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The Effect of Different Socket Types on Implant Therapy While Using Flapless Ridge Preservation

Li-Ching Chang [1,2,]* and Yu-Min Cheng [3]

1 Department of Dentistry, Chang Gung Memorial Hospital, Chiayi 613, Taiwan
2 Department of Nursing, Chang Gung University of Science and Technology, Chiayi 613, Taiwan
3 Cheng's Dental Office, Pingtung 900, Taiwan; fredchengdds@gmail.com
* Correspondence: liching@ms39.hinet.net; Tel.: +886-5-3621000 (ext. 2277)

Featured Application: Considering socket types in flapless ridge preservation may improve implant therapy.

Abstract: This retrospective study compared the effects of different extraction sockets when using flapless ridge preservation during dental implant therapy. The extraction sockets were divided into four groups: Class I, intact soft tissue wall and bone walls; Class II, intact soft tissue wall with the destruction of at least one bone wall; Class III, the recession of all soft tissue walls by $\leq$5 mm; and Class IV, the recession of at least one soft tissue wall by >5 mm. We compared clinical parameters of dental implant therapy using flapless ridge preservation among these groups. Seventy patients with 92 dental implants, including 53 maxillary and 39 mandibular implants, involving flapless ridge preservation were enrolled. The implant survival rate was not affected by socket morphology. Total treatment time from extraction to final prosthesis placement was significantly longer in Class II and III than in Class I, among the maxillary sockets. However, there was no significant difference in the total treatment time among the different groups in the mandible. Therefore, implant survival rates did not differ according to socket morphology; however, total treatment time was significantly affected by socket morphology in the maxilla and was longer in socket classes associated with periodontitis.

Keywords: implant survival rate; ridge preservation; extraction socket; dental implant

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Citation: Chang, L.-C.; Cheng, Y.-M. The Effect of Different Socket Types on Implant Therapy While Using Flapless Ridge Preservation. *Appl. Sci.* **2021**, *11*, 970. https://doi.org/10.3390/app11030970

Academic Editor: Nissan Joseph

Received: 30 November 2020
Accepted: 19 January 2021
Published: 21 January 2021

1. Introduction

Alveolar ridge resorption occurs rapidly during the first 6 months after extraction, resulting in aesthetic, phonetic, and functional problems, and complicates implant placement [1,2]. Thin buccal plates undergo progressive bone resorption, even when a ridge preservation method is used [3,4]. Although ridge preservation is useful for decreasing post-extraction alveolar ridge contraction, it cannot eliminate ridge resorption after tooth extraction [5,6]. Ridges with damaged extraction socket walls benefit more from alveolar ridge preservation (ARP) than ridges with intact extraction sockets [7].

Various methods are used in ARP, including closed (flapless procedure) and open (flap procedure) approaches [8,9]. There is no significant histological difference between flapped and flapless groups; thus, the percentage of new bone, connective tissue, and residual bone graft is similar between these two groups [10]. However, more buccal bone resorption is found in extraction sockets with full-thickness flap elevation, which would disturb the surrounding periosteum [9,11–13]. The flapless procedure is less traumatic and results in more keratinized tissue than the flap procedure [8,9,14]. Flapless ridge preservation is made possible either by rapid formation of a biological seal under a non-resorbable membrane or substitution of a resorbable barrier by a connective matrix [9,10,15]. Moreover, soft tissue grafts or primary closure did not provide beneficial effects in preserving alveolar bone in previous studies [16–18]. Therefore, a simplified flapless procedure is desirable for both patients and surgeons.

A buccal wall thickness >1.0 mm in a socket has been reported to show better ridge preservation outcomes than achieved with a thinner buccal wall [5]. In a previous animal study, the final alveolar ridge profile of sockets with buccal plate destruction was more favorable after using flapless ridge preservation than after natural healing [19–21]. Additionally, in extraction sockets of maxillary anterior teeth with buccal plate dehiscence or with sockets of molars with deficient bone plates, flapless ridge preservation could minimize ridge resorption after tooth extraction and improve soft tissue outcomes [22–26]. Thus, buccal plate loss is a predictor of alveolar ridge-remodeling when flapless ridge preservation is used [27].

Though there are a few studies that have focused on the association between ridge preservation and socket morphology [28–30], none have analyzed the relationship between dental implant treatment and flapless ridge preservation in the different socket types with distinct hard and soft tissue characteristics. We hypothesized that there would be differences in clinical parameters of implant therapy among the different socket types when flapless ridge preservation is used. Thus, the aim of this retrospective study was to compare the effects of the different extraction socket types on various parameters of dental implant therapy when flapless ridge preservation is used.

2. Materials and Methods

This was a retrospective study involving adults who underwent flapless ridge preservation and dental implant insertion between January 2013 and August 2019 by a single surgeon (L.C.C). Implant sites were excluded if final prosthesis placement was not completed before this study commenced. The retrospective study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2013. The protocol was approved by Chang Gung Medical Foundation Institutional Review Board (IRB No. 201901611B0) and the need to obtain informed patient consent was waived due to the retrospective nature of the study.

2.1. Classification of Extraction Sockets

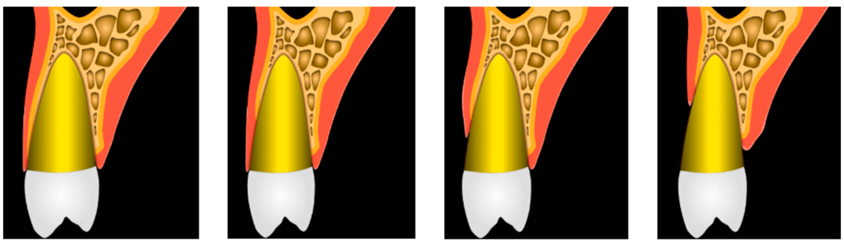
The extraction sockets were divided into different groups according to the authors' socket classification system, which was modified from Elian et al.'s classification of extraction sockets of anterior teeth [31]. Chang's classification system was based on the severity of tissue destruction of the extraction socket walls, including buccal, palatal/lingual, mesial, and distal walls, as shown in Figure 1.

Class I: intact soft tissue walls and bone walls

Class II: intact soft tissue walls, but the destruction of at least one bone wall in the socket

Class III: recession of all soft tissue walls by $\leq$5 mm

Class IV: recession of at least one soft tissue wall by >5 mm.



(a) (b) (c) (d)

Figure 1. Chang's classification of extraction sockets is based primarily on the extent of destruction to the walls: (**a**) Class I: intact soft tissue walls and hard tissue walls; (**b**) Class II: intact soft tissue wall, but the destruction of at least one bone wall in the socket; (**c**) Class III: recession of all soft tissue walls by $\leq$5 mm; and (**d**) Class IV defect: soft tissue recession > 5mm (figures provided by Dr. Fred Cheng).

2.2. Surgical Procedures

In the selected cases, the flapless ridge preservation procedures had been performed in indicated sites with the following steps: (1) atraumatic tooth extraction and wound debridement; (2) bone grafting to the soft tissue wall margin; (3) coronal seal and suturing. Three treatment groups were defined according to the materials used. In Group A, bovine xenograft (Bio-Oss, Geistlich Biomaterials, Princeton, NJ, USA) was placed in the socket, a collagen plug was used as a coronal seal (Teruplug, Olympus Terumo Biomaterials, Tokyo, Japan), and a resorbable suture (4-0 Vicryl, Ethicon, Somerville, NJ, USA) was placed. In Group B1, Bio-Oss combined with allograft material (OraGraft, LifeNet, Virginia Beach, VA, USA), porcine collagen membrane (Sunmax collagen dental membrane, Sunmaxbiotech Co. Ltd., Tainan, Taiwan), and polytetrafluoroethylene (PTFE) suture (ACE sutures, ACE Surgical Supply Co, Brockton, MA, USA) were used. In Group B2, porcine xenograft material (Miner-Oss XP®, BioHorizons, Birmingham, AL, USA), porcine collagen membrane (Sunmax), and PTFE suture (ACE) were used. After tooth extraction, antibiotics and analgesics were used for 7 days. After at least 3 months of healing, the dental implant body was placed into the grafted sites using a two-stage implant system (Osseotite Taper Certain Implant, Biomet 3i LLC, Palm Beach Gardens, FL, USA).

2.3. Patient Characteristics and Parameters of Implant Sites

We analyzed the basic characteristics of the patients and parameters of implant sites according to socket classification. The characteristics of the patients included sex, age, systemic diseases, and smoking status. The parameters of implant sites included the location (molar vs. non-molar), aetiology of extraction (periodontal disease vs. non-periodontal disease), implant insertion torque as reference for primary stability (N/cm), bone density (according to Misch classification based on the clinician's tactile sensation while drilling) [32], implant survival rate, and total treatment time (the period between extraction and final prosthesis placement).

2.4. Statistical Analysis

Continuous data for the age at extraction and age at dental implant placement were expressed as means with standard deviation. The differences in age at extraction and age at dental implant placement among the four-socket classes were assessed by one-way analysis of variance (ANOVA). When one-way ANOVA revealed significant differences among the groups, post-hoc tests were used for the comparisons of each pair of groups, with Bonferroni correction. The continuous data for the period from extraction to stage I implant placement surgery, the period from stage I surgery to final prosthesis placement, and total treatment time had skewed distributions. Thus, these data were expressed as medians with inter-quartile range, and the differences among the four-socket groups were assessed by the non-parametric Kruskal-Wallis test. When these tests revealed significant differences, non-parametric Mann-Whitney tests with Bonferroni correction were used to compare each pair of groups. Categorical data were expressed as counts with percentage, and Fisher's exact tests were performed to evaluate their associations with socket classification. The Z test was performed to compare proportions in each pair of groups.

To find independent factors influencing total treatment time, univariable and multivariable general linear models were used. Variables showing statistical significance in univariable models were entered into the final multivariable model according to stepwise selection. The estimated differences and corresponding 95% confidence interval (CI) of the general linear models are presented.

All statistical analyses were performed using IBM SPSS Statistics 25.0 (IBM Corporation, Armonk, NY, USA). A two-tailed p-value < 0.05 represented statistical significance.

3. Results

In this study, 70 patients with 92 dental implants that used flapless ridge preservation were enrolled. The 92 dental implants included 53 maxillary implants and 39 mandibular implants.

3.1. Maxillary Implants

The association of the baseline conditions and extraction socket classification of the 53 maxillary implants is presented in Table 1. No significant difference was observed among the four-socket classes (I–IV) in terms of age at dental implant placement, age at extraction (year), smoking habits, and systemic diseases. Sex was significantly associated with socket classification ($p = 0.008$): the proportion of males in the Class III socket group was significantly higher than that in the Class I socket group (78.6% vs. 16.7%, $p = 0.003$).

Table 1. Association of patients' characteristics and socket classification for maxillary implants with flapless ridge preservation.

		Socket Classification				p-Value
		I (n = 6)	II (n = 16)	III (n = 28)	IV (n = 3)	
Age at dental implant (years)		46.6 (13.4)	50.8 (10.8)	51.9 (10.0)	61.6 (14.2)	0.280
Age at extraction (years)		46.3 (13.4)	50.5 (10.8)	51.5 (10.0)	61.2 (14.3)	0.286
Sex	Female	5 (83.3%)	8 (50.0%)	6 (21.4%)	0	0.008 *
	Male	1 (16.7%)	8 (50.0%)	22 (78.6%) †	3 (100.0%)	
Smoking	Non-smoker	5 (83.3%)	14 (87.5%)	18 (64.3%)	3 (100.0%)	0.283
	Former smoker	1 (16.7%)	2 (12.5%)	10 (35.7%)	0	
Systemic diseases	Healthy	5 (83.3%)	10 (62.5%)	12 (42.9%)	1 (33.3%)	0.075
	Diabetes mellitus	0	0	1 (3.6%)	0	
	Osteoporosis	1 (16.7%)	0	0	0	
	Other diseases	0	6 (37.5%)	15 (53.6%)	2 (66.7%)	

* Indicates $p < 0.05$; a significant difference is observed among the four-socket classes I-IV. † The male proportion with Class III is significantly higher than that with Class I ($p = 0.003$).

The association of the socket classification and implant site development for the maxillary teeth is presented in Table 2. Socket classification was significantly associated with the materials and methods used ($p = 0.008$): the proportion of Class IV sockets prepared by method B2 was significantly higher than that of Class III sockets (66.7% vs. 3.6%, $p < 0.001$). Socket classification was also significantly associated with extraction aetiology ($p < 0.001$): the proportion of cases that had periodontitis as aetiology was significantly higher in Class III sockets than in Class I and II sockets (82.1% vs. 16.7% and 31.3%, both $p = 0.001$). Socket classification was significantly associated with total treatment time ($p = 0.004$): among the four groups, implants placed in Class III sockets had the longest total treatment time (median of 19.0 months), followed by those placed in Class II sockets (median of 15.9 months). Implants placed in the above two classes of sockets needed significantly longer treatment time than those placed in Class IV sockets (medians of 19.0 and 15.9 months, respectively, vs. 14.0 months, with $p = 0.008$ and 0.007, respectively, by the non-parametric Mann-Whitney test). No significant association of socket classification with implant site (upper molar [UM]/non-UM regions), bone density, bone re-grafting, primary stability, implant survival, the period from extraction to stage I surgery, and the period from stage I surgery to final prosthesis placement was observed.

Table 2. Association of socket classification and implant site development for maxillary implants with flapless ridge preservation.

		Socket Classification				*p*-Value
		I (*n* = 6)	**II** (*n* = 16)	**III** (*n* = 28)	**IV** (*n* = 3)	
Implant site	UM	1 (16.7%)	4 (25.0%)	14 (50.0%)	2 (66.7%)	0.191
	Non-UM	5 (83.3%)	12 (75.0%)	14 (50.0%)	1 (33.3%)	
Extraction aetiology	Periodontitis	1 (16.7%)	5 (31.3%)	23 (82.1%) ‡	2 (66.7%)	<0.001 *
	Non-periodontitis	5 (83.3%)	11 (68.8%)	5 (17.9%)	1 (33.3%)	
Materials and methods	A	4 (66.7%)	13 (81.3%)	25 (89.3%)	0	0.008 *
	B1	0	1 (6.3%)	2 (7.1%)	1 (33.3%)	
	B2	2 (33.3%)	2 (12.5%)	1 (3.6%)	2 (66.7%) †	
Bone density	D1	0	0	0	0	0.247
	D2-D3	2 (33.3%)	2 (12.5%)	3 (10.7%)	1 (33.3%)	
	D4	4 (66.7%)	14 (87.5%)	25 (89.3%)	2 (66.7%)	
Bone re-grafting	Yes	4 (66.7%)	10 (62.5%)	18 (64.3%)	3 (100.0%)	0.786
	No	2 (33.3%)	6 (37.5%)	10 (35.7%)	0	
Primary stability	<20 N/cm	1 (16.7%)	3 (18.8%)	6 (21.4%)	1 (33.3%)	0.965
	20-35 N/cm	3 (50.0%)	5 (31.3%)	8 (28.6%)	1 (33.3%)	
	>35 N/cm	2 (33.3%)	8 (50.0%)	14 (50.0%)	1 (33.3%)	
Implant survival	Success	6 (100.0%)	16 (100.0%)	27 (96.4%)	3 (100.0%)	>0.999
	Late failure	0	0	0	0	
	Early failure	0	0	1 (3.6%)	0	
Period from extraction to stage I surgery (months)		3.3 (2.8, 4.0)	3.6 (2.8, 4.1)	4.1 (3.6, 5.8)	3.2 (3.2, 6.0)	0.085
Period from stage I surgery to final prosthesis placement (months)		11.7 (9.7, 14.2)	12.4 (10.8, 14.3)	14.0 (11.0, 16.6)	9.4 (8.2, 10.8)	0.057
Total treatment time between extraction and final prosthesis placement (months)		15.1 (13.6, 16.0)	15.9 (14.8, 17.8) §	19.0 (15.1, 21.5) §	14.0 (12.5, 14.2)	0.004 *

* Indicates $p < 0.05$ and a significant difference is observed among the four-socket classes I-IV. † For materials and methods, the proportion of B2 in Class IV is significantly higher than that of B2 in Class III ($p < 0.001$). ‡ For extraction aetiology, the proportion of periodontitis in Class III is significantly higher than that in Class I and II (both $p = 0.001$). § The total treatment time for those with Class II and III is significantly longer than that for those with Class IV ($p = 0.008$ and 0.007). UM, upper molar.

3.2. Mandibular Implants

The associations of the baseline conditions and socket classification for the 39 mandibular teeth are presented in Table 3. No significant difference was observed among the four-socket classes for all baseline conditions (all *p*-values > 0.05), including age at dental implant placement, age at extraction, sex, smoking habits, and systemic diseases.

Table 3. Association of the baseline conditions and socket classification for mandibular implants with flapless ridge preservation.

		Socket Classification				*p*-Value
		I (*n* = 6)	**II** (*n* = 14)	**III** (*n* = 16)	**IV** (*n* = 3)	
Age at dental implant (years)		54.0 (10.4)	50.3 (10.7)	52.9 (6.6)	56.2 (11.0)	0.688
Age at extraction (years)		53.8 (10.4)	50.0 (10.7)	52.5 (6.6)	55.5 (11.4)	0.712
Sex	Female	3 (50.0%)	4 (28.6%)	9 (56.3%)	0	0.229
	Male	3 (50.0%)	10 (71.4%)	7 (43.8%)	3 (100.0%)	
Smoking	Non-smoker	4 (66.7%)	9 (64.3%)	13 (81.3%)	2 (66.7%)	0.688
	Former smoker	2 (33.3%)	5 (35.7%)	3 (18.8%)	1 (33.3%)	
Systemic diseases	Healthy	2 (33.3%)	8 (57.1%)	7 (43.8%)	1 (33.3%)	0.068
	Diabetes mellitus	0	0	1 (6.3%)	2 (66.7%)	
	Osteoporosis	1 (16.7%)	0	0	0	
	Other diseases	3 (50.0%)	6 (42.9%)	8 (50.0%)	0	

The associations of the socket classification and implant site development for the mandibular implants are presented in Table 4. Socket classification was significantly associated with bone re-grafting ($p = 0.041$), the materials and methods used ($p = 0.001$), and extraction aetiology ($p = 0.010$). Class II sockets required significantly more bone re-grafting than Class I sockets (92.9% vs. 33.3%, $p = 0.005$). Method A was used for almost all Class I-III sockets (100%, 92.9%, 87.5%, respectively), but all Class IV sockets ($n = 3$) underwent method B1. In terms of extraction aetiology, periodontitis was involved in 28.6%, 56.3%, and 100% of Class II, III, and IV sockets, respectively, while none of the six Class I sockets had a periodontitis extraction aetiology. No significant association of socket classification with implant site (UM/non-UM), bone density, primary stability, implant survival, the period from extraction to stage I, the period from stage I to final prosthesis placement, and the total treatment time was observed.

Table 4. Association of socket classification and implant site development for mandibular implants with flapless ridge preservation.

		Socket Classification				*p*-Value
		I ($n = 6$)	II ($n = 14$)	III ($n = 16$)	IV ($n = 3$)	
Implant site	LM	4 (66.7%)	10 (71.4%)	11 (68.8%)	3 (100.0%)	0.861
	Non-LM	2 (33.3%)	4 (28.6%)	5 (31.3%)	0	
Extraction aetiology	Periodontitis	0	4 (28.6%)	9 (56.3%)	3 (100.0%)	0.010 *
	Non-periodontitis	6 (100.0%)	10 (71.4%)	7 (43.8%)	0	
Materials and methods	A	6 (100.0%)	13 (92.9%)	14 (87.5%)	0	0.001 *
	B1	0	0	2 (12.5%)	3 (100.0%)	
	B2	0	1 (7.1%)	0	0	
Bone density	D1	0	0	1 (6.3%)	1 (33.3%)	0.453
	D2-D3	2 (33.3%)	6 (42.9%)	9 (56.3%)	1 (33.3%)	
	D4	4 (66.7%)	8 (57.1%)	6 (37.5%)	1 (33.3%)	
Bone re-grafting	Yes	2 (33.3%)	13 (92.9%) †	12 (75.0%)	2 (66.7%)	0.041 *
	No	4 (66.7%)	1 (7.1%)	4 (25.0%)	1 (33.3%)	
Primary stability	<20 N	0	0	1 (6.3%)	0	0.475
	20-35 N	2 (33.3%)	1 (7.1%)	4 (25.0%)	0	
	>35 N	4 (66.7%)	13 (92.9%)	11 (68.8%)	3 (100.0%)	
Implant survival	Success	6 (100.0%)	12 (85.7%)	15 (93.8%)	3 (100.0%)	0.649
	Late failure	0	2 (14.3%)	0	0	
	Early failure	0	0	1 (6.3%)	0	
Period from extraction to stage I surgery (months)		3.7 (1.8, 4.0)	3.5 (2.8, 3.8)	4.0 (3.0, 4.8)	5.2 (4.7, 13.0)	0.052
Period from stage I surgery to final prosthesis placement (months)		8.6 (7.4, 11.6)	8.4 (7.0, 9.5)	8.9 (6.5, 9.8)	9.8 (7.8, 10.7)	0.716
Total treatment time between extraction and final prosthesis placement (months)		13.1 (12.0, 13.4)	12.2 (10.6, 12.8)	13.1 (11.1, 14.1)	15.9 (14.5, 20.8)	0.086

* Indicates $p < 0.05$; a significant difference is observed among the four socket classes I-IV. † The proportion of bone re-grafting in Class II is significantly higher than that of Class I. DM, diabetes mellitus; LM, lower molar.

3.3. Independent Factors Influencing Total Treatment Time

According to univariate analyses (Table 5), total treatment time was not significantly associated with subjects' age, sex, smoking habits, systematic diseases, bone re-grafting, and materials and methods used in dental surgery. The implant sites in the UM region, and the upper anterior and premolar (non-UM) regions had significantly longer treatment time than those in the lower anterior and premolar (non-lower molar [LM]) regions, with estimated differences of 4.72 ($p < 0.001$) and 6.06 ($p = 0.001$) months. Sites with a bone density of D2-D3 had a significantly shorter treatment time than those with a bone density of D4, with an estimated difference of −2.77 months ($p = 0.004$). Sites with an extraction aetiology of periodontitis had a significantly longer treatment time than those without periodontitis, with an estimated difference of 2.63 months ($p = 0.003$). Sites with primary stability of >35 N/cm had significantly shorter treatment times than those with primary stability of <20 N/cm, with an estimated difference of −2.86 months ($p = 0.033$). Class III sockets had a longer treatment time than Class I sockets, with an estimated difference of 3.09 months ($p = 0.024$).

Table 5. The independent factors influencing total treatment time.

		Univariable Linear Model		Multivariable Linear Model	
		Estimated Difference (95% CI)	*p*-Value	Estimated Difference (95% CI)	*p*-Value
Age at dental implant (year)		0.05 (−0.04, 0.13)	0.304		
Age at extraction (year)		0.04 (−0.04, 0.13)	0.332		
Sex	Female	−0.60 (−2.42, 1.23)	0.519		
	Male	reference			
Smoking	Former smoker	0.00 (−2.04, 2.03)	0.997		
	Non-smoker	reference			
Systemic diseases	DM	1.71 (−2.69, 6.10)	0.442		
	Osteoporosis	0.38 (−5.71, 6.47)	0.901		
	Other diseases	1.12 (−0.72, 2.97)	0.229		
	NP	reference			
Tooth site	UM	4.72 (2.02, 7.41)	0.001 *	4.06 (1.43, 6.69)	0.003 *
	non-UM	6.06 (3.51, 8.61)	<0.001 *	5.82 (3.36, 8.27)	<0.001 *
	LM	1.18 (−1.41, 3.76)	0.368	1.12 (−1.37, 3.60)	0.374
	non-LM	reference		reference	
Bone density	D1	−2.38 (−8.17, 3.42)	0.417		
	D2-D3	−2.77 (−4.65, −0.89)	0.004 *		
	D4	reference			
Bone re-grafting	Yes	−0.96 (−2.91, 0.98)	0.327		
	No	reference			
Materials and methods	A	reference			
	B1	−0.08 (−3.05, 2.89)	0.956		
	B2	−1.77 (−4.89, 1.36)	0.265		
Extraction aetiology	Periodontitis	2.63 (0.94, 4.31)	0.003 *	2.08 (0.61, 3.54):	0.006 *
	Non-periodontitis	reference		reference	
Primary stability	<20 N	reference			
	20-35 N	−2.14 (−5.07, 0.80)	0.151		
	>35 N	−2.86 (−5.49, −0.24)	0.033 *		
Socket classification	I	reference			
	II	0.94 (−1.85, 3.72)	0.506		
	III	3.09 (0.43, 5.76)	0.024 *		
	IV	1.50 (−2.57, 5.57)	0.466		

DM, diabetes mellitus; UM, upper molar; LM, lower molar. * $p < 0.05$.

To determine whether the above five factors (implant site, bone density, primary stability, extraction aetiology, and socket classification) had an independent influence on the total treatment time, they were included in a model by stepwise selection. The final multivariable model contained two factors: implant site and extraction aetiology (Table 5); i.e., tooth site and extraction aetiology had independent and significant influences on total treatment time. At the same implant site, if the extraction aetiology was periodontitis, a significantly longer treatment time was required than without periodontitis, with an estimated difference of 2.08 months ($p = 0.006$). With the extraction aetiology, UM and non-UM regions required significantly longer treatment time than non-LM regions, with an estimated difference of 4.06 ($p = 0.003$) and 5.82 ($p < 0.001$) months, respectively.

4. Discussion

4.1. Major Findings

In this study, we investigated the effect of socket morphology on dental implant therapy with flapless ridge preservation. The implant survival rate was not affected by socket morphology in this study. However, the total treatment time was longer in socket types associated with periodontitis. Significantly longer treatment time was required in

Class II and Class III sockets than in Class I sockets, in the maxilla. However, there was no significant difference in total treatment time among the different socket classes in the mandible. Therefore, total treatment time may be affected by several factors unrelated to treatment techniques, including patient factors or delay in final prosthesis placement. However, socket characteristics may affect the total treatment time indirectly, through its effect on primary stability and osseointegration time.

4.2. Treatment Flowchart

A flowchart of the treatment performed according to the condition of the extraction site and the socket morphology is shown in Figure 2. This classification system is simple and easily implementable by clinicians. Many factors need to be considered when making decisions about socket management after tooth extraction: systemic diseases, infection, primary stability, hard and soft tissue destruction of the socket, the thickness of the buccal wall, soft tissue phenotype, aesthetics, and pathological/physiological processes associated with wound healing [28–30,33]. Signs of infection at the extraction site include abscess, sinus tract, and pus drainage. Tooth abscesses could affect alveolar ridge remodeling [27] and infection could lead to poor healing outcomes when using flapless ridge preservation [33,34]. Therefore, flapless ridge preservation is not indicated in cases with infected sockets. There are other treatment options that could be chosen according to the primary stability and aesthetic demand in Class I sockets. If primary stability could be gained by placing implants into the native bone (as ascertained from a CT scan), then immediate implantation may be suggested.

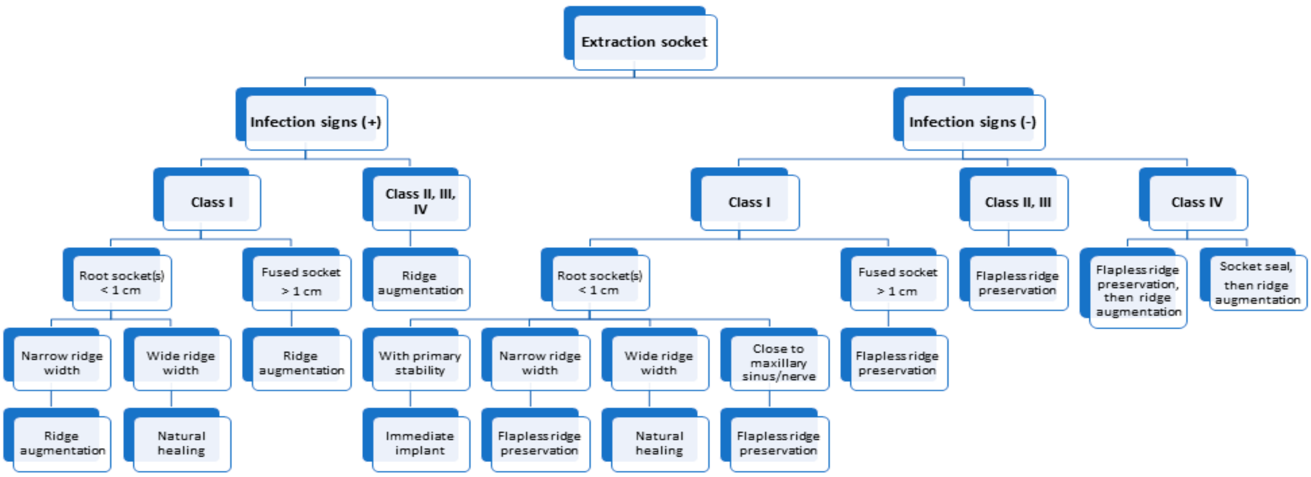


Figure 2. Treatment flowchart of management for extraction socket depending on Chang's classification.

A critical size defect is defined as an osseous defect that fails to heal spontaneously. Therefore, ridge preservation or ridge augmentation is suggested for a Class I socket size with a diameter greater than 10×10 mm^2 because of poor bone repair [35,36]. Additionally, when an extraction socket is close to the maxillary sinus, ridge preservation could be used to reduce sinus pneumatization and alveolar bone resorption [37,38].

Severe soft- and hard-tissue loss is characteristic of Class IV sockets, which induces poor space maintenance. It may be recommended that a collagen plug is placed into the extraction socket to avoid soft tissue wall collapse. Rather than using flapless ridge preservation, performing ridge augmentation (ridge contouring) after the soft tissue has healed would be preferable for such large defects.

Each socket should be managed individually due to the complexity of the defect [29]. Furthermore, multiple root sockets of molars should be treated individually, based on the tissue loss of the area. For example, ridge preservation is necessary for mesial root sockets without a buccal plate, but natural healing is preferred for distal root sockets with intact bone walls.

4.3. Factors Associated with Socket Class

Aetiologies of extraction can be divided into periodontal and non-periodontal diseases. The total treatment time was found to be longer in extraction sockets associated with periodontitis in this study. It may be because periodontitis results in hard and soft tissue destruction, such as seen in Class III and Class IV sockets. Additionally, the post-extraction healing in periodontally affected sockets is slow, complicated, and unpredictable [39]. Bone density is usually less in the maxilla than in the mandible; therefore, it takes longer for high-quality bone regeneration in the maxilla. However, ridge preservation or augmentation still has positive effects in periodontally compromised sockets, as compared to natural healing [26,34]. Class II, III, and IV sockets had at least one bone wall with resorption; however, soft tissue walls could provide space for bone grafting in flapless ridge preservation [40]. Additionally, there was no significant difference in bone density distribution and implant insertion torque among the four-socket classes. Total treatment time is longer for maxillary implants than for mandibular implants. In addition, our study showed that a longer treatment time is associated with periodontal destruction of the socket. Increased bone destruction and, especially, greater soft-tissue recession in these sockets would decrease space maintenance and the potential for bone regeneration. However, there was no significant difference in the total treatment time among the different socket types in the mandible in the present study.

4.4. Materials

A few types of coronal seal materials have been used to block infiltration of soft tissue into the lower bone graft area in flapless ridge preservation; these include membranes and collagen plugs [16,20,31,41]. Sockets have previously been sealed with a porcine collagen matrix, epithelial connective tissue grafts or membranes, and these approaches all yielded the desired outcomes [16,20,41–43]. Currently, leukocyte- and platelet-rich fibrin membrane is also used to seal post-extraction sockets [44]. Bio-Oss has been successfully used in oral surgery for a few decades, and, it could enhance alveolar ridge dimensions and bone formation in flapless ridge preservation procedure [45]. Most of the key physiochemical characteristics of the porcine-derived grafting material are similar to those of Bio-Oss [46]. Additionally, there are similarities between pigs and humans in terms of physiology and bone biology [47]. MinerOss XP® is a highly porous anorganic porcine-derived bone mineral matrix with a particle size between 0.25 and 1.0 mm [43]. Ridge preservation with porcine xenograft results in histomorphometric outcomes, physicochemical characteristics, and dimensional stability that are comparable to those obtained with bovine xenografts [48,49]. Therefore, we used different xenografts in this study, instead of autografts. There was no significant difference in the total treatment time among the sockets prepared using the three different materials and methods.

4.5. Implant Survival Rate

There is currently insufficient evidence to support the use of a ridge protection procedure in conjunction with dental implant treatment to improve treatment outcomes [6,50]. In this study, the average implant survival rate was 95.7% at implant level and 94.3% at the patient level. The lowest survival rate was 85.7% (two failed implants) in mandibular Class II sockets. One implant failed in a patient with end-stage renal disease under peritoneal dialysis; this patient's poor systemic condition may have reduced bone regeneration. Another implant failed because of a residual root tip-like substance in the implant site, which was found upon removal of the failed implant. When combined with proper case selection, flapless ridge preservation is a simple and predictable treatment for implant site development in different socket morphologies.

4.6. Limitations of the Study

A major limitation of this retrospective study was the small and unbalanced sample sizes of the different socket classes. There were intact soft tissue and bone walls in Class I sockets, which decreased the need for flapless ridge preservation. Flapless ridge preservation was typically not indicated for Class IV defects with severe soft tissue and hard tissue destruction. Consequently, there were fewer cases in Class I and Class IV than in Classes II and III. The use of different materials and short-term follow-up were also limitations of this retrospective study. Therefore, it is necessary to identify other factors, such as different materials and methods, associated with socket morphology in a larger and longer clinical trial.

5. Conclusions

Implant survival rate was not affected by socket class when flapless ridge preservation was performed after proper case selection. However, poor socket morphology would extend the total treatment time between extraction and final prosthesis placement, especially in the maxilla. The total treatment time was longer in extraction sockets associated with periodontitis. Furthermore, future clinical trials should be able to establish other factors associated with socket morphology while using flapless ridge preservation in implant therapy.

Author Contributions: Conceptualization, L.-C.C.; methodology, L.-C.C.; software, L.-C.C.; validation, L.-C.C.; formal analysis, L.-C.C.; investigation, L.-C.C.; resources, L.-C.C.; data curation, L.-C.C.; writing—original draft preparation, L.-C.C.; writing—review and editing, Y.-M.C.; visualization, Y.-M.C.; supervision, L.-C.C.; project administration, L.-C.C.; funding acquisition, none. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of Chang Gung Medical Foundation (IRB No. 201901611B0 and date of approval: 2019/11/4).

Informed Consent Statement: Patient consent was waived due to the retrospective nature of the study.

Data Availability Statement: Data sharing not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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