Original Article

Loss of Muscle Mass in Patients Underwent Orthognathic Surgery

Naratorn Prachasartta[1], Kiti Siriwatana[1], Vorapat Trachoo[1], Suwimol Sapwarobol[2]

[1]Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand

[2]The Medical Food Research Group, Department of Nutrition and Dietetics, Faculty of Allied Health Sciences, Chulalongkorn University, Bangkok, Thailand

Abstract

Orthognathic surgery, a surgical intervention to correct dentofacial deformities, imposes oral intake limitations on patients for a duration up to 8 weeks, leading to weight loss and decreased muscle mass. Reduced muscle mass impairs the body's ability to acquire essential amino acids and cytokines, affecting its defence mechanisms against infection. We aimed to study the impact of orthognathic surgery on muscle mass. A study was conducted to examine changes in weight, body mass index (BMI), and muscle mass in patients following orthognathic surgery. Twenty-nine patients were included in the study. The patients' height, weight, BMI, and muscle mass were measured pre-operatively and 2 and 4 weeks post-operatively. Patients experienced an average weight loss of 3.5 kg at 2 weeks post-operation with only a marginal gain of 0.1 kg, resulting in a weight loss of 3.4 kg by the 4-week mark. The BMI decreased by an average of 1.3 at 2 weeks and remained unchanged at 4 weeks. Analysis of muscle mass revealed a drop of 2.0 kg at 2 weeks post-operation with subsequent marginal gain of 0.1 kg, leading to a total loss of 1.9 kg at the 4-week mark, accounting for 57.1 % and 55.9 % of the total weight loss. The site of the surgery, specifically the oral cavity, has a significant impact on the patients' nutritional intake and wound healing processes. Surgical interventions can lead to protein catabolism and muscle mass loss. The findings highlight the need for further research and the development of a specific nutritional therapy protocol to minimise postoperative complications and help patients maintain a balanced diet while dealing with a metabolic load.

Keywords : Orthognathic surgery, Postoperative muscle mass loss, Postoperative weight loss

Received Date: Jun 13, 2023 **Revised Date:** Jul 25, 2023 **Accepted Date:** Aug 11, 2023

doi: 10.14456/jdat.2023.27

Correspondence to :

Naratorn Prachasartta, Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University, 34 Henri-Dunant Road, Wangmai, Pathumwan, Bangkok, 10330, Thailand. Tel: 083-447-4436 E-mail: n.prachasartta@gmail.com

Introduction

Orthognathic surgery has gained popularity in recent years due to its ability to restore balanced anatomical and functional relationships and enhance the aesthetic facial appearance in patients with dentofacial deformity.[1] Dentofacial deformities can result in a range of negative outcomes, including impaired respiration, speech, chewing, temporomandibular joint disorders, and psychosocial distress, leading to the need for orthognathic surgery.[2] It has been documented that significant weight loss can occur as a prominent side effect following orthognathic

surgery.[3-6] Patients undergoing orthognathic surgery experience a 3.9 % decrease in body weight at two weeks post-operatively and a further 8.3 % decrease at four weeks post-operatively.[3,6]

The surgical intervention triggers hormonal responses that impact the body's metabolism, leading to the loss of muscle mass through muscle protein catabolism. This is caused by the activation of the sympathetic nervous system, which releases hormones that trigger the degradation of glycogen, fat, and protein storages and affect muscle tissue.[4,7] Muscle is broken down via proteolysis. This type of breakdown occurs when energy demands are high, such as stress response after surgery.[8] The surgical stress response results in negative nitrogen balance and accelerated muscle wasting, causing a decrease in muscle mass and function. This is due to the prioritisation of the production of positive acute phase for immune response and tissue repair over muscle protein by the liver and the negative impact of cytokines on muscle tissue, including promoting degeneration, inhibiting tissue synthesis and repair, and inducing apoptosis.[4,7]

Moreover, oral intake is reduced in patients undergoing orthognathic surgery. Since the patients are prescribed a clear or full liquid diet postoperatively to minimise chewing activity to promote bone healing, therefore patients are unable to take a regular diet for 6 or 8 weeks. If maxillomandibular fixation (MMF) is applied after surgery, which is widely used to stabilize and promote the healing of osteotomized bones, then patients are required to take liquid diet until the MMF is removed.[5,9] Therefore, patients undergoing orthognathic surgery are subject not only to the hormonal and cytokine response resulting from the surgical intervention, but also to a restriction in oral nutrition intake, and these potentially exacerbate the extent of muscle mass loss.

To address the limited literature on postoperative muscle mass loss in orthognathic surgery patients, we carried out a study at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University in Bangkok, Thailand. We aimed to provide valuable insights into the impact of orthognathic surgery on muscle mass.

Materials and Methods

Twenty-nine patients with dentofacial deformity who were scheduled for either a bilateral sagittal split osteotomy or a Le Fort 1 osteotomy or both, with or without genioplasty, at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University, from May to November 2022, were prospectively recruited to the study. Certain inclusion and exclusion criteria were established to ensure the homogeneity and representativeness of the study population. Patients under the age of 18, those with pre-existing medical conditions, and those undergoing segmental or genioplasty procedures only were excluded from the study. Internal miniplate fixation and MMF were applied to all patients. Postoperative care was given by the attending surgical and anaesthetic staff as clinically indicated. MMF was applied for two weeks following surgery. In such a manner, all patients were required to consume a full liquid diet for 4 weeks. Hospitalized patients were given a clear liquid diet on the first post-operative day, followed by a full liquid diet until their discharge. After the 4-week period, a soft diet was started and progressed to regular diet after the 6-week period.

Prior to surgery, as well as 2 and 4 weeks post-operatively, the patient underwent assessments for height, weight, BMI, and muscle mass. The height measurement was conducted using a standardised measuring device that was applied consistently across all patients. Weight and muscle mass were assessed utilising the Bio Tanita MC-580 dual frequency segmental body composition analyser (Tanita Inc., Tokyo, Japan), which was validated for the assessment of body composition.[11]

Each participant was fully informed about the purpose of the study and provided written informed consent for the use of their clinical data. The collected datawere subjected to statistical analysis using the Mann–Whitney U test with SPSS 22.0 software (SPSS Inc., Illinois, United States of America).

The study received approval from the Human Research Ethics Committee of the Faculty of Dentistry at Chulalongkorn University in Bangkok, Thailand. The assigned ethical code for the project is HREC-DCU 2022 - 008.

Results

The study enrolled a total of 29 patients (Table 1). In the 2-week post-operative period, a significant decrease was observed in body weight, BMI, and muscle mass (Fig. 1) (Table 2-3), accounting for 57.1% of the total weight loss. Similarly, in the 4-week post-operative period, there was a significant reduction in body weight, BMI, and muscle mass (Fig. 1) (Table 2-3), contributing to 55.9 % of the total weight loss. Ninety-three percent of the patients experienced a loss of muscle mass, with two patients showing an increase in muscle mass (Table 2).

No statistically significant difference was observed between male and female patients in terms of weight loss, decrease in BMI, and reduction in muscle mass (Table 4).

Table 1 *Clinical background of patients underwent orthognathic surgery*

Characteristics	Patients (n=29)
Male/female	13/16
Single-jaw surgery/ double-jaw surgery/double-jaw surgery with genioplasty	11/15/3
Age	27 (20 to 48)
Preoperative body weight (kg)	59.0 (41.2 to 99.7)
Preoperative BMI (kg/m^2)	21.8 (15.9 to 29.1)
Preoperative muscle mass (kg)	41.3 (31.2 to 66.2)

Data are number or mean (range)

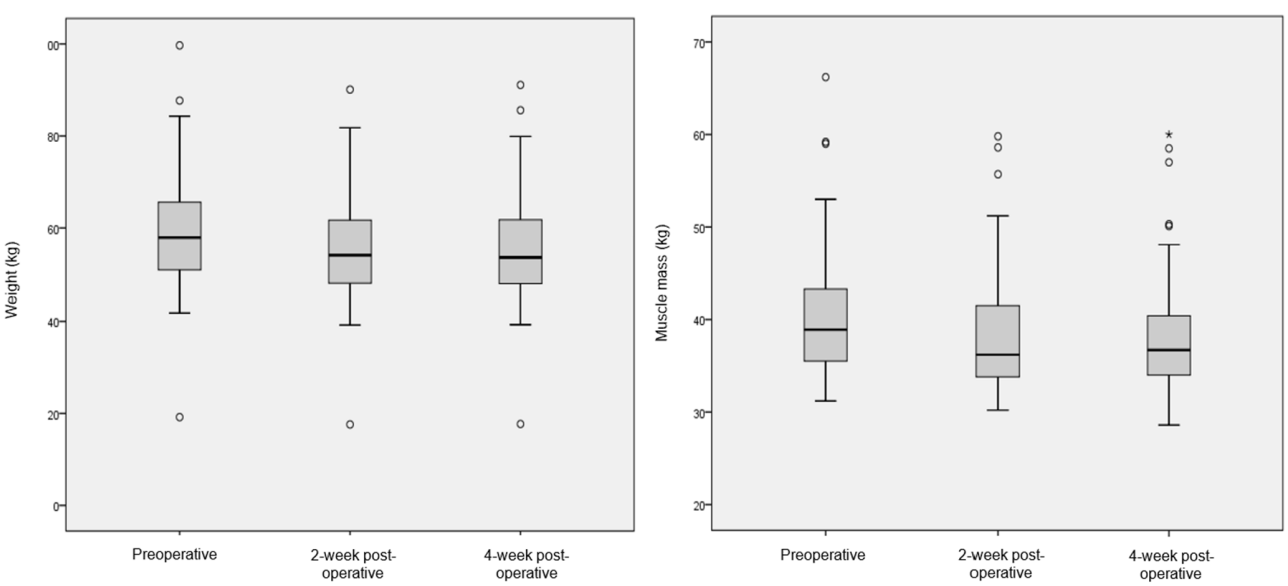

Figure 1 *The body weight and muscle mass of patients at preoperative period, 2-week post-operative period, and 4-week post-operative period*

Table 2 *The changes in body weight, BMI, and muscle mass in all 29 patients at 2-week post-operative period and 4-week post-operative period compared with the preoperative period*

Operation	Weight change at T1 (kg)	Weight change at T2 (kg)	BMI change at T1 (kg/m^2)	BMI change at T2 (kg/m^2)	Muscle mass change at T1 (kg)	Muscle mass change at T2 (kg)
Single jaw	-4.5	-2.5	-1.4	-0.8	-1.8	-2.7
Single jaw	-3.0	-3.0	-1.3	-1.3	-1.2	-1.7

Table 2 *The changes in body weight, BMI, and muscle mass in all 29 patients at 2-week post-operative period and 4-week post-operative period compared with the preoperative period (cont.)*

Operation	Weight change at T1 (kg)	Weight change at T2 (kg)	BMI change at T1 (kg/m^2)	BMI change at T2 (kg/m^2)	Muscle mass change at T1 (kg)	Muscle mass change at T2 (kg)
Single jaw	-5.3	-5.8	-1.8	-2.0	-3.0	-3.6
Single jaw	-3.9	-4.4	-1.2	-1.4	-0.4	-0.5
Single jaw	-3.8	-4.6	-1.4	-1.7	-2.0	-2.0
Single jaw	-2.2	0.3	-0.9	0.1	-1.4	0.7
Single jaw	-3.7	-3.3	-1.5	-1.3	-1.5	-0.9
Single jaw	-3.3	-3.7	-1.3	-1.5	-1.1	-0.9
Single jaw	-5.2	-4.7	-1.8	-1.6	-2.4	-2.1
Single jaw	-3.5	-2.5	-1.3	-0.9	-1.2	-1.0
Single jaw	-2.1	-1.7	-0.8	-0.7	-1.4	-0.8
Double jaw	-2.0	-3.0	-0.8	-1.2	-1.8	-2.9
Double jaw	-3.9	-4.6	-1.4	-1.7	-2.6	-2.1
Double jaw	-4.3	-4.3	-1.6	-1.6	-2.7	-2.0
Double jaw	-1.2	-2.3	-0.5	-1.0	-0.2	-0.1
Double jaw	-1.3	-0.8	-0.4	-0.3	-0.1	0.6
Double jaw	-9.6	-8.6	-2.8	-2.5	-6.4	-6.2
Double jaw	-2.6	-2.4	-0.9	-0.9	-1.8	-1.3
Double jaw	-2.6	-2.5	-1.0	-0.9	-1.6	-2.3
Double jaw	-4.3	-5.4	-1.5	-1.9	-2.9	-2.3
Double jaw	-3.2	-3.5	-1.2	-1.3	-3.4	-3.6
Double jaw	-1.7	-1.9	-0.7	-0.8	-1.3	-1.5
Double jaw	-2.5	-2.8	-1.5	-0.9	-1.4	-1.7
Double jaw	-3.7	-3.5	-1.3	-1.3	-1.6	-1.7
Double jaw	-5.9	-2.1	-1.9	-0.7	-3.5	-2.2
Double jaw	-4.9	-3.0	-1.8	-2.1	-4.4	-3.1
Double jaw + genioplasty	-2.3	-6.8	-0.9	-2.6	-0.6	-2.8
Double jaw + genioplasty	-1.6	-1.5	-1.6	-1.5	-2.8	-2.9
Double jaw + genioplasty	-2.0	-3.9	-0.8	-1.6	-1.0	-2.6
Average (S.D.)	-3.5 (1.7)	-3.4 (1.8)	-1.3 (0.5)	-1.3 (0.7)	-2.0 (1.3)	-1.9 (1.4)
N=29						
P value	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

T1 at 2-week post-operative period, T2 at 4-week post-operative period

Table 3 *The percentage of average changes in body weight, BMI, and muscle mass in all 29 patients at 2-week post-operative period and 4-week post-operative period compared with the preoperative period*

Weight change at T1	Weight change at T2	BMI change at T1	BMI change at T2	Muscle mass change at T1	Muscle mass change at T2
-5.93 %	-5.76 %	-5.96 %	-5.96 %	-4.84 %	-4.60 %

T1 at 2-week post-operative period, T2 at 4-week post-operative period

Table 4 *The average changes in body weight, BMI, and muscle mass between male and female patients*

	Male (n=13)	Female (n=16)	*P*-value
Weight change at T1 (kg)	-3.9 (2.2)	-3.1 (1.1)	0.46
Weight change at T2 (kg)	-3.6 (2.1)	-3.3 (1.5)	0.91
BMI change at T1 (kg/m^2)	-1.4 (0.6)	-1.2 (0.4)	0.24
BMI change at T2 (kg/m^2)	-1.4 (0.7)	-1.3 (0.5)	1.00
Muscle mass change at T1 (kg)	-2.3 (1.8)	-1.7 (0.8)	0.42
Muscle mass change at T2 (kg)	-2.4 (1.6)	-1.6 (1.0)	0.07

Data are mean (S.D.)
T1 at 2-week post-operative period, T2 at 4-week post-operative period

Discussion

The study aimed to analyse weight, BMI, and muscle mass changes in patients after orthognathic surgery. Twenty-nine patients underwent the procedure, and their weight, BMI, and muscle mass were measured 2 weeks and 4 weeks after the surgery. The results showed that the patients had an average weight loss of 3.5 kg at 2-week post-operative period with only a marginal gain of 0.1 kg, resulting in a weight loss of 3.4 kg by the 4-week mark. The average decrease in BMI was 1.3 in the first two weeks, but remained unchanged in the fourth week. Additionally, the muscle mass of the patients declined by an average of 2.0 kg at 2-week post-operative period with subsequently marginal gain of 0.1 kg, leading to a total loss of 1.9 kg at the 4-week mark, accounting for 57.1 % and 55.9 % of the total weight loss, respectively (Table 2).

The surgery site is a major factor that can impact nutrition intake. Diseases and surgeries in the oral and maxillofacial regions can disrupt food intake. Patients undergoing orthognathic surgery may be limited to a liquid diet for up to 8 weeks. If MMF is applied, patients may be limited to a liquid diet until MMF is removed, further reducing caloric intake, and exacerbating the issue.[5,9] Patients undergoing orthognathic surgery in our department were applied with MMF for a period of 2 weeks, restricting them to liquid diets. Our post-op diet protocol progressed from clear liquid, full liquid, soft, and regular diets over 6 weeks. It is important to note that the lack of improvement in weight, BMI, and muscle mass at the 4-week post-operative mark compared to the 2-week post-operative period in this study can be reasonably attributed to the patients' continued adherence to a liquid diet during this recovery phase. Relying solely on a liquid diet during this time falls short in providing the necessary support for effective muscle recovery and growth. Furthermore, the surgical intervention can activate the sympathetic nervous system and cause alterations in metabolism through the secretion of hormones and cytokines. This results in the glycogenolysis, fatty acid oxidation and proteolysis, releasing glucose, free fatty acids, and amino acids into the circulation contributing to a decrease in muscle mass.[4,7,12] Additionally, the secretion of cortisol also directly promotes the catabolism of muscle tissue, resulting in the proteolysis and release of amino acids for tissue repair and synthesis, further contributing to the reduction in muscle mass.[12]

Two patients demonstrated an increase in muscle mass at 4 weeks post-op (Table 2). This increase is likely due to their consistent participation in resistance training exercises, which they resumed 2 weeks after surgery, as supported by scientific literature that recognises resistance training as an effective way to promote muscle protein synthesis.[13] These findings highlight the significance of resistance training in maintaining or increasing muscle mass in those who undergo surgery. The results emphasise the need for resistance training to be incorporated as a key component in postoperative rehabilitation.

There was no statistically significant difference in weight loss, decrease in BMI, and muscle mass loss between male and female patients (Table 4). The results

align with recent researches that disprove the idea of disparities in muscle protein metabolism between men and women.[14,15] Testosterone plays a crucial role in regulating muscle protein metabolism. It stimulates muscle protein synthesis and has anabolic effects. This, in turn, enhances the production of new muscle and reduces muscle breakdown, resulting in an overall increase in muscle mass. The differences in testosterone levels between men and women, with men typically having higher levels,[16] have resulted in the common assumption that men possess a clear advantage in muscle protein synthesis compared to women. However, recent studies have discovered that female hormones play important roles in muscle building and maintenance. Progesterone has been shown to stimulate muscle protein synthesis. Additionally, estrogen has been shown to have a dual effect on muscle tissue, both promoting muscle protein synthesis and inhibiting muscle protein breakdown.[17,18] It is acknowledged that hormones represent only one aspect of the determinants of muscle mass. Other factors include physical activity, diet, and genetics.[19] Despite the hormonal differences, both genders can benefit from a balanced diet and regular exercise programmes to promote muscle growth and maintenance.

A change in muscle mass in orthognathic surgery patients has not been extensively researched. The most recent study conducted by Worrall in 1994 found that after 6 weeks, patients treated with MMF lost 0.9 kg of body mass, while patients treated with miniplate only lost 0.3 kg. This indicates that the use of MMF may have a greater impact on muscle mass compared to miniplate fixation in patients who underwent orthognathic surgery or treatment of jaw fractures.[5] A more recent study investigated acute muscle loss resulting from surgery in patients who underwent gastrectomy. The study found 31.82 % of patients, experienced a loss of over 10 % of their muscle mass within one week after the surgery. This muscle loss was linked to decreased quality of life, as well as an increased frequency of post-operative complications, longer hospital stays, and higher medical expenses.[20] In comparison to this study, the loss of muscle mass in patients who underwent orthognathic surgery may appear to be relatively lower, but it is crucial to recognise that such a loss could lead to negative consequences. However, it is crucial to acknowledge the potential adverse effects of such a loss. The literature suggests that decreased muscle mass can impair the wound healing process and reduce the efficacy of the immune system both of which elevate the probability of postoperative complications.[4,7,10] Thus, the loss of muscle mass should be taken into consideration and monitored carefully to minimise the potential negative impacts. In our center, a study was conducted over the course of ten years from 2009 to 2018 to examine the occurrence of adverse events and complications associated with orthognathic surgery. The analysis included 891 patients. Although 85 % of the patients received post-operative intravenous antibiotics, followed by oral medications after discharge, 4.9 % of them still encountered post-operative infections.[21]

Despite advancements in surgical techniques, including the use of miniplates for bone stabilization and shortened or eliminated MMF periods, the incidence of postoperative weight loss has remained comparable to that observed in previous decades.[5,6,22,23] These findings highlight the persistent of this issue and the need for determining potential solutions. Orthognathic surgery is mainly dependent on successful bone healing, and adequate protein intake plays a crucial role in this process. Protein is essential for the synthesis of new tissues, activation of cells involved in the healing process, and regulation of the balance between bone resorption and formation. Adequate protein intake can aid in supporting the healing process and minimising the risk of complications.[12,24] Reduced nutrient intake affects glucose utilisation in tissues. When food intake is low, the body initially utilises glucose from glycogenolysis in the liver, but if this persists for more than 48 hours, the body begins to break down muscle for glucose production through gluconeogenesis. This degradation of proteins for energy can have negative impacts on overall health and body functions.[5,12] To ensure successful healing and optimal outcomes, it is critical for

orthognathic surgery patients to maintain a balanced diet that includes sufficient amounts of protein.

The metabolic response plays a critical role in facilitating postoperative recovery and restoring physiological homeostasis. It involves adequate nutritional support and the interaction of various cellular and molecular mediators. Surgical outcomes are not solely determined by surgical techniques, but also by the patient's metabolic support and nutritional intervention. Effective nutrition therapy aims to provide enough nutrients to meet the metabolic demands of the healing process, thereby contributing to optimal restoration of the patient.[12] Inadequate nutrition can impair immunity and anabolism, negatively impacting wound healing, leading to postoperative complications, and decreased muscle mass. These findings highlight the significance of nutrition in postoperative outcomes.[25,26]

The management of postoperative muscle loss typically involves nutrition therapy as the initial approach. Adequate nutrition can significantly impact the nutritional status of patients and is crucial to improving the functional recovery, nutritional status, and quality of life of patients during the postoperative period.[27,28] Despite its potential impact, nutrition therapy has received limited attention in the field of orthognathic surgery. In 1984, Olejko and Fonseca found that preoperative nutritional supplementation for the purpose of inducing weight gain prior to surgery had no significant benefit for healthy orthognathic surgical patients. On the other hand, postoperative supplementation with commercially available dietary supplements has been shown to aid orthognathic surgical patients in maintaining their body weight.[23] A recent study was conducted on orthognathic surgery patients. The results showed that on average, the patients lost 4.96 kg, had a reduction of 3.07 % in body fat, and a decrease of 1.63 in their BMI at 4 weeks following the surgery, despite the fact that all patients were provided with dietary advice and commercially available liquid oral nutritional supplements by a dietician after the surgery.[6] The possible explanation for this could be the fact that the characteristics of oral nutritional supplements, such as taste, texture, and odour, can significantly impact the compliance of patients. To increase the likelihood of successful supplementation, it is important to consider variations in flavour and consistency. In this regard, results have shown that chocolate milk-based supplements tend to be less well received compared to those with vanilla, coffee, or strawberry flavour. Similarly, among fruit juice-based supplements, tomato flavour was observed to be more favourably received than orange or apple flavour.[29] It is noted that some patients may opt not to consume the prescribed oral nutritional supplements due to concerns over their appearance.[30] This misguided belief that they are losing weight without realising that it is primarily muscle mass that is being lost highlights the importance of providing comprehensive nutritional counselling as part of the nutritional therapy protocol.

The study's generalizability may be compromised due to its small sample size. However, the participants' relatively homogeneous clinical characteristics could help alleviate some of this limitation. Another factor contributing to potential bias is the single-centre study design, which could be influenced by the specific practices, protocols, and patient populations of our department. To enhance the reliability of the results, future researches should aim to conduct larger-scale, international multicentre studies with diverse settings.

Conclusion

The study's results indicate that patients who underwent orthognathic surgery experienced a reduction in weight, body mass index, and especially muscle loss in the immediate postoperative period, with no significant gender-based differences.

The success of orthognathic surgery is contingent upon both surgical expertise and nutritional support. The findings from this study emphasise the importance of investigating the alterations in weight and body composition, especially muscle, following orthognathic surgery. It is recommended to develop a specific nutrition therapy protocol for patients undergoing orthognathic

surgery. This plan should aim to prevent loss of muscle mass, enhance wound healing, and reduce the likelihood of postoperative complications. Implementation of such a protocol would contribute to optimising patient outcomes and recovery following orthognathic surgery.

Acknowledgement

We extend our sincere gratitude to Kanit Dhanesuan, Sunisa Rochanaibhata, and Wichuda Kongsong from the Department of Oral and Maxillofacial Surgery at the Faculty of Dentistry, Chulalongkorn University, for their support in allowing us to conduct this study on their patients.

Conflict of Interest Statement

There are no potential conflicts of interest to declare.

References

1. Weiss RO, 2nd, Ong AA, Reddy LV, Bahmanyar S, Vincent AG, Ducic Y. Orthognathic Surgery-LeFort I Osteotomy. ***Facial Plast Surg*** 2021;37(6):703-8.

2. Berger JL, Pangrazio-Kulbersh V, Bacchus SN, Kaczynski R. Stability of bilateral sagittal split ramus osteotomy: rigid fixation versus transosseous wiring. ***Am J Orthod Dentofacial Orthop*** 2000;118(4):397-403.

3. Ooi K, Inoue N, Matsushita K, Yamaguchi HO, Mikoya T, Kawashiri S, *et al.* Factors related to patients' nutritional state after orthognathic surgery. ***Oral Maxillofac Surg*** 2019;23(4):481-6.

4. Gillis C, Carli F. Promoting Perioperative Metabolic and Nutritional Care. ***Anesthesiology*** 2015;123(6):1455-72.

5. Worrall SF. Changes in weight and body composition after orthognathic surgery and jaw fractures: a comparison of miniplates and intermaxillary fixation. ***Br J Oral Maxillofac Surg*** 1994;32(5):289-92.

6. Hammond D, Williams RW, Juj K, O'Connell S, Isherwood G, Hammond N. Weight loss in orthognathic surgery: a clinical study. ***J Orthod*** 2015;42(3):220-8.

7. Margraf A, Ludwig N, Zarbock A, Rossaint J. Systemic Inflammatory Response Syndrome After Surgery: Mechanisms and Protection. ***AnesthAnalg*** 2020;131(6):1693-707.

8. Argilés JM, Campos N, Lopez-Pedrosa JM, Rueda R, Rodriguez-Mañas L. Skeletal Muscle Regulates Metabolism via Interorgan Crosstalk: Roles in Health and Disease. ***J Am Med Dir Assoc*** 2016; 17(9):789-96.

9. Hayter JP, Cawood JI. The functional case for miniplates in maxillofacial surgery. ***Int J Oral Maxillofac Surg*** 1993;22(2):91-6.

10. Fischer M, JeVenn A, Hipskind P. Evaluation of muscle and fat loss as diagnostic criteria for malnutrition. ***Nutr Clin Pract*** 2015; 30(2):239-48.

11. Vasold KL, Parks AC, Phelan DML, Pontifex MB, Pivarnik JM. Reliability and Validity of Commercially Available Low-Cost Bioelectrical Impedance Analysis. ***Int J Sport Nutr Exerc Metab*** 2019;29(4):406–10.

12. Badwal RS, Bennett J. Nutritional considerations in the surgical patient. ***Dent Clin North Am*** 2003;47(2):373-93.

13. Lopez P, Radaelli R, Taaffe DR, Newton RU, Galvão DA, Trajano GS, *et al.* Resistance Training Load Effects on Muscle Hypertrophy and Strength Gain: Systematic Review and Network Meta-analysis. ***Med Sci Sports Exerc*** 2021;53(6):1206-16.

14. Dreyer HC, Fujita S, Glynn EL, Drummond MJ, Volpi E, Rasmussen BB. Resistance exercise increases leg muscle protein synthesis and mTOR signalling independent of sex. ***Acta Physiol (Oxf)*** 2010;199(1):71-81.

15. Smith GI, Atherton P, Reeds DN, Mohammed BS, Jaffery H, Rankin D, *et al.* No major sex differences in muscle protein synthesis rates in the postabsorptive state and during hyperinsulinemia-hyperaminoacidemia in middle-aged adults. ***J Appl Physiol (1985)*** 2009;107(4):1308-15.

16. Vingren JL, Kraemer WJ, Ratamess NA, Anderson JM, Volek JS, Maresh CM. Testosterone physiology in resistance exercise and training: the up-stream regulatory elements. ***Sports Med*** 2010;40(12):1037-53.

17. Hansen M. Female hormones: do they influence muscle and tendon protein metabolism? ***Proc Nutr Soc*** 2018;77(1):32-41.

18. Smith GI, Yoshino J, Reeds DN, Bradley D, Burrows RE, Heisey HD, *et al.* Testosterone and progesterone, but not estradiol, stimulate muscle protein synthesis in postmenopausal women. ***J Clin Endocrinol Metab*** 2014;99(1):256-65.

19. Verbrugge SAJ, Schönfelder M, Becker L, Yaghoob Nezhad F, Hrabe de Angelis M, Wackerhage H. Genes Whose Gain or Loss-Of-Function Increases Skeletal Muscle Mass in Mice: A Systematic Literature Review. ***Front Physiol*** 2018;9:553.

20. Huang DD, Ji YB, Zhou DL, Li B, Wang SL, Chen XL, *et al.* Effect of surgery-induced acute muscle wasting on postoperative outcomes and quality of life. ***J Surg Res*** 2017;218:58-66.

21. Damrongsirirat N, Kaboosaya B, Siriwatana K, Subbalekha K, Jansisyanont P, Pimkhaokham A. Complications related to orthognathic surgery: A 10-year experience in oral and maxillofacial training center. ***J Craniomaxillofac Surg*** 2022;50(3):197-203.

22. Kendell BD, Fonseca RJ, Lee M. Postoperative nutritional supplementation for the orthognathic surgery patient. ***J Oral Maxillofac Surg*** 1982;40(4):205-13.

23. Olejko TD, Fonseca RJ. Preoperative nutritional supplementation

for the orthognathic surgery patient. ***J Oral Maxillofac Surg*** 1984; 42(9):573-7.
24. Sathyendra V, Darowish M. Basic science of bone healing. ***Hand Clin*** 2013;29(4):473-81.
25. Williams JZ, Barbul A. Nutrition and wound healing. ***Surg Clin North Am*** 2003;83(3):571-96.
26. Chandra R. Nutrition and immunity in the elderly: clinical significance. ***Nutr Rev*** 1995;53(4 Pt 2):S80-3; discussion S3-5.
27. Weimann A, Braga M, Carli F, Higashiguchi T, Hübner M, Klek S, *et al.* ESPEN guideline: Clinical nutrition in surgery. ***Clin Nutr*** 2017; 36(3):623-50.
28. Mitchell LJ, Ball LE, Ross LJ, Barnes KA, Williams LT. Effectiveness of Dietetic Consultations in Primary Health Care: A Systematic Review of Randomized Controlled Trials. ***J AcadNutr Diet*** 2017;117(12):1941-62.
29. Darmon P, Karsegard VL, Nardo P, Dupertuis YM, Pichard C. Oral nutritional supplements and taste preferences: 545 days of clinical testing in malnourished in-patients. ***Clin Nutr*** 2008;27(4):660-5.
30. Vulink NC, Rosenberg A, Plooij JM, Koole R, Bergé SJ, Denys D. Body dysmorphic disorder screening in maxillofacial outpatients presenting for orthognathic surgery. ***Int J Oral Maxillofac Surg*** 2008;37(11):985-91.