.98 ± 0.27	3.37 ± 0.49	2.67 ± 0.47	3.86 ± 0.41	2.58 ± 0.59	3.97 ± 0.64
t value	1.154	2.821	0.225	2.255	0.133	4.052
P value	0.252	0.006	0.822	0.027	0.894	0.000

Table 5 Comparison of the implant deviations in the three-dimensional plane between the groups (mean ± SD)

Group	Top (mm)	Middle (mm)	Angle (°)
Control group (n = 43)	1.66 ± 0.97	1.51 ± 0.28	2.95 ± 1.23
Intervention group (n = 43)	0.54 ± 0.34	0.43 ± 0.15	1.78 ± 0.69
t value	7.122	22.295	5.440
P value	0.000	0.000	0.000

Table 6 Comparison of the quality of life between the groups (mean ± SD)

Group	Functional limitation		Physiological pain and discomfort		Psychological and social		Total score	
	Before	After	Before	After	Before	After	Before	After
Control group (n = 43)	3.70 ± 1.52	1.70 ± 0.96	2.37 ± 1.57	1.21 ± 0.41	3.26 ± 1.54	1.56 ± 0.98	9.33 ± 2.54	4.47 ± 1.32
Intervention group (n = 43)	3.74 ± 1.38	1.21 ± 0.68	2.33 ± 1.32	0.65 ± 0.48	3.21 ± 1.77	1.09 ± 0.75	9.28 ± 2.48	2.95 ± 1.11
t value	0.148	2.721	0.148	5.773	0.130	2.466	0.086	5.755
P value	0.882	0.008	0.882	0.000	0.897	0.016	0.932	0.000

implant restoration is directly implemented, it may expose the patients to the unfavorable implants and aesthetics, and reduce the repair effect because of abnormalities such as the loss of anterior teeth. Therefore, orthodontic treatment before implantation can potentially improve the outcomes of subsequent implant repair[10]. In the treatment of patients with dentition defects, an implant guide plate constitutes a pivotal part in the treatment of multiple missing teeth and poor alveolar bone[9]. Implant guide plates play a considerable guiding role, particularly for doctors with little experience.

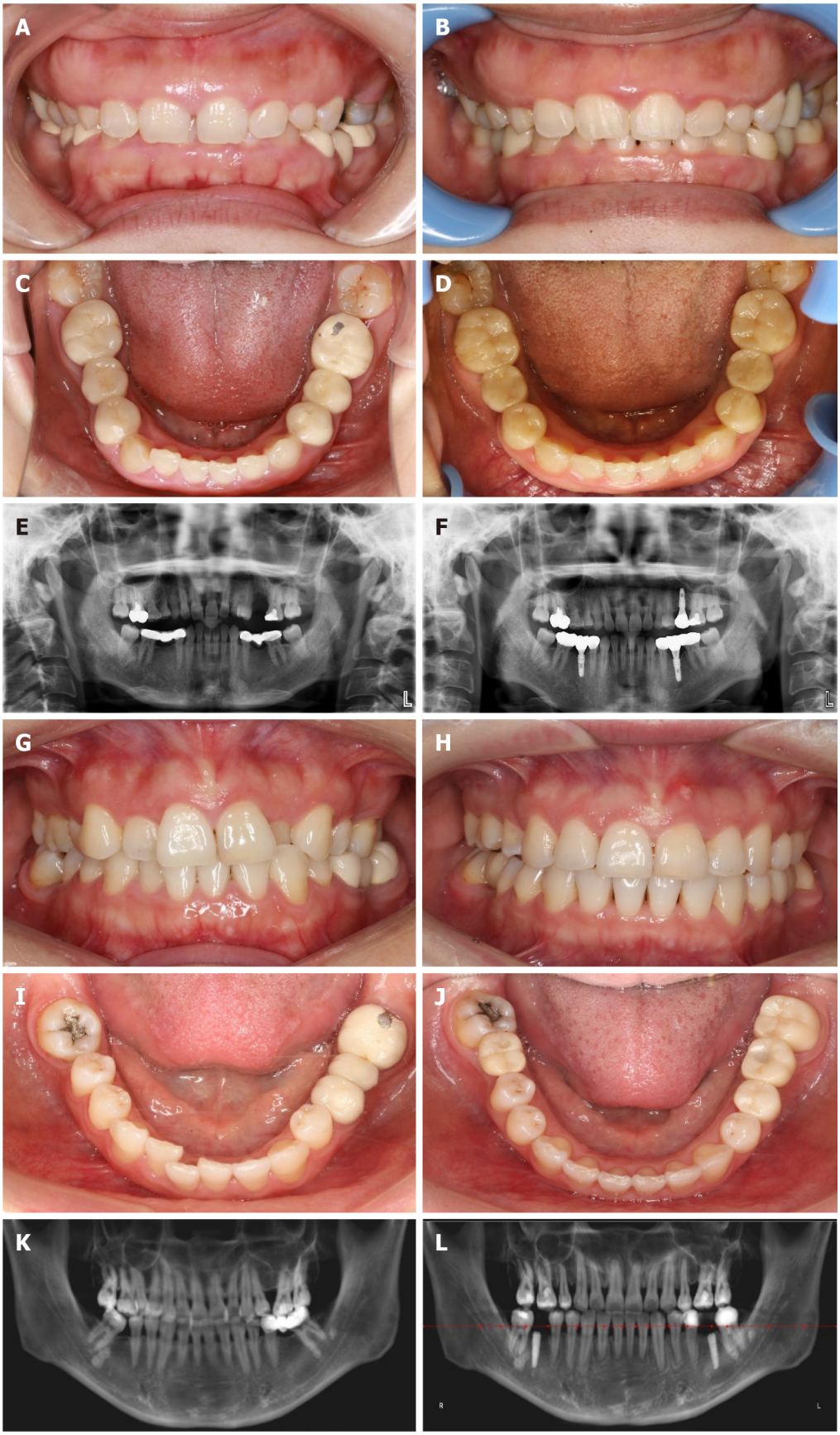

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Figure 1 Comparison of the treatment effect between the groups. A: Preoperative frontal images of patients in the control group; B: Postoperative frontal images of patients in the control group; C: Preoperative occlusal images of patients in the control group; D: Postoperative occlusal images of patients in the control group; E: Preoperative panoramic radiography of patients in the control group; F: Postoperative panoramic radiography of patients in the control group; G: Preoperative frontal images of patients in the intervention group; H: Postoperative frontal images of patients in the intervention group; I: Preoperative occlusal images

of patients in the intervention group; J: Postoperative occlusal images of patients in the intervention group; K: Preoperative panoramic radiography of patients in the intervention group; L: Postoperative panoramic radiography of patients in the intervention group.

Therefore, in the course of implant application, the selection of an appropriate implant guide plate plays a decisive role[10]. The fabrication of implant guide plates has many advantages, and plaster casts are routinely used for their preparation. Although the fabrication process is simple, there have been few analyses of the internal bone tissue structure of the edentulous sites. After implantation, the risk of implant deviation increases markedly[11]. Simultaneously, it is necessary to rely on clinical experience during implantation[12]. During this process, the matching accuracy of the model and tooth may be insufficient owing to the use of the vacuum-formed pressure film technology. During model preparation, it was necessary to rotate the model repeatedly. This process may increase the unreliability of the implant guide plate and further enlarge the offset after treatment. With the continuous clinical application of 3D technology, the anatomical position of the dentition defect site is fully considered in the preparation of the model and its accuracy is greatly improved.

In this study, we found that the efficacy in the intervention group was better than that in the control group, and the aesthetics also significantly improved. In the treatment of dentition defects, a substantial inflammatory response inevitably occurs in the alveolar bone of the lesion site, which is markedly destructive to both the bone surface and the periosteal structure. A meta-analysis of studies comparing the clinical outcomes of denture restorations and implants for the treatment of edentulism showed that implant restorations are more effective in the treatment of edentulism than dentures[13]. However, challenges still exists. During implant restoration, the mismatch between the implant and anatomical position of the body[14] causes tooth wear in the gingival and oral tissues[15], and the continuous inflammatory response in gingival tissues[16] further damages the local aesthetics[17]. Involuntary muscle spasms can also be caused by mismatched implant restorations[17], and abnormal changes in appearance can occur as the disease progresses[18]. Complications, due to unpredictability such as pulpal necrosis, root resorption, loosening, and loss of teeth are often observed after dental implantation that therefore not often promoted clinically[19]. In this study, the deviation values at the top and middle parts of the implants in the intervention group were lower than those in the control group, which also confirmed the significant advantage of 3D printing guide plate implantation[20]. In a comparative study of traditional and 3D-printed implant plates, Suo *et al*[21] showed that 3D-printed implant plates had a significant accuracy advantage in the treatment of patients with dentition defects.

In terms of dental function after treatment, the masticatory, swallowing, and phonic functions of the intervention group were significantly better than those of the control group in our study, suggesting that with the use of 3D printing guide plate implantation, the matching of implants to the body is markedly improved, which has a positive role in the recovery of muscle strength at the local lesions. In addition, the quality of life of the intervention group was significantly higher than that of the control group, showing that through the improvement of the tooth function and aesthetics of the patients, the use of 3D printing guide plate implantation has a positive role in improving the quality of life of patients after surgery.

In summary, following the orthodontic treatment combined with 3D printing guide plate implant restoration in patients with dentition defects, the masticatory and phonic functions of the patients significantly improved, so did the quality of life and psychological health. On the basis of these findings, 3D printing guide plate implantation is recommended for clinical application.

CONCLUSION

To sum up, we have confirmed the significant advantages of 3D printing guide plate implantation, including significant recovery of muscle strength, significant improvement in oral function and quality of life, and a more aesthetic facial appearance in patients at the local lesion site 3D printing guided implant reconstruction is conducive to improving masticatory and phonic functions, and is recommended for clinical application.

ARTICLE HIGHLIGHTS

Research background

Dentition defects are among the most common oral diseases in clinical practice. Progression of this disease causes not only masticatory dysfunction and articulation difficulties but also aesthetic damage among patients, seriously affecting their quality of life.

Research motivation

There exists a gap between the conventional prosthesis and the body, resulting in a decrease in the reliability of the prosthesis, consequently impacting the recovery of the occlusal relationship of the body.

Research objectives

This study aimed to investigate the influence of orthodontic treatment combined with 3D printing guide plate implantation on masticatory and language functions in patients with dentition defects.

Research methods

The study included 86 patients with dentition defects who were divided into two groups using a random number table, with each group including 43 patients. The control group received traditional implant prosthesis, whereas the intervention group received 3D printing guide plate implantation.

Research results

In terms of dental function after treatment, the masticatory, swallowing, and phonic functions of the intervention group were significantly better than those of the control group.

Research conclusions

Orthodontics combined with 3D printing guide plate implant restoration can significantly improve the masticatory and language functions of patients with dentition defects.

Research perspectives

The results of this study on orthodontics combined with 3D printing guide plate implant restoration will lay the foundation for further clinical utility of this method.

FOOTNOTES

Author contributions: Yan LB contributed to methodology and writing - original draft preparation; Zhou YC contributed to software and validation; Wang Y contributed to data curation and investigation; Yan LB and Li LX contributed to data curation and investigation; Li LX contributed to supervision; and all authors have read and agreed to the published version of the manuscript.

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