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A Computed Tomographic Study of the Bonwill Triangle for the Taiwanese Population.
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Editorial

Greetings to the 30th anniversary of the Academy of Prosthetic Dentistry, R.O.C. The glory of self-improvement in efforts, wisdoms, and expectation of all prosthodontists, furthermore with strong faith and pride accomplishes tremendous growing developments over the 30 years. As the founder member, I am honored to be the committee member and dedicate my best to the Academy.

There are no short cuts to success. It accumulates in result of preparations, hard work, and learning from failure. Review the past helps one to understand the present. In this volume, three cases and two studies are deliberated. Within case reports, experiences may improve judgements. In place of studies, findings from experiences can assembled such measures and be attainable to the dental practices. These articles are worth of your reading and I am pleased to share this issue with you. At last, great appreciation to all participants and we look forward to more distinct articles may be beneficial to all prosthodontists in the future.

Hsiu-Na Lin
Editor-in-Chief

Original Article

A Computed Tomographic Study of the Bonwill Triangle for the Taiwanese Population

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Abstract

Purpose

The distances between the mandibular incisors and condyle or the distance between the right and left condyles are among the factors that affect the correct positioning of casts. Most dentists use the average value of the Bonwill triangle to position casts in an articulator if a face-bow is not used. However, there is some controversy as to whether the distance, as described by Bonwill, is consistent. The aim of this study, therefore, was to provide dentists with a reference value for the Bonwill triangle of the Taiwanese population for use in mounting casts in an articulator.

Material and methods

Ninety-nine computerized tomographic (CT) images of the heads of patients treated at China Medical University Hospital (48 females and 51 males; mean age: 40 years) were selected. The distance between the contact points of the mandibular central incisors' incisal edges and the central point of each condyle and the distance between the central points of both condyles were calculated using Mimics 10.01 software.

Results

The results showed that the distances between the mandibular incisors and the centers of the left and right condyles were 104 mm and 103 mm, respectively, while the distance between both condyles was 106 mm. Together, these distances approximately formed an equilateral triangle, as proposed by Bonwill, although the resulting triangle was slightly larger than that suggested by Bonwill. Also, while the length of the left side was slightly longer than that of the right side, the distance of both sides decreased with age above 30 years old, whereas the distance between the centers of the condyles increased with age until the age of 50 and then decreased.

Conclusion

This study showed that, among Taiwanese, the size of the Bonwill Triangle is larger for males and changes with age. The study also confirmed that the Bonwill triangle provides a feasible means of mounting casts in an articulator if a face-bow transfer cannot be employed.

Key words: Bonwill triangle, computerized tomographic (CT) images.

Introduction

An articulator is a mechanical tool for establishing the relationship between the upper and lower jaws outside the oral environment. The articulator simulates the patient's jaw movement and the position used by dentists to determine the occlusion of prostheses[1-3].

The Bonwill triangle was defined as a four-inch equilateral triangle with two sides connecting the contact points of the mandibular central incisors' incisal edges (or the midline of the mandibular residual ridge) to the midpoint of each condyle and one side connecting the condyles to each other. It was also suggested that the cusp angulation for complete dentures could be influenced by the size of this triangle. The Bonwill triangle was first described by William Gibson Arlington Bonwill in 1858, based on measurements of 6,000 skulls and 4,000 living persons. According to Bonwill, the length of each side, with few exceptions, is equal to 4 inches. However, various researchers have argued against the symmetry and correctness of the proposed figure. For example, Maggetti et al. used three-dimensional (3D) cone beam computed tomography (CBCT) scans of 120 arbitrarily selected individuals and found that the mean arm length of the Bonwill triangle was 103.3 mm, with a range of 90.2 mm (minimum) to 117.9 mm (maximum), and that the mean base length was 99.6 mm, with a range of 85.2 mm to 112.6 mm. There was a high correlation between the length of the left and right arms, but not between the arms and the base.

Although the theory of the average Bonwill triangle is often used in mounting casts to an articulator, significant occlusion errors in full mouth reconstruction cases have frequently been found. In such cases, the occlusion is complex and requires time-consuming adjustments. The consistency of the occlusal relationship of the cast in an articulator with that of the casts in a patient's mouth is affected by many factors, such as the 3D position of the casts, the choice of the anteroposterior reference point, the condylar and Bennett's inclinations, etc. Scholars have discussed these factors but have been unable to reach definite conclusions about them, and the average value of the Bonwill triangle has not been widely explored by measuring CT images for different ethnicities.

This study used CT images to measure the distances between the incisors and both condyles of the mandible and the distance between both condyles. The aim was to provide dentists with a reference value for the Bonwill triangle of the Taiwanese population for use in mounting casts in an articulator.

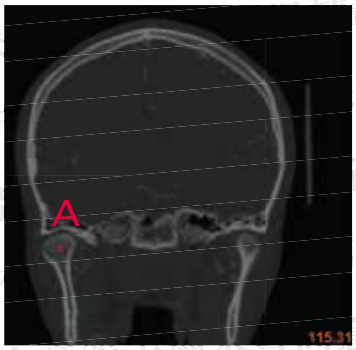
Material and methods

This study used CT images to measure the distances between the incisors and both condyles of the mandible and the distance between both condyles. The aim was to provide dentists with a reference value for the Bonwill triangle of the Taiwanese population for use in mounting casts in an articulator. The CT images were obtained (Light Speed, General Electric, Milwaukee, WI, USA) with the following technical parameters: 1.25-mm increments, 120 kV, 300–400 mAs, 240-mm field of view, and 512 × 512 pixels. All of the CT images were obtained between December 2007 and July 2009. The ethical issues of this study were approved by the institutional research board of China Medical University and Hospital. The measurements of the lengths between designated points were made according to the protocol described by Wu et al[4]. Briefly, before measuring, the coordinate system of each head was created in professional medical imaging software (Mimics 10.0, Materialise, Leuven, Belgium) using the "reslice" function, where the head was rotated first in the Frankfort horizontal (FH) plane parallel to the horizontal plane, followed by continued rotation with the head centered on the midsagittal plane of the image perpendicular to the FH plane (making the head face the anatomical frontal view). The coordinates of the slices in the frontal planes containing the longest condylar length were selected first and adjusted to coincide with the midpoint of the widest condylar width in the horizontal plane as points A and B shown in (Fig. 1). Meanwhile, the point where the mandibular central incisors first contacted in the horizontal plane is shown as point C in (Fig. 1).

The average values of the lengths between the lower incisor and condylar joint (IC-R and IC-L) and the right and left joints (C-LR) were calculated using the coordinates determined for the aforementioned 3 points. The distance between any two points in space was calculated using the formula shown below:

$$d \overset{\text{def}}{=} \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

Data were analyzed using the t-test and Wilcoxon signed-rank test in order to make comparisons between genders and the ANOVA and Kruskal-Wallis tests in order to make comparisons among age groups.



Coordinate:
X- 70.04, Y-124.45, Z-110.69

Coordinate:
X-180.18, Y-121.17, Z-111.83

Coordinate:
X-70.01, Y-124.89, Z-111.38

Coordinate:
X-180.31, Y-121.63, Z-112.00

Coordinate:
X-119.18, Y-65.97, Z-60.13

Fig. 1. Determinations of three points. A and B: midpoints coinciding both in the frontal and horizontal planes with the longest length and widest width. C: the point where the mandibular central incisors first contacted in the horizontal plane.

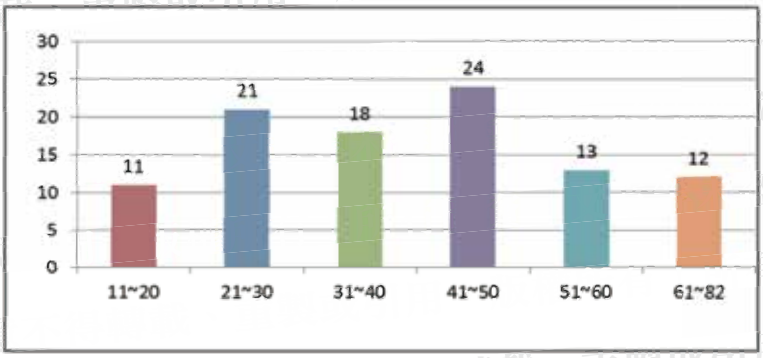


Fig. 2. Distribution of participants in different age groups.

Results

CT images from 99 Taiwanese subjects between 11 and 82 years of age, including 48 females and 51 males with a mean age of 40 years, were selected. The age distribution of the participants is shown in (Fig. 2). The measured lengths of the three sides of the Bonwill triangle for men and women, respectively, are shown in Table 1. The overall mean distance between the lower incisor and the center of the left condyle was 104 mm (IC-L; male: 107.3 mm; female: 100.6 mm), while that between the lower incisor and the center of the right condyle was 103 mm (IC-R; male: 106.1 mm; female: 100 mm). The differences between males and females for both the IC-L and IC-R were approximately 6 mm, with these differences being statistically significant.

The overall mean distance between the condyles on both sides (C-LR) was 105.9 mm. The difference between males (108 mm) and females (103.8 mm) was approximately 4 mm, with this difference also being statistically significant.

The measured lengths of the three sides of the Bonwill triangle for different age groups are shown in Table 2. The average measured lengths of the three sides of the Bonwill triangle in these Taiwanese subjects were roughly consistent with Bonwill's proposed equilateral triangle, although the lengths were 2 mm longer, on average, than the 4-inch sides proposed by Bonwill. The results of this study also indicated that the size of the Bonwill triangle changes with age.

While the mean triangle for these Taiwanese subjects was close to an equilateral triangle, the length of the left side was slightly longer than that of the right side (104 mmvs103 mm), although both of these distances decreased with age above the age of 30 (by about 1 to 2.5 mm per decade). In contrast, the length between the center points of both condyles increased with age until the age of 50 (from 101.9 mm to 107.8 mm), and then decreased (by about 1 to 1.4 mm per decade).

Table 1. Measured lengths for the three sides of the Bonwill triangle for males and females.

Sides	Gender	N	Mean ± SD	Median (Q1-Q3)	p-value[1]	p-value[2]
IC-L	F	48	100.62 ± 5.25	100.35 (97.52-103.23)	<.0001	<.0001
	M	51	107.32 ± 6.17	106.92 (103.86-111.68)		
IC-R	F	48	99.99 ± 4.97	99.74 (97.10-102.70)	<.0001	<.0001
	M	51	106.09 ± 6.16	105.35 (102.05-110.05)		
C-LR	F	48	103.82 ± 4.84	104.07 (100.70-107.71)	<.0001	0.0001
	M	51	107.96 ± 5.09	108.33 (104.25-110.74)		

* [1] t-test [2] Wilcoxon signed-rank test.
* IC-L: the length between the lower incisor andthe left condylar center; IC-R: the length between the lower incisor andthe right condylar center; C-LR: the length between the right and left condylar centers.

Table 2. Measured lengths for the three sides of the Bonwill triangle for different age groups.

Sides	Age	N	Mean±SD	Median (Q1-Q3)	p-value[1]	p-value[2]
IC-L	20 and below	11	101.60 ± 8.02	103.86 (92.45-106.98)	0.0041	0.01
	21-30	21	107.82 ± 7.28	106.89 (102.91-112.54)		
	31-40	18	105.50 ± 6.26	104.39 (100.86-109.13)		
	41-50	24	104.33 ± 5.70	104.83 (100.39-108.32)		
	51-60	13	101.97 ± 3.58	102.02 (99.62-103.80)		
	61and above	12	99.43 ± 5.40	99.07 (96.03-101.78)		
IC-R	20 and below	11	101.40 ± 7.40	102.07 (96.53-104.81)	0.0228	0.0793
	21-30	21	106.59 ± 6.87	105.35 (103.00-111.31)		
	31-40	18	104.51 ± 6.81	102.42 (98.67-107.58)		
	41-50	24	102.50 ± 5.37	102.31 (97.91-106.36)		
	51-60	13	101.60 ± 3.39	101.92 (99.87-103.91)		
	61 and above	12	99.54 ± 5.88	100.22 (98.69-102.02)		
C-LR	20 and below	11	101.88 ± 6.35	102.64 (98.72-104.25)	0.085	0.088
	21-30	21	105.73 ± 4.45	106.67 (104.23-108.80)		
	31-40	18	106.35 ± 6.25	107.09 (100.65-110.25)		
	41-50	24	107.79 ± 5.06	107.13 (105.04-110.26)		
	51-60	13	106.38 ± 5.20	105.41 (101.24-109.52)		
	61 and above	12	105.36 ± 3.90	106.29 (101.62-108.69)		

* [1] ANOVA [2] Kruskal-Wallis test
* IC-L: the length between the lower incisor andthe left condylar center; IC-R: the length between the lower incisor andthe right condylar center; C-LR: the length between the right and left condylar centers.

Discussion

Even as Bonwill's triangle theory remains controversial and various studies have reported different lengths for the different sides of the triangle, relevant data for Asian populations is still lacking[5]. The aim of this study, therefore, was to provide basic data for an Asian population and compare it with the values originally proposed by Bonwill. The average measured lengths of the 3 sides (104 mm for the left side, 103 mm for the right side, and 106 mm between the condyles on both sides) for the Taiwanese subjects in this study formed an approximately equilateral triangle and thus confirmed the validity of Bonwill's triangle theory to some extent. However, the size of the formed triangle was larger than that of the triangle originally proposed by Bonwill, who proposed that the length of each side length should be equal to 4 inches (101.6 mm). Maggetti et al. used cone beam computed tomography (CBCT) scans of 120 arbitrarily selected individuals and found that the mean side length of the Bonwill triangle was 103.3 mm, with a range of 90.2 mm (minimum) to 117.9 mm (maximum), and that the mean base length of the triangle was 99.6 mm, with a range of 85.2 mm to 112.6 mm[6]. The lengths from the mandibular central incisors to both the left and right condyles were close for both studies, but there was a difference of 6 mm for the length between both condyles. This might be due to differences in the head form among people of different ethnicities. For example, among Taiwanese people, the head form is more brachycephalic[7]. Therefore, the triangle formed in the study by Maggetti et al. was closer to being isosceles in shape, while the triangle formed in this study was closer to being equilateral in shape.

There were statistically significant differences in the side lengths of the formed triangle between the male and female subjects (IC-L: 107.32 ± 6.17 vs.100.62 ± 5.25; IC-R: 106.09 ± 6.16 vs. 99.99 ± 4.97; C-LR: 107.96 ± 5.09 vs.103.82 ± 4.84), as shown in Table 1. The overall difference in the sizes of the formed triangles might be attributed to fact that females are generally smaller in terms of body size than males.

The observed tendency toward increased side length with increasing age is in accordance with the downward and forward development of the face. However, it is interesting to note that the lengths between the mandibular incisors and both condyles began to decrease in middle age.

An articulator simulates the movement of the lower jaw and monitors the contact relationship of the teeth. Articulators can mainly be divided into the simple, semi-adjustable, and fully-adjustable categories. There is no consensus as to which category is the best because a more complex process may result in sources of error. Clinicians should thus choose suitable articulators according to the specifics of different cases in order to achieve the best and most predictable treatment results.

Nowadays, the use of a semi-adjustable articulator is recommended for most clinical cases given that these articulators are typically reasonably priced, provide sufficient clinical functions, allow for face-bow transfers, and are easy to use. The different positions of casts mounted in an articulator may change the moving distance, such that different motion patterns might occur. The posterior occlusal morphology and depth of the cingulum for anterior teeth may also be changed. During chewing and swallowing, the teeth will come into contact at and around the center of the occlusion position. If the occlusal contact is not smooth or is obstructed, it would cause occlusal interference. Relatedly, if a clinician is negligent in carefully and cautiously adjusting any occlusal interference, the occlusal interference may be a possible causative factor of temporomandibular joint syndrome symptoms such as headache, joint pain, and muscle pain.

When it is necessary to use the average values of the distances between the joints to mount the casts, we should simulate intraoral conditions to the extent possible in order to achieve the required occlusal coordination[8-13]. The mandibular occlusal morphology in the posterior region suggests that the buccal and lingual groove placement should be more mesial clinically for Taiwanese people, as the results from our study showed a smaller triangle. This study provides information helpful to achieving 3 out of the 9 goals of biological occlusion mentioned by Becker 8: no interference between centric occlusion and centric relation, no balancing contacts, and no cross-tooth balancing contacts.

Conclusion

The results of this study showed that the average side length values of the formed triangle in Taiwanese people are roughly consistent with Bonwill's proposed equilateral triangle, although the lengths were 2 mm longer, on average, than the 4-inch sides proposed by Bonwill, and they also changed with age. If CT imaging technology was applied to provide better measurement results, the positioning of casts in articulators may be more accurate. Dentists will then be able to increase the usage of articulators and improve the quality of the care they provide.

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Original Article

The Association Between Relative Bite Force and Lip Pressure

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Abstract

Objective

The aim of this study was to determine the correlations between perioral soft tissue performance and masticatory function.

Material and methods

Fourteen subjects aged 23 to 40 years old (mean: 29.4 years) were enrolled in this study. All of the participants had normal oral anatomic structures and stable posterior tooth support. The relative bite force (%) compared to the maximal bite force in the right and left arches was measured using the T-Scan III® system. The lip pressure (kPa) over the right and left cheeks was evaluated by the Iowa Oral Performance Instrument (IOPI®) Pro system and its bulbs. The data were presented as the mean ± standard deviation (SD) and compared using the paired t test.

Results

The mean relative bite force of the subjects was 51.2±21.7 % (mean ± SD) on the left side and 48.4±21.7 % (mean ± SD) on the right side. The mean lip pressures on the left side and right side were 24.9 ±5.2 kPa (mean ± SD) and 23.9 ±4.2 kPa (mean ± SD), respectively. There were significant correlations between the relative bite force and lip pressure on both the left and right sides ($p<0.01$).

Conclusion

The study results indicated a significant association between relative bite force and lip pressure. In clinical terms, we might thus infer that improved masticatory function would perhaps result in improved lip pressure. Relatedly, it is worth further investigating whether prosthodontic rehabilitation resulting in increased perioral soft tissue strength is correlated with improvements to the sucking or swallowing functions.

Key words: lip pressure, relative bite force

Introduction

According to the equilibrium theory of tooth position, the forces exerted by the lips, cheeks, and tongue all affect the positions of the teeth. Relatedly, previous studies have shown that the most important environmental factors affecting tooth position are the pressures exerted by the lips and cheeks[1]. The force generated by perioral soft tissues plays a role in guiding tooth eruption and maintaining dental arch form and stability[2]. Therefore, lip pressure is closely related to the state of occlusion, and may even have a significant effect on oropharyngeal function.

Masticatory function impairment can adversely affect quality of life[3]. Sufficient masticatory function, in contrast, is considered to contribute substantially to general health[4]. Evaluating the chewing performance is one common way to obtain an overall measurement of masticatory function. Masticatory performance would be influenced by a number of factors, including the teeth, masticatory muscle strength, jaw movements, and maximum bite force[3]. The maximum bite force is directly related to masticatory performance; it can not only explain over 60% of the variance in masticatory efficiency but also 72% of the variation in masticatory performance among children and adults[3-6].

Oral functions including swallowing and chewing are accomplished by complex and coordinated neuromuscular actions. However, few studies have investigated the association between perioral soft tissue and bite force, and there is some controversy regarding whether strong lip tension has any impact on masticatory performance. At the same time, it is important for prosthodontists to know if high lip pressure affects denture stability or has any other effects that could influence prosthodontic treatment planning. Moreover, it would also be valuable to know whether increasing the bite force can effectively increase the tension of the muscles around the oral cavity in a way that, in turn, improves the swallowing function. With these issued in mind, we sought in this study to measure the lip pressure and relative bite force of the study participants in order to determine the correlations between the tension of the perioral soft tissue and masticatory function.

Materials and Methods

Fourteen subjects including five men and nine women were analyzed in this study. Their ages ranged from 23 to 40 years old, and their mean age was 29.4 years. All of the subjects had normal oral anatomic structures and stable posterior tooth support; their occlusal classification was limited to Angle's Class I occlusion. In addition, none of them had any neuromuscular disorders or dysphagia. Their consciousness was clear and they could cooperate as necessary in order to complete the entire study. Furthermore, they were all enrolled in the study only after they were well informed of its details and had signed a consent form.

The relative bite force of each subject was measured using the digital occlusion analysis T-Scan III® system (Fig. 1), which utilizes a thin-film interface

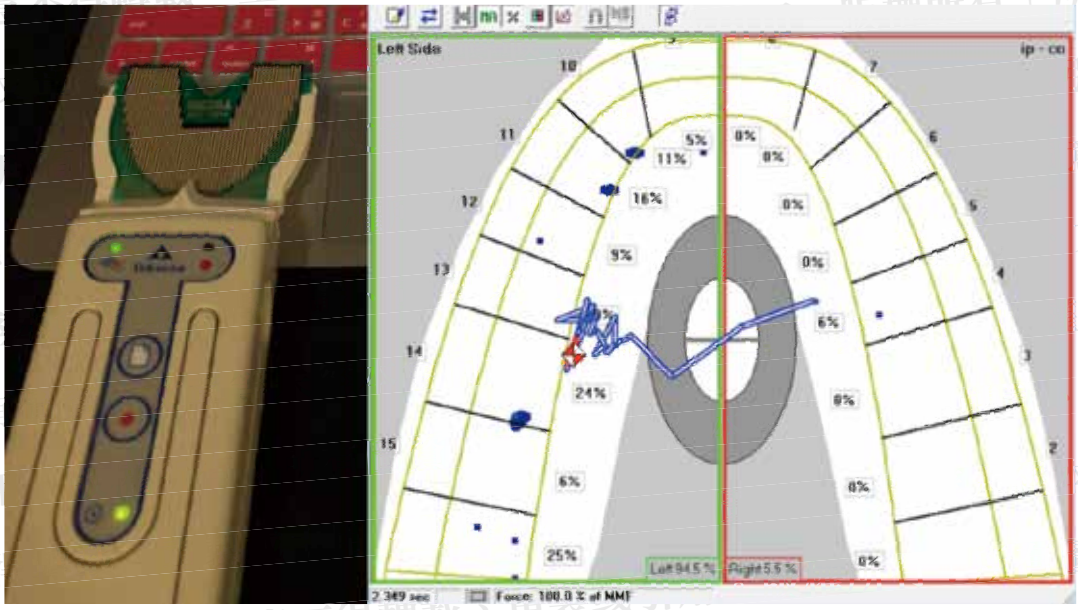

Fig. 1. T-Scan III® is a digital occlusal analysis system consisting of a patented sensor, ergonomic handpiece, and proprietary software that reveals the level and timing of force on individual teeth and the stability of the patient' s bite

pressure mapping sensor to detect the relative bite force. Each participant was invited to sit in a relaxed and upright position during the relative bite force evaluation and trained to firmly bite the sensor until maximal intercuspation lasting one to three seconds. Once the given participant was familiar with operation of the instrument, he or she was instructed to bite so as to indicate the centric occlusion. The percentages (%) of the relative bite force distribution to the bilateral arches compared to maximal bite force were calculated.

The Iowa Oral Performance Instrument (IOPI®) Pro system (Fig. 2), a new type of pressure measuring instrument, was utilized to evaluate the lip pressure (kPa) over the right side and left side. For this evaluation, the patient sat upright in the chair, the IOPI bulb was placed between the lips, and the patient squeezed the IOPI® bulb against the buccal surface of the teeth by pursing the lips as hard as possible. The lip pressure measurement was performed five times on both the left and right sides.

This study separately analyzed the data for the left side and right side in order to explore the correlation between lip pressure and relative bite force. The data were presented as the mean ± standard deviation (SD) and compared with using the paired t test. The IBM SPSS Statistics Version 20.0 was utilized for statistical analysis, and a P <0.01 was considered to indicate a statistically significant difference.

Results

The mean relative bite forces of the 14 subjects were 51.2±21.7 % (mean ± SD) on the left side and 48.4±21.7 % (mean ± SD) on the right side. (Table1) The mean lip pressures on the left side and right side were 24.9 ±5.2 kPa (mean ± SD) and 23.9 ±4.2 kPa (mean ± SD), respectively (Table 1). We used the paired t test to determine the correlations between the relative bite force and lip pressure, and there were significant correlations on both the left and right sides (p<0.01) (Table 1).

Fig. 2. The Iowa Oral Performance Instruments (IOPI®) Pro and its bulb

Discussion

Many factors influence masticatory performance, including the perioral musculature, the positions of the teeth, the jaw movements, the occlusion pattern, the occlusal contact area, and the bite force[3,5,6]. Meanwhile, impaired masticatory function can have significant negative effects on an individual's quality of life. The functional harmony and balance of the muscles converging in the lip and cheek area are important in the growth and development of the dento-alveolar morphology and craniofacial region[7]. The force generated by perioral soft tissues plays an important role in guiding tooth eruption and maintaining dental arch form and stability[2]. Therefore, lip pressure is not only closely

Table 1. Comparison between relative bite force and lip pressure (n=14)

	Relative bite force (%)		Lip pressure (kPa)			
	Mean	SD	Mean	SD	95% CI	P
Right side	48.37	21.66	23.91	4.16	36.59 (5.62 to 12.31)	.001**
Left side	51.18	21.72	24.90	5.21	40.16 (6.42 to 12.40)	.001**

Paired t test **P<0.05

SD indicates standard deviation; CI indicates confidence interval

related to the state of occlusion but also affects the abilities of feeding, eating, speech, saliva control, and the articulation of labial consonants[8,9]. Moreover, the results of this study preliminarily indicated a significant association between lip pressure and relative bite force ($P < 0.001$) (Table 1). This finding was consistent with those of a previous study showing that maximum lip force and maximum bite force significantly predict masticatory performance in healthy elderly patients and stroke patients[10] .Another investigation furhter revealed that lip force is also closely related to swallowing capacity; in that study, dysphagia was improved when the lip force was raised and the lip pressure was significantly lowered in a patient who had a history of choking on food[11]. In patients with impaired mimic muscles or in denture patients, the lip seems to take over more critical roles and thus might also contribute to the bolus-kneading process[10]. Based on previous research, the lip-closing function might represent the pharyngeal strength involved in swallowing[11,12].

Maximum bite force is an indicator of masticatory function.13 Relatedly, measurements of bite force can provide useful data for evaluations of jaw muscle function and activity[14]. A variety of devices with a diversity of designs and working principles have been used to record bite forces. In this study, the T-Scan III® system, which utilizes an ultra-thin (0.004 inch, 0.1 mm), reusable sensor that is shaped to fit the dental arch, was used to evaluate the relative bite force and occlusal contact area in the intercuspal position and to acquire the associated data[15]. The relative bite forces distributed over the right and left arches were represented in this study as percentages compared to the maximum bite force instead of with actual units of force such as Newtons. Because this research was mainly conducted to explore the relationship between the relative bite force and lip pressure, the unit could be ignored. Besides, the inclusion criteria used for subject selection were strict and included fully intact dentition and no previous history of orthodontic or prosthodontic treatment. Furthermore, this study was designed to compare the relative bite force and lip pressure in individuals in a way that could prevent experimental error resulting from individual differences and thus increase the realism of the results.

In clinical practice, efforts aimed at training the strength of the perioral soft tissue are usually aimed at swallowing function rehabilitation. The results of this study showed that there were significant correlations between the lip pressures and relative bite force on both the left and right sides ($p<0.01$). These results suggest that increasing the lip pressure might not only resolve dysphagia but also improve masticatory function. Moreover, we could infer that measurements of lip pressure can be used as a reference in prosthodontic treatment planning. For example, in clinical practice, patients with stronger lip strength might be expected to benefit more from implant therapy than from being fitted with a removable denture. It is also worth further investigating whether successful prosthodontic rehabilitation can not only increase the bite force but also help in the recovery of other oral functions such as sucking or swallowing. Furthermore, one limitation of this study was that the smile lines of the subjects had to be restricted, so it would be interesting to investigate in the future whether the smile line has any impact on the association between lip pressure and relative bite force. Another hypothesis derived from this investigation is that the clinical training of oral muscle strength could perhaps improve masticatory force in those wearing removable dentures. In fact, given that the results of this study indicated close associations between the different elements of the oral apparatus, including the perioral musculature and dentition, there are a number of related interesting topics that need to be explored in the future.

Conclusion

The results of this study indicated significant correlations between the relative bite force and lip pressure. Clinical training of perioral muscle strength may thus improve the masticatory function, while increasing the relative bite force with prosthodontic rehabilitation might aid in the recovery of oral functions related to lip pressure, such as sucking or swallowing.

Acknowledgement

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Case Report

Prosthodontic Rehabilitation of Edentulous Patients with Implant-Retained Overdentures : A Clinical Report

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Abstract

Diminished ridge dimensions following tooth loss complicate prosthodontic rehabilitation, especially for edentate elderly patients who are usually not the right candidates for complex treatment procedures. Implant-retained or -supported overdentures can enhance the stability and retention of conventional complete dentures and rebuild the soft tissue profile and oral function through a relatively conservative procedure. The Locator system (Zest Anchors, Inc, homepage, Escondido, CA, USA) is widely applied around the world as the anchorage for overdentures. The aim of this clinical case report was to demonstrate the rehabilitation of an edentate patient with maxillary and mandibular implant-retained overdentures and to review the related literature.

Key words: dental implants, edentulous mandible, edentulous maxilla, locator, overdenture

Introduction

Life expectancy has improved in most nations in recent years, especially developed countries such as Japan and Singapore, among others, due to advances in medical knowledge as well as clinical techniques. According to the 2015 world population data sheet from the website of the Ministry of the Interior of Taiwan, the life expectancy at birth in 2015 was estimated to be 77 years for males and 84 years for females in Taiwan[1]. Therefore, it is expected that the population of elderly people who generally suffer from a higher risk of losing their teeth due to oral diseases will gradually increase in the future. It is thus urgent to consider how quality of life relating to oral health, as well as medical and psychosocial conditions, can be enhanced for this growing population.

The loss of teeth usually results in dimensional changes to the residual alveolar ridge that make it more complicated to rehabilitate the function and esthetics of dentition with either conventional removable dentures or prostheses assisted with implants[2-4]. At the same time, the ongoing development of widely accepted and evidence-based tissue preservation and regeneration methods involving the use of various advanced materials and techniques have made it realistic for dental clinicians to utilize fixed implant-supported prostheses in a variety of clinical situations[5,6]. However, many patients do not choose fixed prostheses as a reconstruction

Fig. 1. The patient's existing dentures became loose due to poor adaptation to the underlying tissue, which had undergone dimensional alteration due to ridge resorption. Retention of his maxillary RPD was further compromised after 13 was extracted.

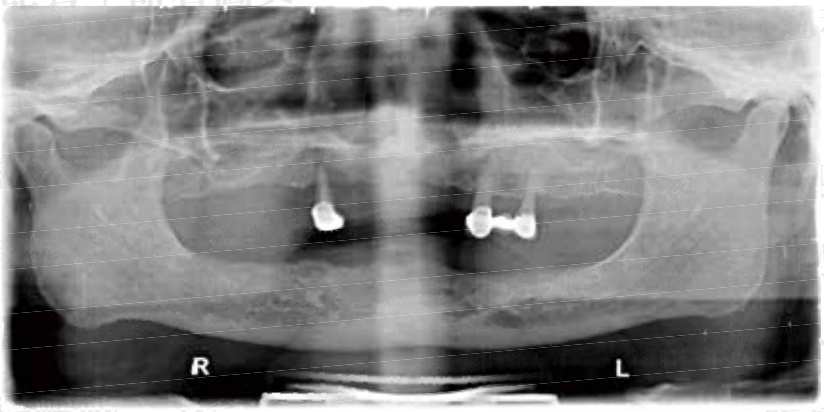

Fig. 2. Panoramic film showing pronounced pneumatization of the right maxillary sinus. The remaining teeth displayed advanced horizontal bony resorption and 13 with old endo and apical radiolucent lesion noted. The mandibular intercanine area exhibited sufficient bone height for implant placement.

plan after considering the associated cost, treatment time, possible surgical procedures, and various other factors[8,9].

It has been proven that overdentures retained or supported by implants can promote the stability and retention of conventional complete dentures, especially in the case of mandibular dentures, which frequently cause patients frustration due to advanced alveolar bony resorption. Implant-supported/retained overdentures (IODs) can be utilized with a relatively conservative procedure to rebuild the soft tissue profile and oral function; moreover, due to the additional support provided by the residual ridge, fewer implants are required and, thus, IODs are sometimes more economical and practical from patients' perspectives[10,11].

The aim of this clinical case report was to demonstrate the rehabilitation of the esthetics and masticatory function of an edentulous patient through the application of maxillary and mandibular implant-retained overdentures.

Case report

A 71-year-old male patient was referred by the Oral & Maxillofacial Surgery (OMS) Department of Taipei Medical University Hospital (Taipei, Taiwan) for full mouth rehabilitation treatment. The patient had adapted well to his old maxillary removable partial denture (RPD) and mandibular complete denture (CD) for several years, but the old dentures had recently become loose (Fig. 1). The patient also had well-controlled type II diabetes and hypertension, without any drug or food allergies. Observation indicated that the patient's maxillary RPD was poorly retained due to the loss of the pivot abutment tooth, 13, which was extracted at the OMS department and, furthermore, that ridge resorption had also contributed to deteriorating stability and retention of both dentures (Fig. 3). Clinically, only a 23 × 25 bridge remained, and it had grade II mobility. Moreover, teeth 23 and 25 displayed advanced horizontal bony resorption on the periapical radiograph, while a panoramic film showed pronounced pneumatization of the right maxillary sinus, accounting for the further reduction of the ridge dimension there compared with the left side (Fig. 2). Two treatment options were suggested: (1) maxillary and mandibular CDs or (2) implant-retained palateless maxillary and mandibular overdentures. The patient preferred the palateless design and demanded more retention; thus, he chose the option 2.

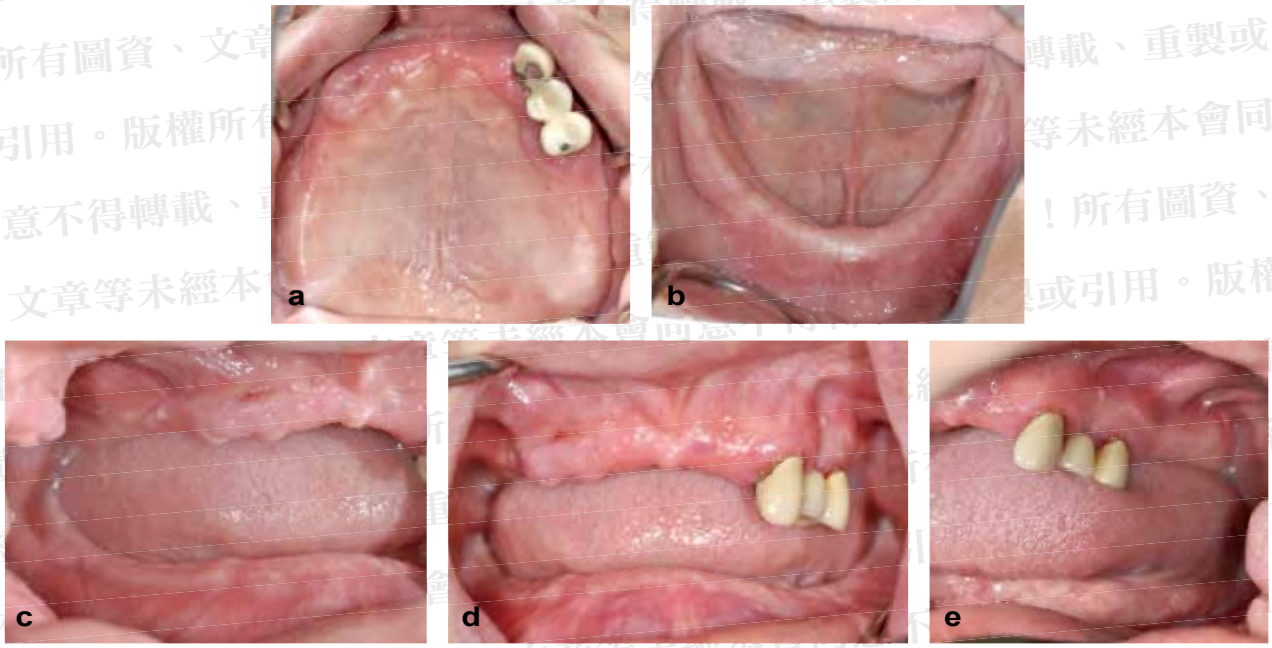

Fig. 3. (a) Occlusal view of maxillary arch showing 23x25 bridge with porcelain chipping. (b) Occlusal view of mandibular arch indicatig adequate bone width for implant placement over the intercanine area. (c) Right-side view showing moderate resorption of the maxillary edentulous ridge. (d) Frontal view of both arches. (e) Left-side view exhibiting the patient's enlarged tongue with a retracted tongue position.

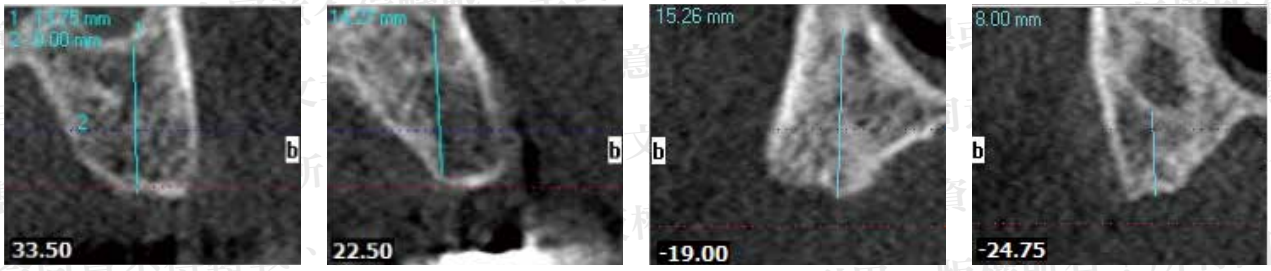

Fig. 4. Cone beam computerized tomographic scan showing sufficient amount of alveolar bone for installing implants over the 14, 16, 24, 26 areas.

After we reached an agreement with the patient, preliminary impressions of both arches were taken and immediately poured with type IV stone. At the next appointment, facebow transfer and centric relation recording was completed for the mounting of the casts on the articulator in the laboratory. Artificial teeth were arranged on the record base for the diagnostic wax-up, as well as for the fabrication of maxillary and mandibular surgical templates. Before the surgical procedure, a cone-beam computerized tomographic scan was arranged to allow for an analysis of the alveolar bone condition and in order to plan the implant positions (Fig. 4). The mandibular intercanine area was manually examined, revealing adequate bone width (Fig. 3), while a panoramic radiograph was used to verify the presence of sufficient bone height (Fig. 2). After extraction of the 23×25 bridge, four implants (Osseospeed™ TX, Astra Tech, Dentsply Implants, Mölndal, Sweden) were placed over the bilateral 1st premolar and 1st molar regions of the maxilla, and two implants were placed over the bilateral canine positions of the mandible through a two-stage protocol (Fig. 5). Parallelism of the implants was accomplished with the application of direction indicators during the osteotomy. Postoperatively, amoxicillin (500 mg) and Ponstan (500 mg) t.i.d. were prescribed for the patient for 7 days. One week later, the patient's existing dentures were repaired and relined with tissue conditioner (GC Soft-Liner, GC Corp, Tokyo, Japan) to serve as the interim prostheses.

The second-stage surgery was carried out 4

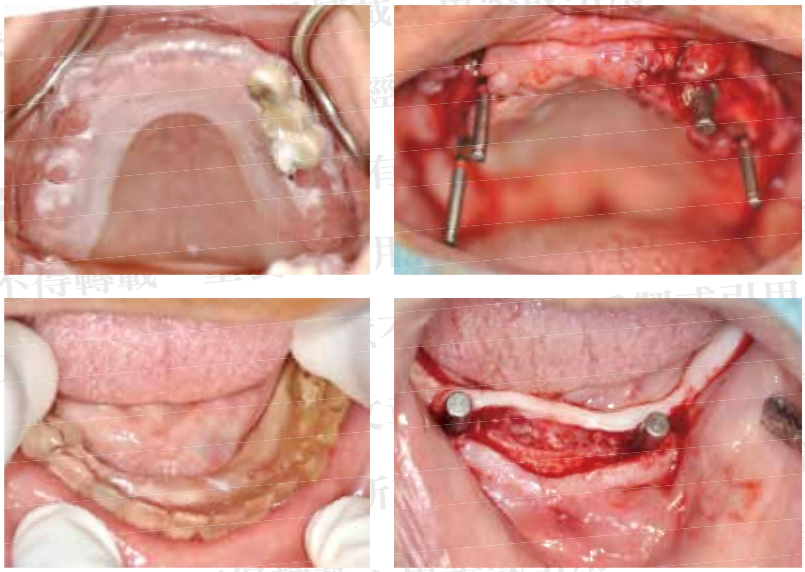

Fig. 5. Four implants were placed over the bilateral 1st premolar and 1st molar region of the maxilla (three OsseoSpeed™ TX 3.5S/9 implants and one 3.5S/11 implant), and two implants were placed over the bilateral canine positions of the mandible (two 3.5S/9 implants).

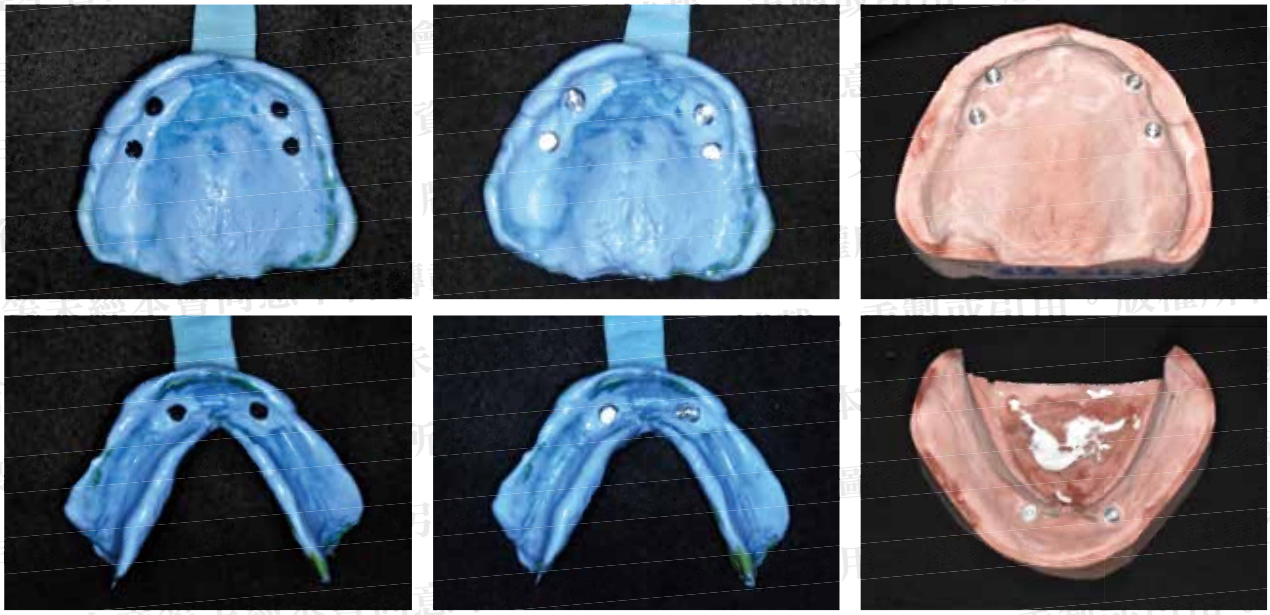

Fig. 6. Abutment-level impressions of the maxillary and mandibular arches were completed by using customized trays with Exadenture. The master casts were fabricated with type III stone after attaching the Locator Abutment Replicas to the black processing caps.

months after the initial surgery, and healing abutments were connected to the implants by the OMS department. Later on at the prosthodontic department, Locator abutments (Zest Anchors, Inc, Escondido, CA, USA) were attached to the implants individually and tightened with a torque wrench (25 Ncm). After we molded the customized trays with green modeling compound (Impression Compound Sticks; Kerr Corp, CA, USA) to obtain fair border sealing, final impressions were made with Exadenture (GC Corp, Tokyo, Japan) and black processing caps were picked up following the manufacturer's specifications. Before pouring the master casts with type III dental stone, we connected the Locator Abutment Replicas to the processing caps (Fig. 6). Because the esthetics and occlusion of the patient's old dentures were unsatisfactory, it was imperative to reassess the occlusal plane and vertical dimension of the definite dentures with the wax rim and recording bases. Bite registration of the centric relation was done with aluwax (Aluwax Dental ProductsCorp, Michigan, USA). The maxillary anterior teeth (Ivoclar Vivadent, Schaan, Liechtenstein) were arranged according to esthetics along with phonetics; as for

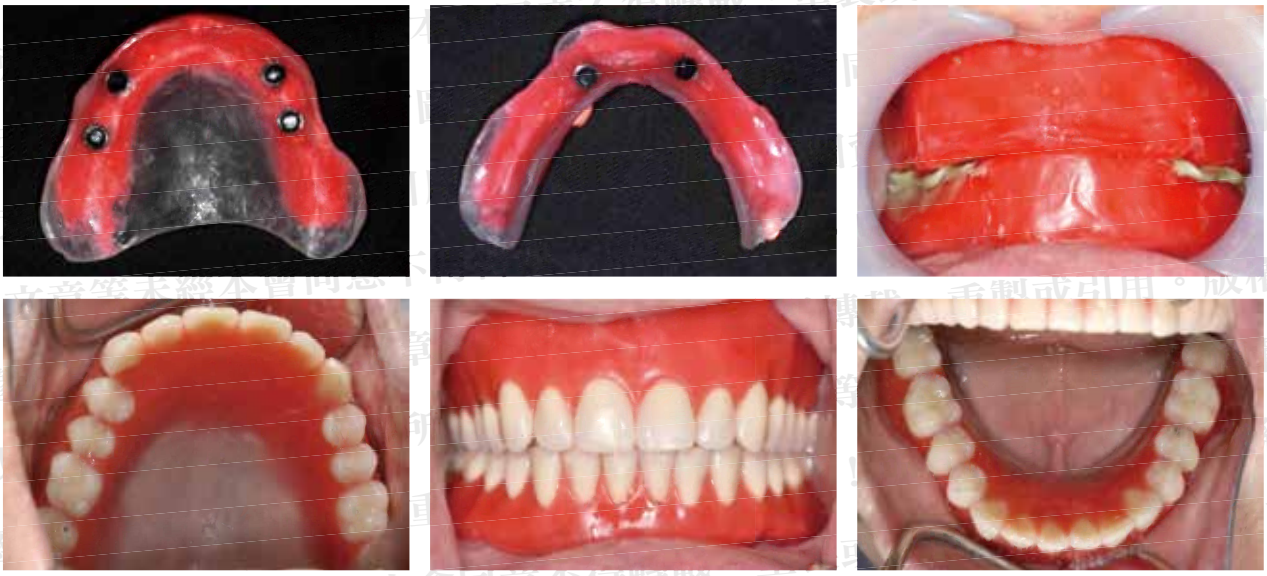

Fig. 7. Bite registration of the centric relation was done with aluwax. The maxillary anterior teeth were arranged according to esthetics and phonetics; as for the posterior teeth, their positions conformed to the occlusal plane determined by the wax rim paralleling Camper's line.

Fig. 8. The maxillary overdenture was designed with a horseshoe shape. Locator matrices were attached to the acrylic bases with black processing inserts.

the posterior teeth, their positions conformed to the occlusal plane that was determined by the wax rim paralleling Camper's line (Fig. 7). A bilateral balanced occlusal scheme was applied. After the esthetics and occlusion of the wax dentures were verified clinically, the maxillary and mandibular dentures were processed with poly methyl methacrylate resin (Lucitone 199, Dentsply International Inc, York, PA) and the Locator matrices were attached to the acrylic bases according to the manufacturer's protocol in the laboratory. At the appointment for the delivery of the definite dentures, the adaptation of the acrylic denture base, the extension of the denture border, and the occlusion were examined and adjusted clinically (Fig. 8).

One month later, after the patient had gradually become accustomed to the new dentures, the black processing inserts were replaced with Locator patrix nylon inserts (blue, 680 g) according to the manufacturer's protocol. The patient was instructed regarding denture hygiene care and asked to make future appointments for clinical maintenance.

At the one year follow-up appointment, the tissue condition and prosthetic restoration were evalu-

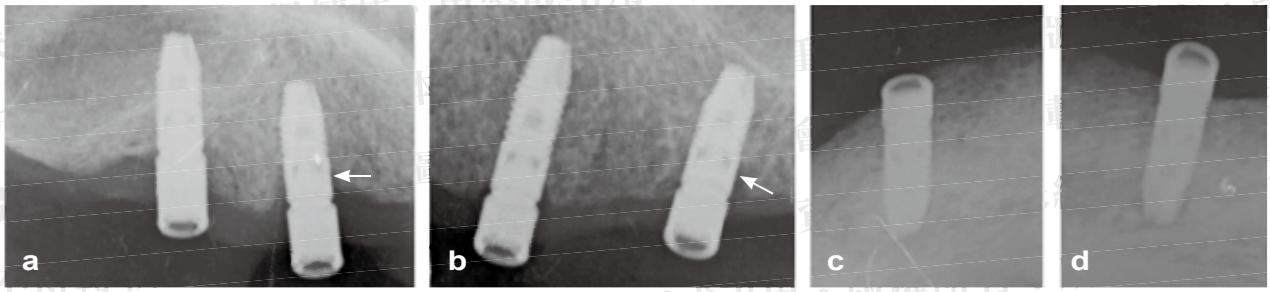

Fig. 9. Periapical radiographs taken at the one year follow-up showing that marginal bone loss was more pronounced at the maxillary implants (a & b) (white arrow) compared with the mandibular ones (c & d), which showed a favorable condition with a quite stable bone level.

ated. We found significant wear on the patrix nylon inserts and so replaced them with new ones. Though the peri-implant tissue appeared quite healthy clinically, a radiographic examination showed more marginal bone loss around the maxillary implants compared with the mandibular ones (Fig. 9).

Discussion

In this case, we applied IODs as the reconstruction therapy for an edentate male patient after considered his oral condition and general health condition. The patient had previously had good experiences with removable prostheses and soon accommodated himself to the new overdentures, which were assisted by four implants in the maxilla and two implants in the mandible. This outcome was consistent with previous studies reporting that people are usually more satisfied with IODs than with conventional removable prostheses[10-12].

According to a meta-analysis study performed by Kodama et al., the application of two-implant retained overdentures in mandibles significantly improves the oral health-related quality of life when compared to the application of conventional ones. Though maxillary implant-retained/supported overdentures frequently served as the mitigation plan for the failure of implant-supported fixed prostheses in earlier studies and displayed lower implant survival, more recent studies support the clinical effectiveness of their use in maxilla on the condition that a reasonable analysis of the restoration space and bone condition is conducted during the diagnostic phase and that implants with moderately rough surfaces are used in optimally distributed positions[12-14]. In our case, we planned the implant positions according to the bone quantity in the molar to canine area, which was limited by the compromised bone volume resulting from sinus pneumatization in the posterior region, and distributed the implants more evenly with a wider anteroposterior spread.

With regard to the necessary number of implants for overdentures, it seems that two implants are required for mandibular IODs in order to improve the retention and stability of conventional dentures and for the acceptable survival of the implants and prostheses[11,15]. As for the maxilla, it appears that at least four to six implants are needed to achieve a more predictable and successful treatment outcome[12,14].

At present, many studies have shown that both solitary and splinted anchorages have their advantages and disadvantages, and we applied the Locator system as the attachment for the overdentures after considering its good retentive force, self-alignment characteristics, and the convenience of its clinical maintenance. The Locator system is widely applied around the world and has proven to be a predictable and reliable anchorage for IODs[16,17].

In the present case, there was more marginal bone resorption around the maxillary implants than around the mandibular implants. Many previous studies had investigated marginal bone loss around the implants for overdentures and several impactful factors were suggested, including smoking, bone quantity, and GBR[18,19]. Though the impacts of implant distribution and attachment design on marginal bone loss in the maxilla have not been conclusively determined [20], the less favorable conditions (that is, the inferior bone quantity and quality, namely, type III or IV) of the posterior maxilla in which the implants were placed in the current case and the use of solitary anchorage without positive load sharing may have been the reasons why more marginal bone resorption occurred around the maxillary implants. Nonetheless, our patient adapted well to his new IODs and was quite satisfied with their improved retention and plateless design. Implant-retained/supported overdentures can rehabilitate edentate patients with acceptable esthetics and function at a relatively low cost and with more conservative treatment procedures, supporting their use as an effective prosthodontic solution for many elderly patients.

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Case Report

An Alternative Approach for Removing a Fractured Implant Abutment Screw: A Case Report

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Abstract

An abutment screw fracture poses a particularly serious problem because removing the fractured abutment screw is time-consuming and difficult. Due to the lack of the screw head as part of the remaining fragment, the deep entrapment of the fragment in the implant fixture makes it difficult for clinical practitioners to locate it and engage it without damaging the interior wall of the fixture. In this case report, an alternative approach to the removal of such fragments involving the use of a customized guide cylinder modified from an "impression post" was applied. With the aid of the customized guide cylinder, a special removal instrument with sharp-edged tips can directly locate and reverse out the fragment without damaging the surface features or the internal threads of the implant. Overall this method was found to be safer and simpler than alternative methods, so if a removal kit for a specific implant system or a guide component is not available, this alternative approach may be the procedure of choice for clinical usage.

Key words: customized guide, implant abutment screw, screw fracture, screw retrieval

Introduction

The application of dental implants is an established treatment modality for oral rehabilitation. However, while the high success rate of implant osseointegration has been clearly demonstrated [1-3], the longevity of implant prostheses on implants is another concern [4-8]. Implant prosthesis failures primarily result from technical complications, including screw loosening, screw fractures, framework fractures, and veneer fractures. Among these complications, abutment screw fractures pose a particularly serious problem because of the excessive complications involved in the removal of a fractured abutment screw. Specifically, it is difficult to remove a fractured screw fragment remaining inside an implant fixture without damaging the implant body; if the fragment is not properly retrieved, the implant may lose its ability to retain the prosthesis despite remaining osseointegrated [8]. Abutment screw fractures have thus been a subject of long-term concern because, although such fractures rarely happen, addressing such situations can be difficult and time-consuming. The standard methods for removing fractured screw fragments are complicated; hence, this report presents a more simplified and straightforward approach.

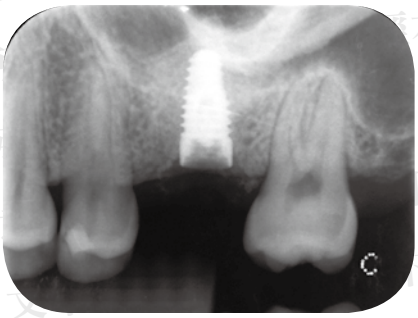

Fig. 1. Radiograph of the fractured abutment screw after crown removal. It demonstrated that the failed abutment screw remained within the implant body.

Fig. 2. Screw removal instrument (Lucky, SC-1713, ADL Bio, Seoul, Korea). The sharp-edged tips of the screw removal instrument can engage the irregular top surfaces of fractured screw fragments.

Over an observation period of 5 years, Kreissl et al. determined that the incidences of abutment screw fracture and abutment screw loosening were 3.9% and 6.7%, respectively [9]. Several contributing factors have been implicated in the etiology of screw failures, including bruxism, malfunction, improper placement techniques, non-passive fit of the superstructures, manufacturing errors, and the use of unfavorable superstructures [10]. These factors predispose screw joints to excessive bending forces and settling effects arising from micromovements at the implant–abutment connection, with these forces and effects leading in turn to abutment screw loosening [11,12]. In clinical practice, practitioners can detect this problem early through routine follow-up examinations. Screw loosening, meanwhile, is the main reason for screw fracture, and when such loosening goes undetected and untreated, over time even common chewing movements can lead to screw fatigue and fracture [13].

When an abutment screw fracture occurs, many methods exist for removing the fractured screw fragment remaining in the implant fixture. Generally, the most convenient way to remove the screw is to reverse it. Regardless of whether the fractured screw fragment is above or below the implant platform, one could thus first try using an explorer probe or an ultrasonic tip to unscrew the abutment screw fragment in a counterclockwise direction over the irregular fractured surface. However, this method sometimes does not work because the reverse torque cannot be effectively applied to the fragment using a freehand approach. Therefore, several retrieval kits have been made available on the market, such as the Certain® Screw Removal Tool Kit (Biomet 3iTM, FL, USA), Retrieval Instruments (Nobel Biocare, Zurich, Switzerland), the Neo Screw Remover Kit (Neobiotech, Seoul, Korea), and the ITI® Dental Implant System (Institut Straumann, Waldenburg, Switzerland). In substance, these retrieval kits consist of two components: first, instruments with different special tip designs to engage the fractured fragment and, second, guide components for the aforementioned instruments that aid in locating the fragment and help to prevent damage to the implant fixture during the retrieval process.

Due to the heterogeneity of implant systems, these removal kits cannot be applied to all systems. Therefore, in the event that a removal kit for a specific implant system is not available, this case report offers an alternative approach in which only a special screw removal instrument and a customized guide cylinder modified from its impression post are required. This method is safer and simpler than alternative methods for clinical practitioners.

Case Report

A 30-year-old male patient presented to our dental clinic with a loosened crown on the maxillary left first molar; the crown had been retained with an abutment screw over an implant (PrimaConnex® implant: Ø5.0 × 10 mm length; Keystone Dental, MA, USA) for 3 years. A dental radiograph indicated that the abutment screw of the maxillary left first molar had fractured at the junction of the screw shank and screw thread. The abutment screw fragment was 2 mm below the platform of the implant fixture (Fig. 1).

To retrieve a fractured screw, an alternative approach is introduced in the following procedure. This technique allows the abutment screw fragment to be removed without the risk of damaging the surface features or the internal threads of the implant. Additionally, it can be applied to most implant systems when a removal kit for a specific implant system is not available.

Fig. 3. To accommodate the slightly wider shank of the screw removal instrument, the channel of the implant impression post was enlarged. The impression post on the left is the enlarged one. The impression post on the right is the original one.

Fig. 4. A C-S2 tungsten carbide bur (Diaswiss SA, Nyon, Switzerland) in an electric straight handpiece was used to enlarge the impression post.

Fig. 5. The screw removal instrument could pass through the enlarged impression post.

Steps of the alternative method:

1. A screw removal instrument (Lucky, SC-1713, ADL Bio, Seoul, South Korea) was selected to remove the fractured fragment (Fig. 2). The sharp-edged tips of this instrument were designed to easily engage the irregular top surface of the fractured screw fragment, which helped the user to unscrew it.
2. A corresponding "impression post" (Ø5.0 mm), a component for implant-level impression to transfer the index position, angle, and depth of the implant, was employed. This component can serve as a specific guide to access the screw hole in the implant bore because the outer feature precisely fits the internal feature of the implant to make the component stable, while the inner channel provides a means of access by which to locate the fractured fragment in the screw hole. Unfortunately, the diameter of the shank of the screw removal instrument was slightly larger than that of the channel of the impression post. Therefore, a customized guide cylinder was modified from the original impression post by enlarging its diameter with a C-S2 tungsten carbide bur (Diaswiss SA, Nyon, Switzerland) in an electric straight handpiece (Fig. 3, Fig. 4, Fig. 5).
3. With the aid of the customized guide cylinder, the screw removal instrument could precisely locate the top surface of the fractured fragment without slippage. A light vertical force was applied parallel to the long axis of the implant so that the screw removal instrument could engage the fractured abutment screw with the sharp-tip end. Then, the screw removal instrument was manually rotated in a counterclockwise direction. Finally, the fractured fragment was retrieved efficiently without damaging the internal threads of the implant fixture (Fig. 6, Fig. 7).
4. A new abutment and screw were employed to fabricate a new implant-supported prosthesis (Fig. 8).

Discussion

In this case, the male patient had hyperactive masseter muscles and was in the habit of chewing betel nuts. The abutment screw fracture occurred in the posterior area, where the molar is subjected to greater masticatory forces than the anterior teeth. Additionally, the coarseness of the betel nut may have contributed to the unusually high incidence of mechanical overloading on the implant prosthesis. We assumed that the great overloading stress and accumulated fatigue loading led to the abutment screw fracture.

One common approach for retrieving a fractured abutment screw is to use the drilling method. This involves drilling a hole on the surface of the fractured screw and then using a special piece of

Fig. 6. Retrieved abutment screw fragment.

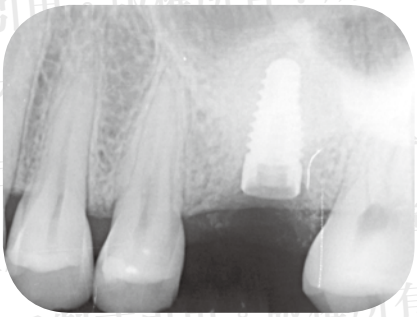

Fig. 7. After retrieval of the fractured abutment screw, a radiograph was taken to confirm its complete removal.

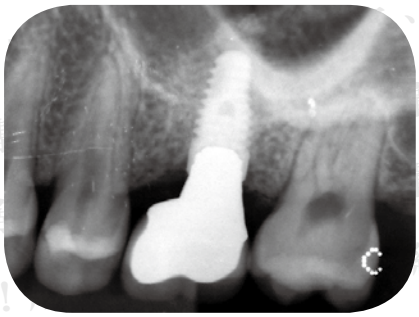

Fig. 8. Radiograph of the new implant-supported prosthesis.

equipment, such as a reverse-tapping rotary drill, to engage the hole in a counterclockwise direction and then rotate the screw out [14]. Compared to this drilling method, the alternative approach adopted in the present case study takes advantage of the uneven surface of the fractured abutment screw to foster rotation without drilling a hole. First of all, screw fractures commonly result in uneven surfaces. Several studies[15-17] have revealed that a crack was initiated on the tensile side of an abutment screw when the abutment screw exceeded the metal fatigue limit under the masticatory forces in the oral cavity. Such cracks typically continue to propagate over time. Fatigue striations running perpendicular to the direction of crack propagation have been observed under microscopes, with these striations being related to chewing cycles. In this study, a compression curl (a curved lip) was found at the end of the total fracture, indicating the existence of a strong bending component and that the fracture origin was on the opposite tensile side [18]. Through an investigation of the fracture process of the screw, the fractured surface of the abutment screw was confirmed to be uneven. By applying leverage on the uneven surface, the special screw removal instrument with sharp-edged tips could rotate and propel the screw fragment without drilling a hole. With this drill-free process, we reduced the risk of overheating the drilled components and generating metal debris. Additionally, using a guide cylinder modified from an impression post helped to prevent the screw removal instrument from slipping and damaging the internal wall of the implant fixture.

When a removal kit from the original manufacturer is unavailable, this alternative approach can serve as a safe and simple screw removal approach. Although there are removal kits with guide components on the market that claim to be universally or mostly compatible with all implant systems, in reality they only provide a general but sometimes unstable fit. Instead, the customized guide cylinder modified from the original impression post used in this study provided a perfect fit and superior stability. It is worthwhile to note that, although a manual screw removal instrument was used in this study, use of a rotary screw removal instrument installed in a dental handpiece is feasible with the modified guide cylinder too. This reduced the complexity of the clinical manipulation, particularly in the subgingival environment, which is deep and can be easily filled with saliva and blood.

Finally, clinicians should identify the reasons for any failure in order to prevent future fractures. To lower the incidence of abutment screw loosening and fracture, clinicians must remain cautious about certain concerns at different stages of the treatment. During the initial assessment, clinicians should plan for an adequate number of implants to bear the occlusal load and avoid the excessive angulation of implants to occlusal load. When delivering a prosthesis, clinicians should use the correct fixation screw; using one supplied by the manufacturer of the implant fixture is recommended. The recommended screw tightening torque should be applied with a torque wrench. Adequate fit of the prosthesis should be confirmed, and occlusal overload of the prosthesis

should be avoided. Lastly, clinicians should perform periodic maintenance and arrange for an immediate dental visit if the patient detects looseness of the prosthesis. Once screw loosening occurs, loose screws should not be retightened, but rather should be replaced with new screws [19,20]. Because damage may occur following screw loosening, the gravity of screw loosening should not be underestimated [17].

Conclusion

A fractured abutment screw fragment was successfully and safely removed using an alternative approach in which a customized guide cylinder modified from an "impression post" was applied. With the aid of the customized guide cylinder, a special removal instrument with sharp-edged tips can directly locate and reverse out the fragment without damaging the surface features or the internal threads of the implant. Overall, the method was safer and simpler than alternative methods, so if a removal kit for a specific implant system or a guide component is not available, this alternative approach may be the procedure of choice for clinical usage.

Conflict of Interests

The authors declare that they have no conflict of interests.

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Case Report

Prosthetic Assistance in Soft Tissue Management After Free Flap Reconstruction for Maxillectomy

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Abstract

Recently, microvascular free flap reconstruction has become an alternative to the use of traditional obturators for patients with maxillary defects. However, the free flap might interfere with the denture retention and stability of edentulous patients due to its mobile characteristic. In this case report, an implant-retained overdenture was used to assist in the soft tissue management after free flap reconstruction of a maxillary edentulous patient. This approach not only created a stable denture bearing area for the patient but also improved the patient's quality of life during the transitional stage.

Key words: flap revision, implant-assisted overdenture

Introduction

Traditionally, obturators have commonly been used to restore defects of the hard palate. An obturator provides a simple, non-surgical means of separating the oral and nasal cavities and concurrently restores speech and swallowing functions to a certain degree[1]. However, the potential for hypernasal speech and the possibility of food and liquid leaking into the nasal cavity will sometimes cause inconvenience to the patient, not to mention the difficulty of maintaining the hygiene of the defect[1,2].

Recent advances in microvascular surgery have provided an alternative method for restoring palatal defects, namely, flap reconstruction. Although flap reconstruction itself has disadvantages, such as higher complication rates and the possibility that the flap's bulk and movement might cause problems in prosthesis fabrication, the advantages it provides in terms of improving patient quality of life in numerous respects still make it an attractive treatment alternative for patients with palatal defects[2-5].

Nevertheless, the mobility of the flap and the fact that it is easily affected by gravity will cause difficulty in fabricating maxillary pros-

Fig. 1. Initial findings. (A) Extraoral view showed swelling and facial asymmetry of left labial side. (B) Intraoral view revealed a 6x4 cm2 verrucous mass on left maxillary gingiva and hard palate. (C) Panoramic film revealed no tumor-related bony change.

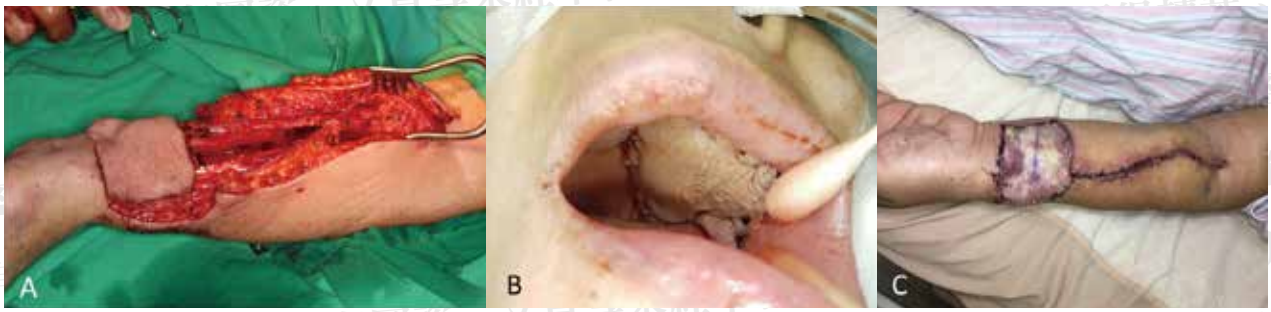

Fig. 2. Free flap reconstruction. (A) The radial forearm free flap was harvested from left arm. (B) Intraoral view of maxilla. (C) Donor site condition after free flap reconstruction.

theses[6-8]. In the case presented herein, an implant-retained overdenture was delivered to the patient, through the cooperative efforts of an oral surgeon and prosthodontist, to assist in the revision of the soft tissue after maxillary free flap reconstruction. This method provided not only a stable supporting area for the complete dentures, but also oral function during the healing period.

Clinical Report

A 70-year-old female patient visited the Oral and Maxillofacial Surgery Department of Taipei Medical University on 2016-10-12 with a complaint of gingival overgrowth noted for 6 months. She had recently suffered difficulty in wearing her dentures and exhibited obvious facial swelling.

Original status:

Intraoral examination showed a 6x4 cm^2 verrucous mass located on the left maxillary gingiva and hard palate. This pink, soft, and cauliflower-like mass extended over the upper left vestibule and left side of the soft palate. No bony change was noted in the panoramic examination (Fig. 1).

A biopsy was performed, and the pathological verification proved the diagnosis of squamous cell carcinoma. A wide excision for tumor removal combined with a partial maxillectomy was conducted, and the defect was immediately reconstructed with the radial forearm free flap (Fig. 2). The patient recovered well after the reconstruction.

Status after tumor excision and free flap reconstruction:

Six months later, the patient was referred to the prosthodontic department. An area of soft and mobile skin was found intraorally at the previously reconstructed site of the left maxilla. Scar constriction was noted around the flap-mucosa junction, mostly at the anterior margin, which drew down the upper lip and caused facial asymmetry (Fig. 3A).

A computed tomography scan of the maxilla revealed bony defects at the surgical site, especially around the canine to second premolar area, which was well covered by the faciocutaneous flap to prevent possible oroantral communication (Fig. 3B).

Since the patient had been wearing complete dentures for more than 30 years, and since she asked for a prosthesis that would be simple and easy to clean, a removable prosthesis was proposed. However, it was thought that the highly mobile and deformable flap might jeopardize denture retention and stability. Treatment options were discussed with the patient, and an implant-assisted overdenture was

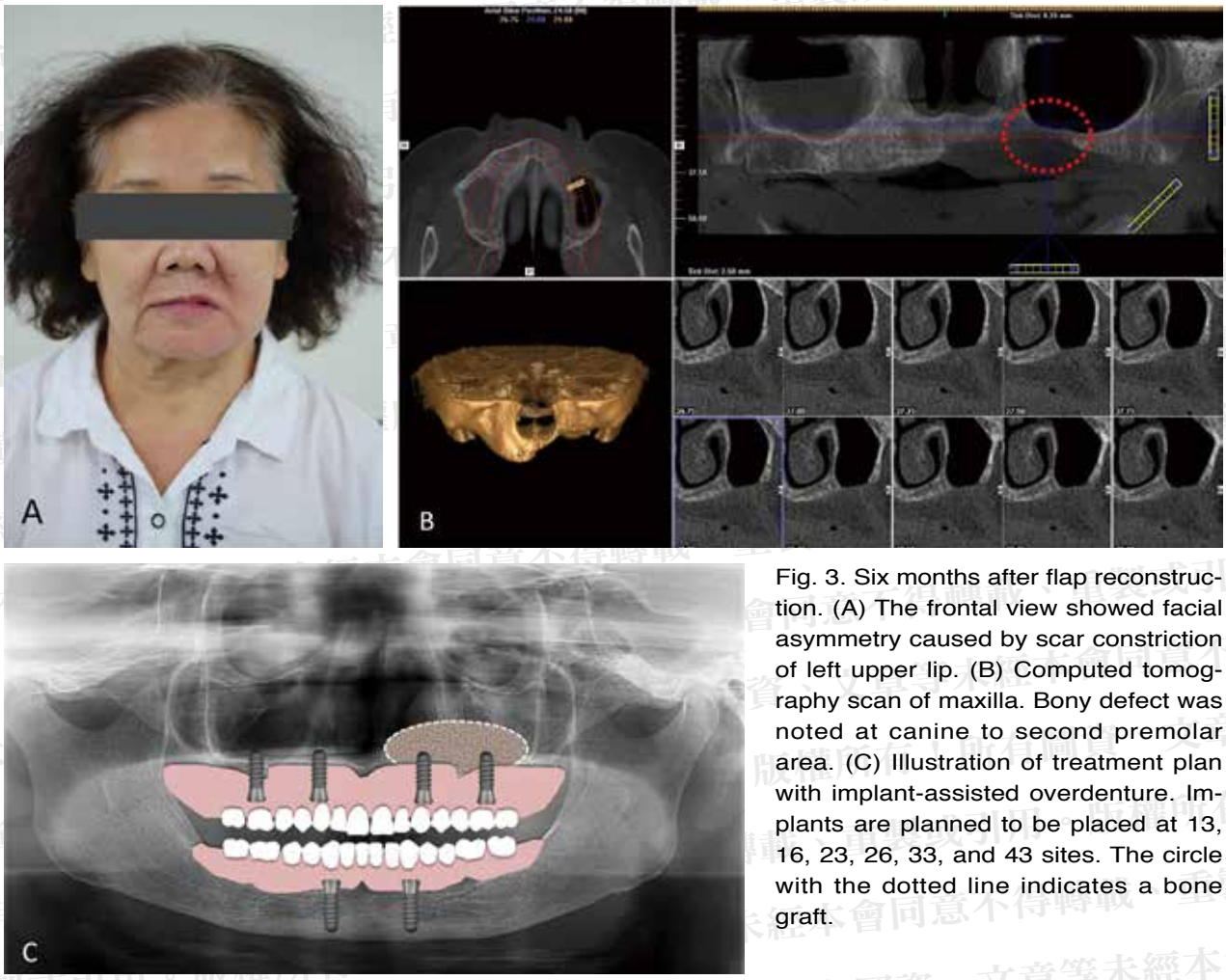

Fig. 3. Six months after flap reconstruction. (A) The frontal view showed facial asymmetry caused by scar constriction of left upper lip. (B) Computed tomography scan of maxilla. Bony defect was noted at canine to second premolar area. (C) Illustration of treatment plan with implant-assisted overdenture. Implants are planned to be placed at 13, 16, 23, 26, 33, and 43 sites. The circle with the dotted line indicates a bone graft.

suggested. The planned implant sites were 13, 16, 23, and 26 in the maxilla, and 33 and 43 in the mandible (Fig. 3C).

A staged treatment approach was conducted. The first stage consisted of a preparation stage for the flap revision. It included implant surgery for the 13, 16, 33, and 43 implant sites and complete denture fabrication. In the following revision surgery stage, the implant-retained maxillary denture would be fixed to the palate with Locator attachments and bone screws, and the denture would serve not only as a surgical stent but also as a masticatory apparatus during the one-month healing process.

The second stage consisted of the flap revision surgery itself. The entire flap margin except the labial margin was revealed, and the revealed flap was elevated and pushed out toward the labial-buccal direction to serve as the new labial and buccal mucosal lining, whereas the palatal wound was left to heal secondarily.

The third stage will consist of sinus floor elevation and implant placement at the 23 and 26 sites. After osseointegration, the upper denture will be readjusted to pick up the Locator metal housing of the 23 26 site implants, and the full-mouth complete dentures retained by the implant attachments (four in the maxilla and two in the mandible) will serve as the definitive prosthesis.

The first stage: implant placement over 13, 16, 33, and 43 sites and fabrication of complete dentures.

Three months after the implant placement, the patient was referred to the prosthodontic department for fabrication of the complete dentures. Clinical examination revealed fully edentulous maxillary and mandibular ridges, with 4 implants placed at the 13, 16, 33, and 43 positions. The implants at the 13 and 16 positions were Ø4.1 mm and 12 mm in length (Bone level implant, Regular CrossFit Connection, Straumann®), and the implants at the 33 and 43 positions were Ø4.1 mm and 10 mm in length (Standard plus, Regular Neck, Straumann®)

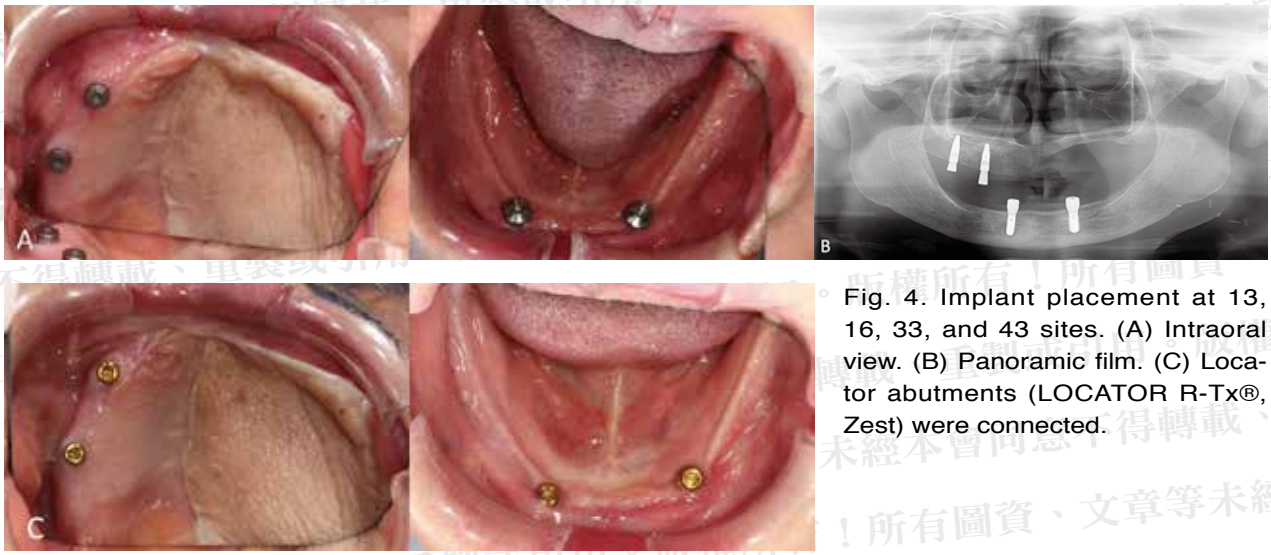

Fig. 4. Implant placement at 13, 16, 33, and 43 sites. (A) Intraoral view. (B) Panoramic film. (C) Locator abutments (LOCATOR R-Tx®, Zest) were connected.

(Fig. 4A, Fig. 4B).

The fabrication of the implant-assisted overdenture was soon completed. Locator abutments (LOCATOR R-Tx®, Zest) were connected to the fixtures with 35 Ncm torque (Fig. 4C). Individual trays were used to make the final impression with additional type silicon impression material (Exadenture, GC Co. Tokyo, Japan). A series of processes including taking the vertical dimension, bite registration, and wax denture try-in were performed, with the aim of achieving bilateral balanced occlusion(Fig. 5).

At the delivery appointment, the dentures were first roughly adjusted to allow the patient to occlude without denture rocking. Then the areas opposite the Locator abutments were relieved and small escape holes were drilled, and the metal housings

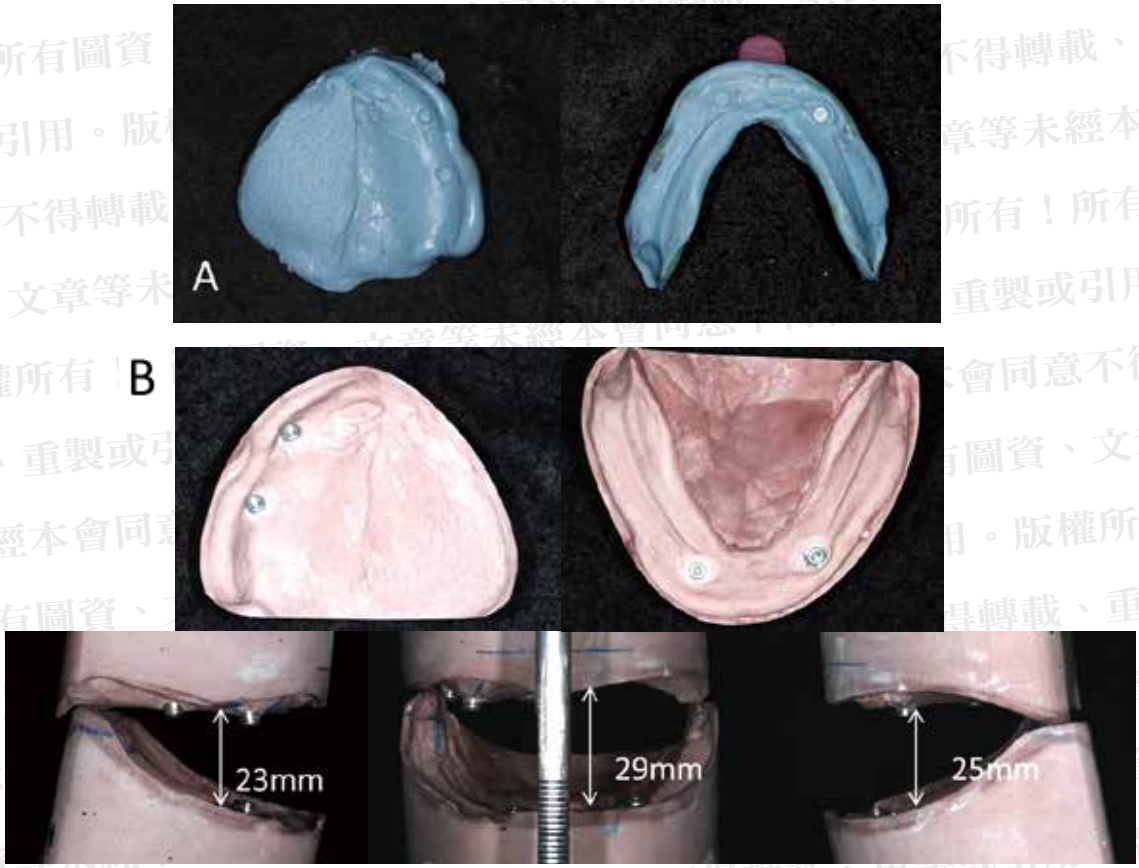

Fig. 5. Processes of denture fabrication. (A) Final impression. (B) Master cast on articulator. (C) Wax dentures. (D) Intraoral view with new dentures. Bilateral balanced occlusion was effectively achieved. (E) Extraoral view with new dentures.

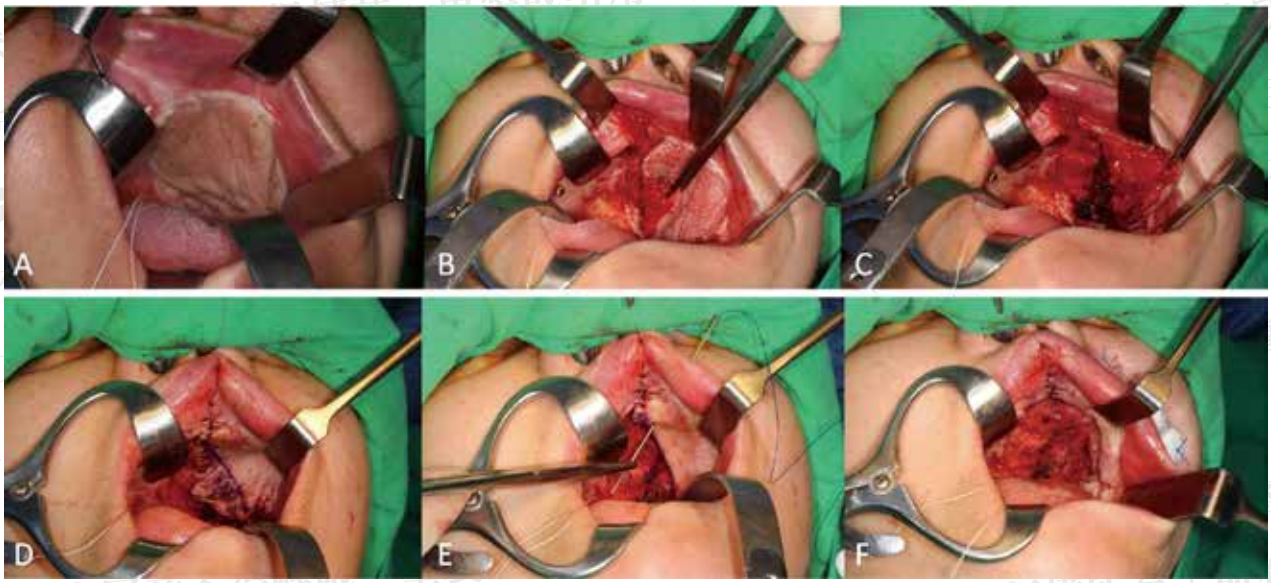

Fig. 6. Free flap revision. (A) Intraoral view before revision surgery. (B) The flap was lifted from palate. (C) The fatty tissue underneath was exposed then removed. (D) Extra part of the flap was marked and excised. (E) The lifted flap was transported to labial-buccal area and fixed trans-facially with straight needle and 2-0 prolene. (F) Intraoral view after flap transposition.

Fig. 7. Denture relining. (A) The correct position of maxillary denture was checked again. (B, C, D) The left part of the denture was relined with self-cured, hard denture reline material. (E, F) The denture was fixated with bone screws. (G) The occlusion of the dentures was checked again.

were picked up with self-cure acrylic (UNIFAST™ TRAD, GC) at chairside. The mandibular denture was processed first, followed by the maxillary denture. The patient was told to close her denture teeth together when we picked up the metal housing. The occlusion of the dentures was checked and adjusted again after the pick-up procedure.

Since the left anterior border of the maxillary denture was affected by the scarring of the skin flap around the 23-25 area, the denture had no labial and buccal flange at this time.

The second stage, part 1: free flap revision using complete dentures as a compression splint

After the denture delivery, the patient was closely monitored for one month to ensure that she was doing well with the new dentures. The flap revision was then arranged on 2018-01-03.

With the patient under general anesthesia, the bulky flap was carefully lifted from the palate, and the fatty tissue was removed. The lifted flap was transported to the labial buccal area and fixed by trans-facial fixation using 2-0 prolene carried by a straight needle. This procedure was intended to create the vestibule part of the left maxilla, which was previously covered by a soft and mobile skin flap. The flap transposition also allowed the surface of the

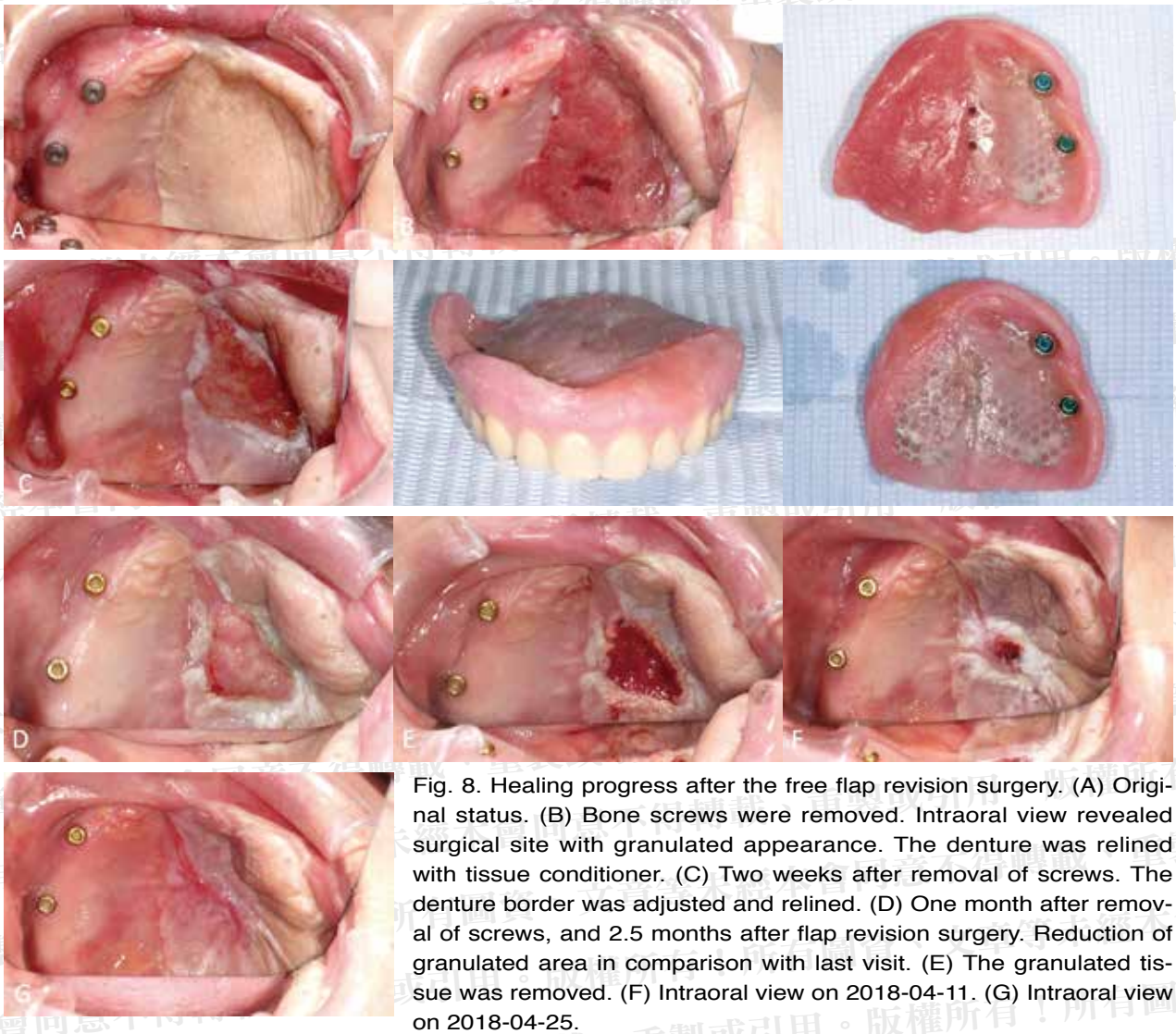

Fig. 8. Healing progress after the free flap revision surgery. (A) Original status. (B) Bone screws were removed. Intraoral view revealed surgical site with granulated appearance. The denture was relined with tissue conditioner. (C) Two weeks after removal of screws. The denture border was adjusted and relined. (D) One month after removal of screws, and 2.5 months after flap revision surgery. Reduction of granulated area in comparison with last visit. (E) The granulated tissue was removed. (F) Intraoral view on 2018-04-11. (G) Intraoral view on 2018-04-25.

hard palate and the alveolar ridge to be exposed for secondary healing (Fig. 6).

The surgical site of the denture was then relined with self-cured, hard denture reline material (Tokuyama® Rebase II) to compensate for the loss of great volume after the flap transposition. Considering that the denture would be fixated intraorally for at least one month, the hard reline material was chosen instead of soft reline material to reduce the possibility of contamination in the oral environment. Moreover, the Locators at the 13 and 16 positions and the right part of the palate helped to retain and locate the denture intraorally. Then, two bone screws were used to fixate the denture onto the hard palate (Fig. 7).

The second stage, part 2: status after lateralization of free flap; secondary healing of palate and mucosalization

Regular follow-up appointments were scheduled for every one or two weeks after the surgery. On 2018-02-21, the screws were removed, and the tissue underneath the denture showed redness and a granulated appearance as it proceeded through the secondary wound healing process. The denture was then adjusted and relined with tissue conditioner (Tempo™ tissue conditioner, Lang Dental Mfg Co Inc.) at the same appointment (Fig. 8A, Fig. 8B).

Two weeks later, the soft tissue was still undergoing the normal healing process. However, the patient had difficulty in wearing the denture and was scared by the mild oozing of the surgical site, so she did not wear the prostheses for 2 weeks. Scar contraction of left buccal border was noted. The denture was adjusted, and the tissue conditioner was replaced (Fig. 8C). On 2018-03-21, intraoral examination revealed reduction of the granulated

area. The granulated tissue was removed to allow the surrounding mucosa to grow in (Fig. 8D, Fig. 8E).

At the follow-up appointment on 2018-04-11, continuous reduction of the granulated area was observed. On 2018-04-25, intraoral examination revealed a great result in terms of the tissue healing of the left palate (Fig. 8F, Fig. 8G).

Compared to the mobile fascopcutaneous flap, the newly grown soft tissue was firm and stable. The soft reline material was thus replaced with self-cured denture reline material (Tokuyama® Rebase II). As the patient adapts to the relined denture, the last two stages of the treatment, which will include left sinus floor elevation, implant placement at the 23 and 26 sites, and re-adjustment of the upper complete denture to fit the new attachments, will be performed.

Discussion

Palatal obturators and flap reconstruction have been commonly used in patients with acquired maxillary defects. However, there is still no consensus in terms of comparisons between the two methods. Those who advocate the use of obturator prostheses consider its advantages to include the shorter operating time, shorter post-operative hospital stay, and lower complication rate in comparison with flap reconstruction[2]. In addition, with an obturator, the defect itself may contribute to the support, stability, and retention of the prosthesis and may increase its success rate[1,6,7]. Moreover, the maxillectomy cavity can be completely visualized during follow-up appointments[6].

Still, there are some disadvantages to this technique, such as the potential for hypernasal speech, the regurgitation of foods and liquids into the nasal cavity, and the need for repeated prosthesis adjustments due to progressive changes in the size and shape of the palatal defect. Difficulty in maintaining the hygiene of the maxillectomy cavity may also cause inconvenience to the patient. Moreover, it is sometimes more difficult to use an obturator in patients who have acquired large palatal defects, as the prosthesis may be overly heavy and difficult or impossible to retain, particularly in partially or totally edentulous patients[2].

As such, surgical reconstruction of the palatal defect with the free flap also has some advantages, which include closure of the oral cavity[1], the reduction of speech and swallowing problems[6], and the provision of psychological benefits to the patient in terms of comfort, convenience, and social interactions.[4] Moreover, surveillance of the area can be performed with a nasoendoscope. In addition, computed tomography (CT) and magnetic resonance imaging (MRI) can also be used as monitoring tools[6].

Previous studies have compared obturator prostheses with flap reconstructions in terms of patient functions and quality of life[2-5]. Some studies have suggested that different methods can be chosen based on the defect size. Okay et al[1] provided a classification system that divided maxillary defects into three types, and established an algorithm for palatomaxillary reconstruction according to the defect type.

Defects that involved the hard palate but not the tooth-bearing alveolus were categorized as class Ia, while class Ib defects were defined as those involving the premaxilla or any portion of the maxillary alveolus and dentition posterior to the canines. Class I palatomaxillary defects can be rehabilitated with a prosthetic obturator or soft tissue to achieve optimal orodental restoration. Soft tissue reconstruction can be achieved with either a local advancement flap or a fasciocutaneous free flap. Class II defects that involve an ipsilateral single canine can be rehabilitated with an obturator prosthesis or a vascularized bone-containing free flap (VBCFF). In contrast, class III defects involving more than 50% of the hard palate can be better managed with a VBCFF. The bone-containing free flap can re-establish the alveolar arch, and can provide a stable base for function and implant prosthodontics.

Moreno et al.[2] concluded that moderate-sized maxillectomy defects involving the palate can be successfully treated with either an obturator or free flap reconstruction. Extensive defects have a better functional outcome with free flaps. However, in the study by Genden et al.[4], the authors concluded that free flap reconstructions improve patient quality of life and function more effectively than an obturator prostheses, even in patients with small and medium size defects of the hard palate.

In our case, the patient had been edentulous for more than 30 years, and the maxillary ridge was thin. Oro-nasal communication was thus observed at the left anterior area after partial maxillectomy. Although immediate flap reconstruction separated the oral and nasal cavities and spared the patient from any possible inconvenience, its mobility and scar constriction have made the fabrication of complete dentures difficult. Even with the help of implants, the stability and retention of the complete dentures are still unfavorable due to the fatty tissue contained in the free flap.

From the previous study by Badran et al.[9], we knew that even though the epithelium of the flap may sometimes change to resemble normal buccal epithelium, the underlying connective tissue will retain the structure of dermis, and will not represent a truly permanent change in epithelial type. Simply removing the fat from the flap might reduce the vol-

ume and softness of the flap to some degree, but the mobility of the skin surface would still affect denture stability. Futhermore, it would be hard to maintain the hygiene of the implants which are currently planned to be placed at the 23 and 26 sites.

In order to create a firm and stable denture-bearing area, we performed a second flap revision surgery with the assistance of a denture prosthesis. During this surgery, the excessive part of the flap covering hard palate was cut off, and the remaining part of the flap was defatted and attached to the buccal side. This procedure transported the mobile part of the flap to the buccal cheek to improve the denture retention and stability. The surface of the left palate was left exposed in the oral cavity for secondary healing, and the complete denture fabricated at the previous stage was used as a surgical stent to protect the palate from irritation. Also, fixating the denture to the palate would help keep the transported flap in position and, to some degree, prevent scar constriction so that the denture-bearing area created could be maintained. The case report of Dexter et al.[6] discussed a similar method of fixing an old denture as a surgical stent. In contrast with our case, however, Dexter simultaneously used the denture in the maxillectomy and flap reconstruction surgery. In both cases, the denture served as a transitional surgical stent, or obturator. The denture was then relined with soft liner after the screws were removed, and then relined again with self-cured hard relining acrylic material after the soft tissue healed.

In the case reported herein, the healed palatal mucosa now shows a firm and stable appearance and is adequate for future denture bearing. The prosthetic-assistance method used thus constitutes a promising procedure for tissue management after free flap reconstruction and could provide not only a more stable denture-bearing area but also better quality of life during the transitional stage.

This clinical case report illustrated an interdisciplinary treatment provided via cooperation between a prosthodontic surgeon and an oral surgeon. Although further bone augmentation and implant placement have yet to be conducted, the progress completed thus far indicates that the method used was successful in improving denture stability at the flap reconstruction area.

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