Clinical effectiveness and influential factors of maxillary rehabilitation with zygomatic implant following tumor resection

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ABSTRACT

الأهداف: تقييم الأثر الطبي والعوامل المؤثرة على إعادة تأهيل الفك العلوي مع زرع الوجني والجراحة الترقيعية بعد استئصال الورم.

الطريقة: تم اختيار 36 مريض بأثر مستقبلي مصاب بتشوهات الفك العلوي وتم علاجه بالزرع الوجني والجراحة الترقيعية لإعادة تأهيل الفك العلوي في قسم طب الأسنان بمستشفى محلي خلال الفترة من مارس 2007م حتى مايو 2010م. تم قياس كلاً من وضوح الكلام، وكفاءة المضغ قبل وبعد إعادة التأهيل في الشهر الأول، و 6، و12، و24 شهر. كما تم تحليل العلاقات بين العوامل التالية التواصل الفموي الأنفي، واستئصال شق الحنك، والحنك الرخو، والأسنان المثبتة وقيمة وضوح الكلام. كما تم تحليل العلاقات بين العوامل التالية: التواصل الفموي الأنفي، والأسنان المزروعة، وكمية تشوه الفك العلوي، ورجعة الورم، وقيمة الإمتصاص.

النتائج: ارتفعت قيمة الإمتصاص ووضوح الكلام بعد إعادة التأهيل في الشهر الأول، السادس، و12، و24 بشكل أعلى أكثر من قبل إعادة التأهيل (p<0.05). أظهر تحليل الانحدار الخطي فعالية أثر التواصل الأنفي الفموي على قيمة وضوح الكلام قبل إعادة التأهيل (p<0.05)، بينما كان هنالك أثر إحصائي لاستئصال الحنك الرخو بعد إعادة التأهيل (p<0.05). أظهرت النتائج كذلك أن التواصل الفموي الأنفي أثر مهم على قيمة الامتصاص قبل إعادة التأهيل (p<0.05) بينما تشوهات الفك العلوي له أثر مهم بعد إعادة التأهيل (p<0.05).

خاتمة: أن الزرع الوجيني والجراحة الترقيعية لها دور في تحسين فعالية الدور اللفظي والمضغي وتحسين جودة حياة المرضى الذين خضعوا لاستئصال الورم الفكي العلوي. لهذا، يعد الزرع الوجيني والجراحة الترقيعية علاج فعال لتشوهات الفك العلوي الناتج من استئصال الورم.

Objectives: To evaluate the clinical effectiveness and influential factors of maxillary rehabilitation with zygomatic implant and prosthesis after tumor resection.

Methods: Thirty-six patients with maxillary defects were collected prospectively in this study and received zygomatic implant and prosthesis for maxillary rehabilitation in the Department of Stomatology of the Municipal Hospital, Taizhou, Zhejiang, China from March 2007 to May 2010. The speech intelligibility (SI) and masticatory efficiency of pre-rehabilitation and post-rehabilitation at one, 6, 12, and 24 months were measured. The relationships between the following factors (oro-nasal communication, hard-palate resection, soft-palate resection, retention teeth) and SI value were analyzed. The relationships between the following factors (oro-nasal communication, retention teeth, the extent of maxillary defect, tumor recurrence) and absorbance value were analyzed.

Results: The SI values and absorbance values of post-rehabilitation at one, 6, 12, and 24 months were higher than that of pre-rehabilitation values (p<0.05). Linear regression analysis revealed that oro-nasal communication had a highly significant influence on the SI value of pre-rehabilitation (p<0.05), while soft-palate resection had a highly significant influence on that of post-rehabilitation (p<0.05). Oro-nasal communication had a highly significant influence on the absorbance value of pre-rehabilitation (p<0.05), while maxillary defect had a highly significant influence on that of post-rehabilitation (p<0.05).

Conclusion: Zygomatic implant and prosthesis improved the near and long-term effectiveness of phonetic and masticatory function, and elevated life quality of patients with maxillary tumor resection. Zygomatic implant and prosthesis are an effective rehabilitation remedy for maxillary defects resulting from tumor resection.

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The maxillary skeletal structure is important to the form of the oral cavity proper, and the face, and function. Maxillary tumor resection, congenital diseases, and injuries are the common reasons that result in a maxillary defect. Maxillary defects, especially severe defects, will result in facial collapse, and oro-nasal communication, and physiological function including pronunciation, mastication, and swallowing will be damaged or even lost.[1] Severe oro-facial malformation and dysfunction will influence physical and mental health, and quality of life. The functional rehabilitation of maxillary defect includes surgical rehabilitation, and prosthesis rehabilitation; for example, adopting the free composite flap combined with dental implant technology. The advantages of prosthesis rehabilitation are fast, simple, easy to repair, the match of shape and color, and so forth, and it is still the main method for rehabilitation of a maxillary defect.[2] However, it alone cannot provide the conditions of good retention for the prosthesis to achieve the desired outcomes. Adopting an implant and prosthesis approach to rehabilitate the maxillary defect could be a potent rehabilitation remedy for maxillary defects. As reported, the long-term survival rate of a zygomatic implant is very high,[3-6] and it can effectively improve the bearing force and retention for prosthesis.[7-9] In particular, the zygomatic implant prosthesis provides a meaningful choice for severe absorption and maxillary bone defects resulting from tumor resection.[10-12] However, there are limited reports on the study of the physiological function of maxillary rehabilitation with zygomatic implant and prosthesis after tumor resection, and its influential factors remain unsure. Therefore, we studied the rehabilitated maxillary defects of patients following tumor resection using zygomatic implant and prosthesis, and evaluated the clinical effectiveness (speech intelligibility [SI] and masticatory efficiency pre-rehabilitation and post-rehabilitation) and its influential factors.

Methods.

Clinical materials. Thirty-six cases with maxillary defects after tumor resection were chosen prospectively in the Department of Stomatology of the Municipal Hospital, Taizhou, Zhejiang, China from March 2007 to May 2010. Seventeen cases were male and 19 female with an age range of 18-66 years, average 47.6 years. The cases included 17 cases of maxillary chondrosarcoma, 6 cases of mucoepidermoid carcinoma, 8 cases of adenoid cystic carcinoma, 3 cases of gingiva cancer, 1 case of lymphoepithelial carcinoma and 1 case of undifferentiated carcinoma. Twenty-nine cases were attending the Institute of Maxillofacial Surgery for maxillary tumor resection, 7 patients were attending outside the hospital for tumor resection. The zygomatic implant prosthesis was used to rehabilitate the maxillary defects for all patients, and post-operative follow-up continued for more than 2 years. Three patients had tumor recurrence during the follow-up period, 2 of the patients subsequently died. The ethics review board of our hospital approved the study design. The written informed consent was obtained from each of patient.

Selection criteria and classification. The inclusion criteria comprised: more than 6 months after tumor resection of maxilla, more than one month after rehabilitation of the zygomatic implant and prosthesis; oro-nasal communication; integrity of the posterior edge of the soft palate; normal intelligence, no significant hearing impairment, fluent in Mandarin; not receiving speech therapy. The patients were classified according to Aramany Classification:[13] Class I: unilateral maxillary resection; Class II: one-fourth maxillary resection; cClass III: maxillary central defect; Class IV: most of the maxillary defect is across the middle route; Class V: maxillary posterior defect; and Class VI: maxillary anterior defect.

Rehabilitation methods. Rehabilitation was carried out by pre-operative CT imaging technology to plan the implanting direction, depth, and location of zygomatic implants. Two to 3 pieces of zygomatic implants were implanted into the zygoma through the slits of the maxillary sinus, combined with implantation of 2-3 pieces of standard length front teeth dental implants. After the 6 month period of osseointegration, the combination of zygomatic implants and zygoma, with ring-shaped brackets connecting the implants, supplemented by magnetic attachments technology, comprised the fixed prosthesis for patients.

Speech intelligibility test. 1) The test word list: Word list for Chinese SI testing,[14] containing 100 characters, including all Chinese common syllables and less common syllables. 2) Test method: it was recorded in the studio, when patients pronounced while sitting up straight in a natural relaxed state, approximately 5 cm from the microphone, following the prompts to read verbatim. 3) The judge method: in the studio, 5 untrained people judged the collected recording, and they recorded the correct verbatim by the voice that they heared, then checked the results using a standard word table. They checked the results using a standard word table, they calculated their respective percentage of correct words, and the final results of the SI test were the average of the 5 judges records.

Related factors affecting speech intelligibility. 1) Oral and nasal cavity communication: the oral and unilateral

nasal communication (n=25); the oral and bilateral nasal communication (n=11). 2) The extent of hard-palate resection: less than half underwent hard-palate resection (n=16); half palate resection (n=13); more than half hard-palate resection (n=7). 3) The extent of soft-palate defects: no soft-palate defects (n=14), with soft-palate defects (n=22). 4) Retention teeth: no retention teeth (n=5); 1-2 retention teeth (n=9); 3 or more retention teeth (n=22).

Masticatory function test. Masticatory efficiency was measured pre-rehabilitative and post-rehabilitative at 1, 6, 12, and 24 months. The specific measuring method was as following: 2g sweet almonds were roasted in a 70 incubator and then packed. The patients used mouthwash before each test, cleaning the oral cavity and prosthesis to ensure no food residue inside the mouth. There was a 3-5 minute test interval to allow patients to have a break, and each patient was tested twice pre-rehabilitative and post-rehabilitative. The time for chewing the sweet almond was 30 seconds, spiting the residues after chewing into a cup, and rinsing over and over again until cleaning. The distilled water was added to the expectoration until diluted to one liter. This was then stirring with a glass rod for one minute, and held for 2 minutes. Five ml of the suspension at one-third cup was imbibed and placed into 722 grating spectrophotometer. After adjusting the wavelength to 590 nm, the absorbance readings were recorded.[15]

Related factors affecting masticatory function. 1) Oral and nasal cavity communication: oral and unilateral nasal communication (n=25); oral and bilateral nasal communication (n=11). 2) Retention teeth: no retention teeth (n=5); 1-2 retention teeth (n=9); 3 or more retention teeth (n=22). 3) The extent of maxillary defect: class I (n=10), class II (n=2), class III (n=1), class IV (n=10), class V (n=6), class VI (n=7); 4) tumor recurrence.

Statistical analysis. The SI and masticatory efficiency pre- and post-rehabilitative at one, 6, 12, and 24 months was compared using the one-way ANOVA test. The correlations between SI values, absorbance, and factors were analyzed using Spearman Bivariate Correlation. The correlations between the synthetic action of various factors and SI values, and absorbance values were analyzed using linear regression. Statistical analyses of data were generated using the Statistical Package for Social Science, version 15.0 (SPSS Inc., Chicago, IL, USA). All *p*-values were based on 2-tailed tests. A $p<0.05$ was considered as statistically significant.

Results. The SI and masticatory efficiency of pre-rehabilitation and post-rehabilitation at one, 6, 12, and 24 months. The mean SI values of post-rehabilitation at one, 6, 12, and 24 months were higher than that of pre-rehabilitation ($p<0.05$). The mean absorbance values of the masticatory efficiency of post-rehabilitation at one, 6, 12, and 24 months were higher than that of pre-rehabilitation ($p<0.05$). However, the masticatory efficiency of post-rehabilitative at 24 months was obviously decreased compared with that of post-rehabilitative at one, 6, and 12 months ($p<0.05$) (**Table 1**). The relationship between the SI values and the various influential factors before and after rehabilitation of the zygomatic implant prosthesis. Before the rehabilitation of zygomatic implant prosthesis, correlation analysis between the SI values and the influential factors displayed that there was a correlation between oro-nasal communication, hard-palate resection, soft-palate resection, and SI values ($p<0.05$) (**Table 2**). After rehabilitation, correlation analysis between the SI values and the influential factors displayed that there was a correlation between oro-nasal communication, soft-palate resection, and SI values ($p<0.05$) (**Table 2**). Under the integrated role of factors, linear regression

Table 2 - The correlation between the speech intelligibility value of pre- and post-rehabilitation and the factors.

Influencing factors	r	*P*-value
Oro-nasalcommunication	0.5390 (pre-)	0.0003
	0.4263 (post-)	0.0098
Hard-palate resection	0.5198 (pre-)	0.0012
	0.2195 (post-)	0.1923
Soft-palate resection	0.5307 (pre-)	0.0096
	0.5590 (post-)	0.0008
Retention teeth	0.1865 (pre-)	0.3617
	0.1379 (post-)	0.4088

Table 1 - The speech intelligibility (SI) values and absorbance values of pre-rehabilitation and post-rehabilitation.

Determination time	Pre-rehabilitation	Post-rehabilitation 1M	Post-rehabilitation 6M	Post-rehabilitation 12M	Post-rehabilitation 24M
SI values	41.3±10.6%	89.6±7.7%*	90.0±8.6%*	88.7±6.9%*	88.4±7.3%*
Absorbance values	0.1268±0.0203	0.5428±0.0304†	0.6303±0.0264†	0.6168±0.0217†	0.4412±0.0192†,#

Note: * or †representatives comparison with that of pre-rehabilitation, *(t=2.572, t=2.568, t=2.585, t=2.585, $p=0.014$, $p=0.012$, $p=0.015$, $p=0.015$, $p<0.05$, respectively); †(t=3.786, 4.581, 4.527, 3.587, $p=0.0006$, $p=0.0002$, $p=0.0003$, $p=0.0009$, $p<0.05$, respectively). # representatives comparison with that of post-rehabilitative 1M, 6M, 12M(t=2.226, t=2.408, t=2.357, $p=0.032$, $p=0.024$, $p=0.029$, $p<0.05$, respectively).

Table 3 - Linear regression analysis of the factors influencing the speech intelligibility (SI) value of pre- and post-rehabilitation.

Independent variable	Unstandardized Coefficients	Standard Error	Standardized Coefficients	t	*P*-value
Oro-nasalcommunication	-18.003 (pre-)	6.089	-0.605	-3.115	0.0035
	-2.912 (post-)	3.107	-0.094	-0.827	0.3735
Hard-palate resection	-2.993 (pre-)	4.780	-0.091	-0.775	0.6011
	-0.774 (post-)	2.787	-0.097	-0.443	0.7428
Soft-palate resection	-5.924 (pre-)	5.156	-0.173	-1.154	0.2698
	-25.131 (post-)	4.367	-0.847	-5.237	0.0007
Retention teeth	-4.593 (pre-)	4.142	-0.180	-0.873	0.3061
	-2.451 (post-)	3.015	-0.119	-0.978	0.5964
Dependent variable: the SI value of pre- and post-rehabilitation					

Table 4 - The correlation between the masticatory efficiency of pre- and post-rehabilitation and the factors.

Influencing factors	r	*P*-value
Oro-nasalcommunication	0.5170 (pre-)	0.0014
	0.4338 (post-)	0.0087
Retention teeth	0.5057 (pre-)	0.0017
	0.2609 (post-)	0.1602
The extent of maxillary defect	0.4364 (pre-)	0.0086
	0.5253 (post-)	0.0011
Tumor recurrence	0.1281 (pre-)	0.3617
	0.4360 (post-)	0.0758

analysis results displayed that the only oro-nasal communication significantly influenced the SI values of pre-rehabilitative patients (p<0.05) (**Table 3**); while only the soft-palate defect significantly influenced the SI values of post-rehabilitative patients (p<0.05) (**Table 3**).

Relationship of masticatory efficiency with the various influential factors before and after rehabilitation of zygomatic implant prosthesis. Before the rehabilitation of the zygomatic implant prosthesis, the correlation analysis between masticatory efficiency and influential factors displayed that there was a correlation between oro-nasal communication, retention teeth, the extent of maxillary defect, and the masticatory efficiency (p<0.05) (**Table 4**). There was also a correlation between oro-nasal communication, the extent of maxillary defect, and masticatory efficiency (p<0.05) (**Table 5**). The linear regression analysis results displayed that under the integrated role of influential factors, the oro-nasal communication and the extent of maxillary defect significantly influenced the masticatory efficiency of pre-rehabilitative patients (p<0.05) (**Table 4**). While only the extent of maxillary defect significantly influenced the masticatory efficiency of post-rehabilitative patients (p<0.05) (**Table 5**).

Discussion. Maxillary tumor resection is one of the common causes of maxillary bone defects. Because of the oro-nasal communication of patients with maxillary defects, it seriously affects the patient's physiological function and appearance; hence, the life quality of patients' decreased. Functional repair of maxillary defects is generally divided into surgical and prosthesis repair. Adopting a free composite flap combined with dental implant technology for functional reconstruction of maxillary bone defects is one of the important achievements of oral rehabilitation in recent years; however, there are difficulties for wide application nowadays. The advantages of prosthesis rehabilitation include: fast, simple, easy to repair, the match of shape and color, and so forth, and it is still the main method

Table 5 - Linear regression analysis of the factors influencing the masticatory efficiency of pre- and post-rehabilitation.

Independent variable	Unstandardized Coefficients	Standard Error	Standardized Coefficients	t-test	*P*-value
Oro-nasalcommunication	-13.924 (pre-)	5.856	-0.473	-2.354	0.0198
	-3.102 (post-)	2.978	-0.087	-0.872	0.4307
Retention teeth	-2.842 (pre-)	4.098	-0.083	-0.857	0.5986
	-2.553 (post-)	3. 103	-0.191	-0. 965	0.6012
The extent of maxillary defect	-17.036 (pre-)	5.894	-0.595	-3.251	0.0046
	-27. 311 (post-)	4. 558	-0.798	-5. 342	0.0021
Tumor recurrence	-4.395 (pre-)	3.912	-0.201	-0.938	0.2904
	-0.847 (post-)	2.384	-0.098	-0.534	0. 8273
Dependent variable: the SI value of pre- and post-rehabilitation					

for the rehabilitation of maxillary defects.[2] However, it alone cannot provide good retention conditions required by the prosthesis to achieve the desired outcomes. Adopting a combination therapy of zygomatic implant and prosthesis, approach to rehabilitate the maxillary defect, the long-term survival rate of zygomatic implant is very high. As reported, the long-term survival rate of zygomatic implant is very high,[3-6] and it can effectively improve the bearing force and retention for prosthesis.[7-9] In particular, the zygomatic implant-retained prosthesis provides a meaningful choice for severe absorption and maxillary bone defects resulting from tumor resection.[10-12]

Speech intelligibility is a sensitive index for comprehensive evaluation of the voice, to analyze the patient's abilities and characteristics of pronunciation. In this study, by judging the voice samples of 36 cases of maxillary defects after tumor resection, we found that after rehabilitation at one, 6, 12, and 24 months, the mean SI values were higher than that of pre-rehabilitation ($p<0.05$), indicating that zygomatic implant prosthesis could better recover the voice capabilities of patients. Arigbede et al[16] reported significant improvements in the mean SI score of 12 cases from 59.8% without prosthetic obturation, to 89.2% following interim obturation, and 94.7% following definitive obturation ($p<0.005$). Moreover, SI is affected by the class of defect. There was an improvement in the SI score from class I to class VI surgical defects without obturation, after insertion of the interim obturator, and after insertion of the definitive obturator. The results of this study were slightly lower than that, and this may be the characteristic of Chinese as it has 4 tones and the difference between English and Chinese languages.

This study showed that, by a single factor analysis, there was a correlation between oro-nasal communication, soft-palate resection, and the SI value of post-rehabilitation. While by multiple regression analysis, the soft-palate defect was one of the major factors affecting the post-rehabilitative SI. Rieger et al[17] also reported that the restoration of the voice function in patients with soft-palate defects, was significantly worse than the defect of patients confined to the hard-palate. This result suggested that in maxillary resection, retaining the soft-palate tissue, would facilitate the functional recovery of post-operative prosthesis repair.

Masticatory efficiency can directly reflect the chewing ability of patients; there are many determination methods of masticatory efficiency, for example, the gravimetric method, absorption spectrophotometry, chemical colorimetry, and automated particle analysis. Absorption spectrophotometry is a more reliable method. When defects of the maxilla occur, the tooth units, which directly support the masticatory function reduces and oro-nasal communication leads to overflow food though the nasal cavity; therefore, it seriously affected the patient's masticatory function. Our results indicated that after rehabilitation at one, 6, 12, and 24 months, the masticatory efficiency was higher than that of pre-rehabilitation ($p<0.05$). It indicated that the zygomatic implant prosthesis could aid in recovery of the masticatory function of patients. Its mechanism may be that the zygomatic implant prosthesis rehabilitation of the maxillary defect not only closed the oro-nasal fistula, but more importantly was effective in improving the bearing force and retention of the prosthesis. However, the masticatory efficiency of post-rehabilitation at 24 months was obviously decreased compared with that of post-rehabilitation at one, 6, and 12 months when there were significant differences. This maybe due to: firstly, the range of maxillary tumor resection was too big, with less remaining zygomatic process and cheekbones, the disadvantages of the implant being located in the defect cavity were difficulties in cleaning, taking or wearing of the prosthesis. Moreover, the length axis of implant could not keep consistent with the direction of occlusal force, and it is to be a big angle, the occlusal force directly passed to implant by side, leading to a larger lever on implant. This may cause bone organization trauma around the implant and affect its long-term effect.[18-20] Secondly, owing to poor self-cleaning function after rehabilitation, over time, the prosthesis oppressed the local soft or hard tissue leading to continuous absorption and conversion, causing worsening of the long-term retention of the prosthesis and decreased masticatory function. Third, tumor recurrence leads to destruction of the maxillary structures, which might also result in worsening of the zygomatic implant and retention of prosthesis, and thereby affecting chewing function.

This study showed that by a single factor analysis, there was a correlation between oro-nasal communication, the extent of maxillary defect, and the post-rehabilitative masticatory efficiency. While by linear regression analysis, under the integrated role of the factors, the extent of maxillary defect was one of the major factors affecting the post-rehabilitative masticatory efficiency.

Study limitations. The study sample was small, and whether or not cancer recurrence and chemo-radiotherapy affect the zygomatic implants and the retention of prosthesis, which then affects masticatory function after zygomatic implant rehabilitation. Still needs further study.

This study observed that due to the use of zygomatic implants, part of the maxillary lateral loads through the zygomatic implant directly conducted to the cheekbone, and restored the pillar role of the zygomatic process.

But the deficiency of the force conduction of canine tooth areas while the stress focus to this canine tooth areas. Therefore, rehabilitating the canine pillar plays a key role in further optimizing the conduction of the masticatory force, if this area were supported by a flap or implant. This indicates that we should as far as possible, reconstruct the mechanical pillar of patients with maxillary defects, especially the canines, and zygomatic process pillar.

The zygomatic implant and prosthesis could not only close the oro-nasal communication to reconstitute the form of the oral cavity proper, and the face, but effectively enhanced the bearing force and retention for the prosthesis, and improved the near and long-term efficacy of the phonetic and masticatory function. It restored the shape of the oral cavity and physiological function of the face, and elevated the quality of life for the patients with maxillary tumor resection. Therefore, rehabilitation of the zygomatic implant and prosthesis has important clinical value.

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