Received: 6 November 2017 | Revised: 25 January 2018 | Accepted: 25 February 2018
DOI: 10.1111/cid.12606

ORIGINAL ARTICLE

WILEY

New classification of maxillary sinus contours and its relation to sinus floor elevation surgery

Lixuan Niu MD | **Juan Wang MD** | **Huajie Yu MD** | **Lixin Qiu MD, PhD**

The 4th Dental Division of School and Hospital of Stomatology, Peking University, Beijing, China

Correspondence
Lixin Qiu, The 4th Dental Division of School and Hospital of Stomatology, Peking University, 41 Middle East 4th Ring Rd, Chaoyang District, Beijing, China, 100025.
Email: qiulixin@263.net

Abstract

Background: It is complicated to select an appropriate sinus floor elevation and the procedure for sinus floor elevation lacks of consensus. Sinus contour plays an important role in choosing a surgery approach. But there are still no published articles revealing the influence of sinus contours to sinus floor elevation surgery.

Purpose: We propose a new classification depending on sinus contours from cone-beam computed tomography (CBCT), analyze clinical characters of different types, and investigate the relationship between sinus contours and sinus floor elevation.

Materials and Methods: We divide sinus into five categories: narrow tapered, tapering, ovoid, square, and irregular. For the first four types, subtypes are classified into three categories: without recess, with buccal-sinus-recess (BSR), and with palate-nasal-recess (PNR). For irregular type, subtypes are classified into three categories: tooth protruding into sinus floor, irregular floor, and septa/exostosis on sinus floor. Then the distribution features of sinuses of 698 patients are described. Sinus widths are measured at second premolar, first and second molar on both sides, and are compared among different types and subtypes.

Results: Narrow tapered sinus occupies 88% at second premolar sites, while tapered sinus occupies almost 50% at first and second molar sites. At second premolar and first molar sites, 62% are without recess types. While 92% are without recess types at second molar. Sinuses with BSR present in only three of 3765 sites. There is an increasing trend of sinus width from narrow tapered to irregular type. Sinus width of the group with recesses is significantly higher than the one without recess. At the end, we provide corresponding treatment recommendations for each sinus types and subtypes.

Conclusion: This is the first classification system that gives treatment recommendations for sinus floor elevation surgery based on sinus contours. The classification system is consistent, easy to visualize, and practicable.

KEYWORDS
CBCT, classification, morphology, sinus floor elevation, sinus width

1 | INTRODUCTION

The posterior edentulous maxilla presents a challenge to the oral surgeon either because of the lack of bone or the low quality of bone. Aiming at insertion and integration of dental implants, several surgical approaches have been proposed: lateral sinus floor elevation with simultaneous implant placement,[1,2] lateral sinus floor elevation with delayed implant placement,[3,4] and transcrestal sinus floor elevation with[2,5,6] or without[6,7] graft. However, selecting of an appropriate sinus floor elevation procedure is too complex and lacks consensus in the literature. It is mainly based on (1) residual vertical bone height,[8,9] (2) the presence of sinus septa,[10–12] (3) the thickness of lateral wall,[13] (4) vascular anatomy,[14,15] (5) contour of sinus,[9,16–18] (6) type of residual bone density, and (7) the number of teeth to be replaced.

Of all the mentioned factors, residual bone height (RBH) is the most important factor for choosing sinus floor elevation procedure. In the academy of Osseointegration Consensus Conference on sinus grafts, held in Boston (Massachusetts) in 1996, one of the consensus statements was that (1) when the RBH is 7–9 mm, transcrestal sinus floor elevation is applied with concomitant implant placement; (2) when RBH is 4–6 mm, lateral sinus floor elevation is recommended, in conjunction with simultaneous placement of implants; and (3) when RBH is less than 3 mm, lateral approach with a delayed implant placement is recommended.[19] Subsequently some authors suggest going beyond the recommendation, and extend the transcrestal sinus floor elevation to the class with 4–6 mm RBH.

Besides of RBH, variations in sinus septa, thickness of lateral wall, and vascular anatomy might increase the risk of complications (eg, Schneiderian membrane perforation, bleeding). There are many studies focusing on the research of prevalence, type, and other details of these characters in sinus cavity.

Contours of sinus play an important role in sinus floor elevation procedure.[7,9,20] But there is still not a standard way to classify sinus contour across the research community, and no published articles revealing the influence of sinus contours to sinus floor elevation surgery. Cho et al. show the angle between the buccal and palatal alveolar walls, defined as angle A, is related to the risk of perforation.[16] Velloso et al. further suggest that sharper angles observed at second premolar sites put membrane perforations at a high risk.[17] Palate-nasal-recess (PNR), firstly described by Wang et al. as the intersection point of the two imaginary lines following the lower part of the lateral nasal wall and the palatal wall in the maxillary sinus, will make the sinus membrane elevation more complicated and increase the occurrence of membrane perforation.[18] There are limited published reports about some characters of sinus contours relating to sinus floor elevation surgery, while they mainly focus on the high risk of complications when performing sinus floor elevation surgery.

On cone-beam computed tomography (CBCT), sinus contours deliver much more details in choosing an appropriate sinus floor elevation procedure. This article is the first one that investigates the association of sinus contours with sinus floor elevation surgery. According to our 20-year experience on maxillary sinus floor elevation, we propose a new classification system, describe the clinical characteristics and distribution features of each type, and give corresponding recommendations on choosing an appropriate sinus floor elevation surgery based on sinus contours.

2 | MATERIALS AND METHODS

2.1 | Patients

The research project was approved by the Institutional Review Board of Peking University Hospital of Stomatology (PKUSSIRB-2016113115). Images, which are not specifically acquired for this study, are selected from the database at the 4th Dental Division of School and Hospital of Stomatology of Peking University. Between January 2016 and April 2017, 698 patients are recruited. Both dentate and edentate patients are recruited. The excluded criteria are: (1) CBCT images with inadequate information (eg, the field of CBCT did not extend to maxillary sinus), (2) sinus with previous operation, and (3) patients younger than 18 years old. For each patient, sinus morphology of six tooth sites (second premolar, first molar, and second molar) are measured on CBCT.

2.2 | Cone-beam computed tomography

CBCT is performed on a Planmeca ProMax 3D (Finland). Patients are positioned parallel to the office floor with a Frankfort-Horizontal plane. Sagittal and coronal images are obtained in the mode at 90 kV and 10/12 mA. The exposure volume is set at 90 mm in diameter and 90 mm in height. The sagittal, coronal, and axial images are reformatted using a software program (Planmeca Romexis 3.7.0.R, Finland). The slice thickness of the multiplanar reconstruction images is 0.2 mm. The measurements are approximated to the nearest 0.01 mm with a caliper.

2.3 | Data collection

Qualified scans are reoriented, so the maxilla is bilaterally symmetrical and the hard palate is parallel to the ground. The reference arch (80 mm wide) is drawn at the level of crestal bone at the cross-sectional view, with its center corresponding to the center of the ridge. We read and record the type of sinus contour using a coronal image obtained in the specific areas of the second-premolar, first molar, and second molar, on both sides.

As a qualitative research, two general practitioners (Niu and Wang) reconstructed and observed images. Inter-examiner variance was measured during the study on CBCT scans by having 100 patients' scans read by the two reviewers (kappa = 0.45, with moderate consistency). The 100 CBCT scans were selected randomly. In the end, one reviewer (Niu) measured and recorded the rest of sinuses.

2.4 | New classifications

1. Firstly, according to the configuration involving sinus floor, buccal and palatal walls, and sinus are classified to the following types (Figure 1): Type A = narrow tapered, Type B = tapering, Type C = ovoid, Type D = square, and Type E = irregular.
2. For types A to D, subtypes are classified according to the presence of PNR or buccal-sinus-recess (BSR) (Figure 2): Subtype 1 = without recess, Subtype 2 = with BSR, and Subtype 3 = with PNR. PNR is presented when the inferior angle of palatal wall in the maxillary sinus and lower part of lateral nasal wall protruding into nasal side. And BSR is presented when the inferior angle of buccal wall in the maxillary sinus and sinus floor protruding into buccal side.
3. For type E, subtypes are classified in the following classes (Figure 1): Subtype 1 = tooth root protruding into sinus floor, Subtype 2 = irregular sinus floor, and Subtype 3 = septa or exostosis on the sinus floor.

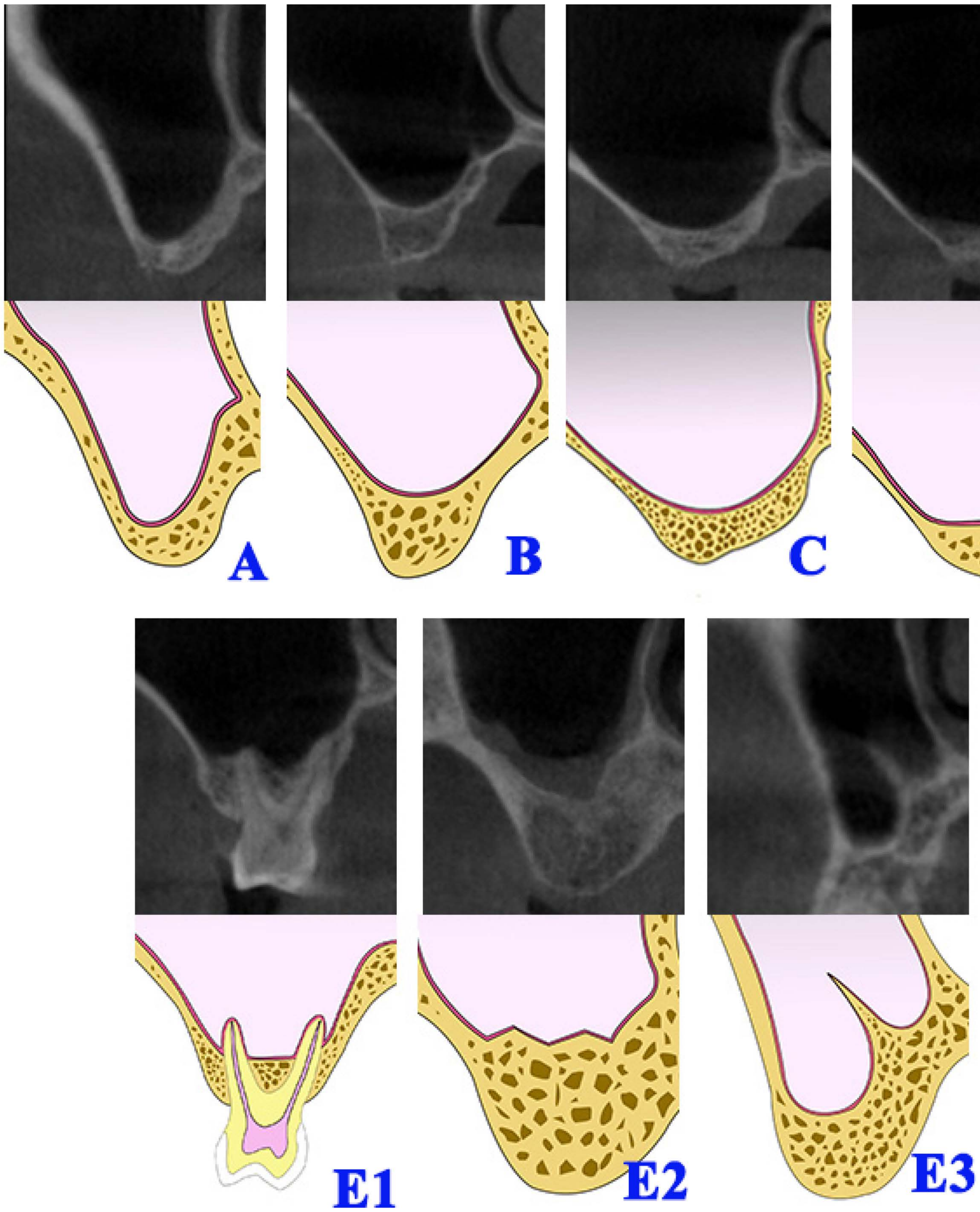

FIGURE 1 Five types of maxillary sinus contour on a coronal image. Type A = narrow tapered, B = tapering, C = ovoid, D = square, and E = irregular, respectively. Type E1 = tooth root protruding into sinus floor, E2 = irregular sinus floor, and E3 = septa or exostosis on the sinus floor

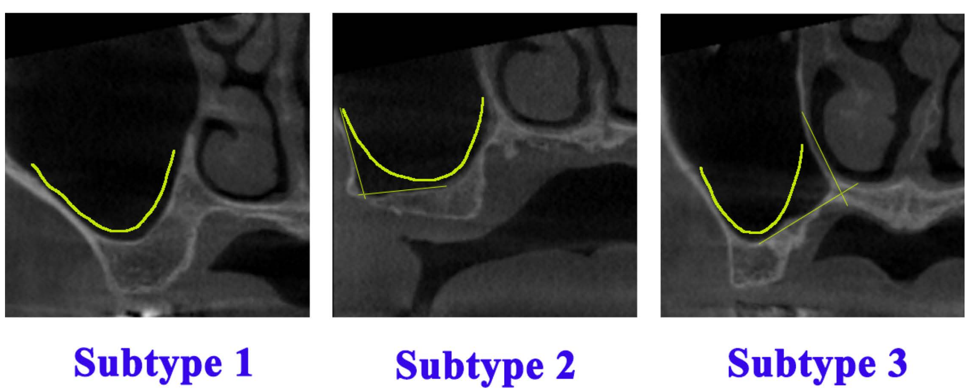

FIGURE 2 Three subtypes of maxillary sinus contour on a coronal image. Subtype 1 = no recesses, 2 = with BSR, and 3 = with PNR

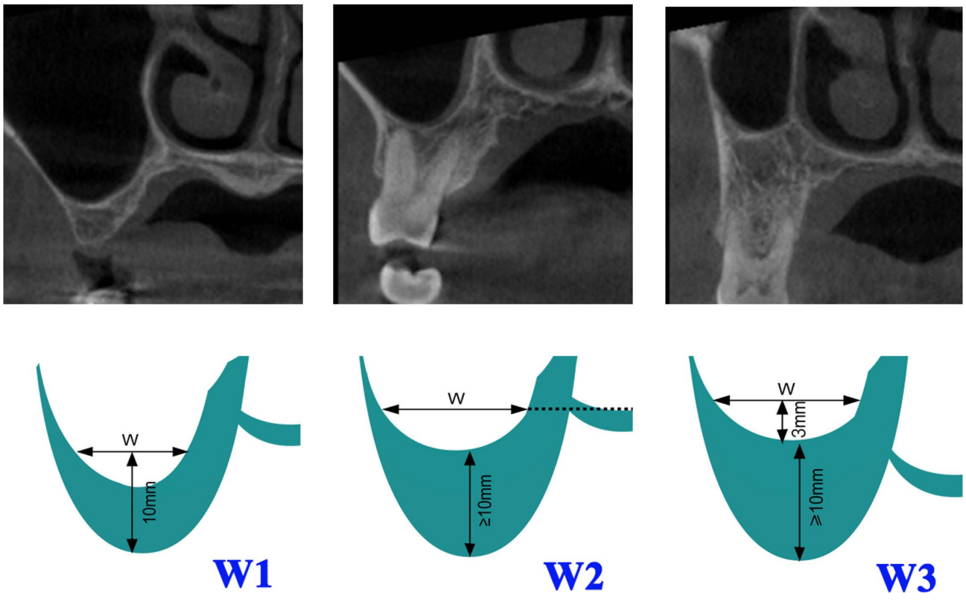

FIGURE 3 Measurements of width of sinus floor in three situations. W1: RBH < 10 mm; W2: RBH ≥ 10 mm; and W3: RBH ≥ 10 mm, but sinus floor is higher than hard palate

2.5 | Sinus width

Subsequently, we measure width of sinus floor (SW), as the distance between buccal and palatal walls, and compare this width among the five types on each tooth site. Since sinus floor level varies among patients, we measure sinus width in following three situations (Figure 3):

1. If RBH is less than 10 mm, we measure the width of sinus floor on level 10 mm from the alveolar crest;
2. If RBH is larger or equal to 10 mm, we measure the width of sinus floor on the same level of the hard palate;
3. If RBH ≥ 10 mm, but sinus floor is higher than hard palate, we measure the width of sinus floor on the level 3 mm above the sinus floor.

Then we compare the width of sinus floor within types and subtypes on each tooth site.

2.6 | Statistical analysis

The mean values and standard deviations of the sinus floor width are calculated. Significant correlations among the mean value of five types are tested by means of the one-way analysis of variance (ANOVA). If the differences among the five types are statistically significant, Duncan's method for post hoc analysis will be performed. A significant correlation between the mean value of two groups (with and without recesses) is also tested by ANOVA. Cohen's kappa value is applied to evaluate interrater agreement. A significant difference is concluded if the *P* value is less than .05.

3 | RESULTS

3.1 | Patients

There are 698 patients included in our study. For those patients, 685 of them are with right side sinuses, while 681 of them are with left side sinuses. Table 1 shows the baseline characteristics of the 698 patients. For each person, we measure sinus morphology at second pre-molar, first molar, and second molar sites on both sides. We have measured sinuses at 3765 tooth sites in total.

3.2 | Distributions of types and subtypes

In Table 2, we have shown the distribution of five types at six tooth sites by the numbers of tooth sites. At second premolar site, the most common types are narrow tapered, and tapering, while narrow tapered occupies about 88%. At first molar site, the most common types are the same with premolar site, but tapering type occupies 46%. Tapering and ovoid are the most common at second molar sites, of which tapering type occupies almost 50%.

Numbers of patients' distribution of subtypes are shown in Table 3. At second premolar and first molar sites, 62% are without recess types, while 38% are with PNR types. At second molar sites, 92% are without recess types. Sinuses with BSR present in only 3 of 3765 sites.

The association of types and subtypes is shown in Table 4. Since sinuses with BSR present in only three sites, only subtype 1 (without recess) and subtype 3 (with PNR) are shown in Table 4. There is one subtype A2 (narrow tapered with BSR) of left first molar, one subtype D2 (ovoid type with BSR) of right second molar, and one subtype D2 (ovoid type with BSR) of left second molar.

3.3 | Width of sinus floor

The widths of sinus floor for the five types are shown in Table 5. At each tooth sites, sinus widths are tested and compared among the five types. For 15 and 25, sinus widths are significant different from type A to the other four types ($P < .05$). For 16 and 26, sinus widths are significantly different among the five types, except for type D versus E

TABLE 1 Baseline clinical characteristics of 698 patients

Patients	15	16	17	25	26	27
Age (range)	18–83	18–83	18–83	18–83	18–83	18–83
Median	47	47	47	47	47	47
Gender						
Male	342 (49.9)	342 (49.9)	342 (49.9)	345 (50.7)	345 (50.7)	345 (50.7)
Female	343 (50.1)	343 (50.1)	343 (50.1)	336 (49.3)	336 (49.3)	336 (49.3)
Sinus						
Present	526 (76.8)	680 (99.3)	685 (100)	516 (75.8)	677 (99.4)	681 (100)
Absent	159 (23.2)	5 (0.7)	0	165 (24.2)	4 (0.6)	0
Tooth						
Edentulous	65 (12.3)	158 (23.2)	127 (18.5)	68 (13.2)	151 (22.3)	128 (18.8)
Dentulous	461 (87.7)	522 (76.8)	558 (81.5)	448 (86.8)	526 (77.7)	553 (81.2)

TABLE 2 Distribution of types of maxillary sinus at 3765 tooth sites

	Type A	Type B	Type C	Type D	Type E	Total
15	469 (89.2)	40 (7.5)	5 (1.0)	4 (0.8)	8 (1.5)	526
16	187 (27.5)	318 (46.8)	114 (16.8)	26 (3.8)	35 (5.1)	680
17	43 (6.3)	340 (49.6)	204 (29.8)	63 (9.2)	35 (5.1)	685
25	455 (88.2)	40 (7.8)	6 (1.2)	3 (0.6)	12 (2.2)	516
26	160 (23.6)	314 (46.4)	145 (21.4)	29 (4.3)	29 (4.3)	677
27	40 (5.9)	322 (47.3)	238 (34.9)	39 (5.7)	42 (6.2)	681
Total	1354	1374	712	164	161	3765

Type A = narrow tapered, type B = tapering, type C = ovoid, type D = square, type E = irregular.

($P > .05$). For 17 and 27, sinus widths are significantly different among the five types, except for type D versus E ($P > .1$).

The sinus widths of without recess group and of with recess (PNR or BSR) group are shown in Table 6. The sinus width of the group with recess differs greatly from the one without recess at six tooth sites ($P \leq .001$).

4 | DISCUSSION

4.1 | Summary of contemporary studies about classifications considering sinus contours

There are various literatures presenting classification based on some characters of sinus contour, since it is very necessary to assess the anatomy of sinus contour.

4.1.1 | Angle A

Cho et al. described angle A—an angulation between the medial and lateral walls of the maxillary sinus, which has a large influence on the incidence of perforation of the Schneiderian membrane. The sharper these angles are, the more difficult the procedure becomes, and the higher risk of the membrane perforation is.[16] Velloso et al. further suggest that the sharper angles observed at the second premolar present a higher risk of membrane perforation than in the areas of molars. Therefore, the surgeon should execute a careful sinus membrane dissection at premolar area to avoid any complications.[17]

4.1.2 | PNR

Wang et al. first described PNR in the maxillary sinus. They defined the risk group as PNR location is less than 15 mm from alveolar crest, and the angulation is less than 90. At second premolar sites, 15% of the recesses are at risk group, compared with 8.2% and 2.4% at first and second molar sites, respectively. Sharp angled recesses might complicate sinus membrane elevation on the medial wall.[18] In our study, PNR at inner walls presents a variety of forms, in 37% sinuses at second premolar, 37% at first molar, and 7% at second molar. We define PNR in the same way as Wang et al., but we do not define a risk group based on PNR. PNR presents in various forms, but we have found that the membrane is difficult to elevate as long as PNR presents (Figure 4).

4.1.3 | Sinus depth

Wagner et al. measured sinus depth from the deepest sinus point to the hard palate on computer, and provided a classification: I (above, 25%), II (0–6 mm below, 50%), and III (more than 6 mm below, 25%) in both edentulous and dentulous CT scans.[21] Sinus depth was found to

TABLE 3 Distribution of subtypes of maxillary sinus at 3765 tooth sites

	15	16	17	25	26	27
Without recess	331 (62.9)	425 (62.5)	634 (92.6)	320 (62.0)	422 (62.3)	631 (92.7)
With BSR	0	0	1 (0.1)	0	1 (0.1)	1 (0.1)
With PNR	195 (37.1)	255 (37.5)	50 (7.3)	196 (38.0)	254 (37.6)	49 (7.2)

BSR, buccal-sinus-recess; PNR, palate-nasal-recess.

TABLE 4 The association of types and subtypes of maxillary sinus at six tooth sites

	A1	A3	B1	B3	C1	C3	D1	D3	E1	E2	E3
15	307	162	13	27	2	3	2	2	2	1	5
16	121	66	196	122	78	36	13	13	8	18	9
17	39	4	323	17	194	10	56	6	7	13	15
25	291	164	19	21	0	6	1	2	2	3	7
26	103	56	202	112	89	56	10	19	8	11	10
27	34	6	309	13	222	16	34	4	16	10	16
Total	895	458	1062	312	585	127	116	46	43	56	62

A1 = narrow tapered without recess, A3 = narrow tapered with PNR, B1 = tapering without recess, B3 = tapering with PNR, C1 = ovoid without recess, C2 = ovoid with PNR, D1 = square without recess, D3 = square with PNR, E1 = tooth protruding into sinus, E2 = irregular sinus floor, E3 = septa/exostosis.

be a reliable anatomical landmark. And they concluded that sinus depth is the first anatomy of the patient independent of gender and dentition.

4.1.4 | Sinus width

Chan et al. and Teng et al. measured sinus width from different levels to build their classifications: narrow, average, and wide. They both indicated that sinus width is wider at molar sites, higher measurement level, and sites with less RBH.[22,23] Jang et al. measured sinus width at the apical end level of implant post-operation. The 0%, 29.9%, 95.7%, and 100% grafts made contact with the medal wall when sinus width is $\geq$16.0, $>$12.1, $\leq$12.1, and $\leq$11.3 mm, respectively. They suggested that rate of graft-contact-medial sinus wall tends to increase in a narrower maxillary sinus.[24] Avila et al.[25] and Claudio et al.[26] both measured sinus width, and concluded that the percentage of vital bone formation after maxillary sinus augmentation is inversely proportional to the sinus width. Mo et al. reported that sinus width was 13.68 $\pm$ 2.66 mm and found a positive association between sinus width and graft resorption.[27]

TABLE 6 Sinus widths are compared between with recess and without recesses groups

Sites	Without recesses	With recesses	*P*
15	6.73 ± 2.89	11.61 ± 3.57	<.001
16	10.69 ± 3.83	13.49 ± 4.47	<.001
17	11.76 ± 3.68	14.11 ± 4.50	<.001
25	6.77 ± 3.09	11.27 ± 3.88	<.001
26	10.52 ± 3.80	13.53 ± 4.61	<.001
27	11.56 ± 3.57	14.57 ± 3.61	.001

4.1.5 | New classification of this study

Our classification system is derived from a combination of angle A, PNR, sinus depth, and sinus width. Sinus contours were classified into five categories: narrow tapered, tapering, ovoid, square, and irregular. For the first four types, subtypes are classified into three categories: without recess, with BSR, and with PNR. For irregular type, subtypes are classified into three categories: tooth protruding into sinus floor, irregular floor, and septa/exostosis on sinus floor. Narrow tapered sinus occupies 88% at second premolar sites, while tapered sinus occupies almost 50% at first and second molar sites. At second premolar and first molar sites, 62% are without recess types. While 92% are without recess types at second molar. Sinus width tends to increase from narrow tapered to irregular type. The sinus width of recesses group is significantly higher than the one without recess. The qualitative classification system described in this article gives more details to assess risk of the surgery and provides more clues for operation planning. According to our surgery experience, this classification system is easy to be visualized in most of the circumstances and practical.

4.2 | Applications of this new classification system

According to our 20-year experience on maxillary sinus floor elevation surgery, we present clinical recommendations based on this new classification. A good classification should always guide clinicians during operation, facilitate communication between clinicians, and indicate patients more easily.

TABLE 5 Sinus widths are compared among the five types at six tooth sites

	Sinus width (mm)				
Sites	Type A	Type B	Type C	Type D	Type E
15	8.22 ± 3.62	13.05 ± 4.10	13.30 ± 3.89	12.43 ± 3.33	13.74 ± 5.08
16	9.41 ± 3.61	11.94 ± 3.91	13.48 ± 4.29	16.62 ± 4.96	14.63 ± 3.87
17	8.15 ± 2.50	10.82 ± 3.25	13.01 ± 3.44	15.74 ± 3.76	14.74 ± 3.05
25	8.18 ± 3.74	12.41 ± 4.15	13.07 ± 4.67	15.70 ± 2.12	11.66 ± 6.10
26	8.72 ± 3.32	11.51 ± 3.57	13.72 ± 4.24	17.51 ± 5.04	17.20 ± 4.20
27	9.05 ± 3.40	10.70 ± 3.29	12.88 ± 3.31	15.05 ± 2.82	14.19 ± 4.26

Type A = narrow tapered, type B = tapering, type C = ovoid, type D = square, type E = irregular.
At 15 and 25, type A vs. B, A vs. C, A vs. D, A vs. E, $P < .05$.
At 16 and 26, type D vs. E: $P > .05$, others: $P < .001$.
At 17 and 27, type D vs. E: $P > .1$, others: $P < .001$.

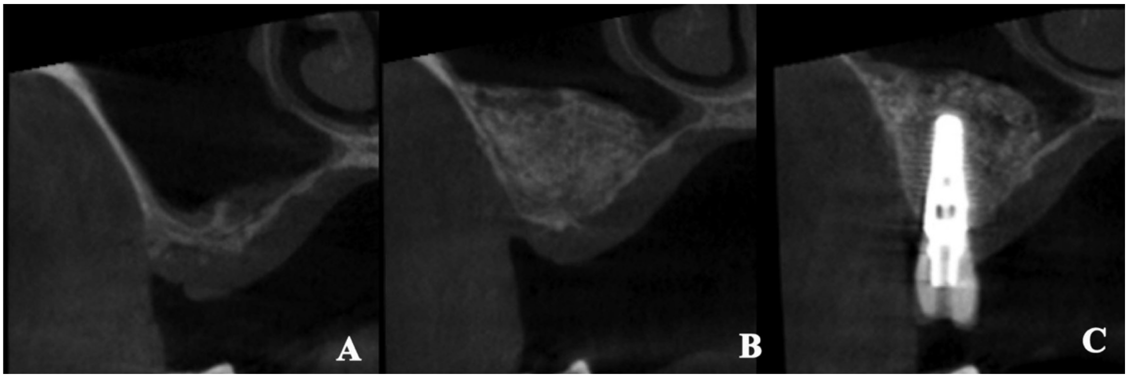

FIGURE 4 Schneiderian membrane is difficult to elevate from the medial wall if PNR presents

1. For a narrow tapered sinus, we recommend modified lateral sinus floor elevation (MLSFE). MLSFE creates the inferior margin of the window at the same level as the sinus floor. Guided-bone-regeneration (GBR) technique should always be performed to cover this window and to prevent any graft leakage. Conventional lateral sinus floor elevation (CLSFE) usually cut the inferior boarder of window at least 3 mm above sinus floor. But for a narrow tapered sinus, instruments are difficult to be set inside, so CLSFE may increase membrane perforation risk. We do not recommend transcrestal sinus floor elevation (TSFE) for a narrow tapered sinus. Both the external and internal walls of a narrow tapered sinus are too thick to get a valid green-stick fracture. And it will increase the perforation risk if the sinus floor is drilled or fractured. Moreover, a great impact force may cause benign paroxysmal positional vertigo.[28]
2. For type B (tapering) and C (ovoid), both LSFE and TSFE are recommended.
3. Type D (square) is seldom observed at premolar sites and molar sites. We suggest LSFE with a wider window for this type. A wider window will provide a better view to find perforation in medial part of Schneiderian membrane, and to prevent adequate filling resulted from dissecting the membrane free from the medial wall of the sinus cavity.
4. Type E (irregular) is the most difficulty type when performing sinus floor elevation. Septa, exostosis, and variety of membrane situations may contribute to membrane perforation. We propose two techniques to deal with this type: one is LSFE with a wider window, the other one is LSFE with double-window. CBCT should be carefully assessed pre-operation, and care should be taken during operation.
5. The PNR is difficult to get access to because the membrane tension is increasing. According to our experience, the membrane is difficult to elevate from the medial wall as long as PNR presents. BSR presents only in dentulous sites, but cautions should be taken when adjacent tooth sites present with BSR.

5 | CONCLUSION

This new classification system provides treatment recommendations based on maxillary sinus contours, and is of good visualization and feasibility. The sinus width tends to increase from narrow tapered to irregular type. The sinus width of recess group is significantly higher than the one without recess group. Treatment suggestions are discussed correspondingly for each type. If PNR or BSR appears, we should pay more attention when dissecting membrane from medial wall.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest with the contents of this article.

ORCID

Lixuan Niu MD http://orcid.org/0000-0002-3693-6818

REFERENCES

[1] Esposito M, Cannizzaro G, Soardi E, et al. Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm-long, 4 mm-wide implants or by longer implants in augmented bone. Preliminary results from a pilot randomised controlled trial. *Eur J Oral Implantol.* 2012;5(1):19–33.

[2] Cannizzaro G, Felice P, Leone M, Viola P, Esposito M. Early loading of implants in the atrophic posterior maxilla: lateral sinus lift with autogenous bone and Bio-Oss versus crestal mini sinus lift and 8-mm hydroxyapatite-coated implants. A randomised controlled clinical trial. *Eur J Oral Implantol.* 2009;2:25–38.

[3] Hallman M, Sennerby L, Lundgren S. A clinical and histologic evaluation of implant integration in the posterior maxilla after sinus floor augmentation with autogenous bone, bovine hydroxyapatite, or a 20:80 mixture. *Int J Oral Maxillofac Implants.* 2002;17:635–643.

[4] Esposito M, Pellegrino G, Pistilli R, Felice P. Rehabilitation of postrior atrophic edentulous jaws: prostheses supported by 5 mm short implants or by longer implants in augmented bone? One-year results from a pilot randomised clinical trial. *Eur J Oral Implantol.* 2011;4:21–30.

[5] Checchi L, Felice P, Antonini ES, Cosci F, Pellegrino G, Esposito M. Crestal sinus lift for implant rehabilitation: a randomised clinical trial comparing the Cosci and the Summers techniques. A preliminary report on complications and patient preference. *Eur J Oral Implantol.* 2010;3:221–232.

[6] Si MS, Zhuang LF, Gu YX, Mo JJ, Qiao SC, Lai HC. Osteotome sinus floor elevation with or without grafting: a 3-year randomized controlled clinical trial. *J Clin Periodontol.* 2013;40(4):396–403.

[7] Qiu LX, Hu XL, Chen B, Li JH, Lin Y, Wang X. [Evaluation of clinical results on osteotome sinus floor elevation and dental implant placement (122 cases report)]. *Zhonghua Kou Qiang Yi Xue Za Zhi*. 2006; 41:136–139.

[8] Chiapasco M, Zaniboni M, Rimondini L. Dental implants placed in grafted maxillary sinuses: a retrospective analysis of clinical outcome according to the initial clinical situation and a proposal of defect classification. *Clin Oral Implants Res*. 2008;19(4): 416–428.

[9] Nunes LS, Bornstein MM, Sendi P, Buser D. Anatomical characteristics and dimensions of edentulous sites in the posterior maxillae of patients referred for implant therapy. *Int J Periodont Restor Dent*. 2013;33(3):337–345.

[10] Shen EC, Fu E, Chiu TJ, Chang V, Chiang CY, Tu HP. Prevalence and location of maxillary sinus septa in the Taiwanese population and relationship to the absence of molars. *Clin Oral Implants Res*. 2012;23(6):741–745.

[11] Naitoh M, Suenaga Y, Kondo S, Gotoh K, Ariji E. Assessment of maxillary sinus septa using cone-beam computed tomography: etiological consideration. *Clin Implant Dent Relat Res*. 2009;11(Suppl 1): e52–e58.

[12] Kim MJ, Jung UW, Kim CS, et al. Maxillary sinus septa: prevalence, height, location, and morphology. A reformatted computed tomography scan analysis. *J Periodontol*. 2006;77(5):903–908.

[13] Kang SJ, Shin SI, Herr Y, Kwon YH, Kim GT, Chung JH. Anatomical structures in the maxillary sinus related to lateral sinus elevation: a cone beam computed tomographic analysis. *Clin Oral Implants Res*. 2013;24(Suppl A100):75–81.

[14] Guncu GN, Yildirim YD, Wang HL, Tozum TF. Location of posterior superior alveolar artery and evaluation of maxillary sinus anatomy with computerized tomography: a clinical study. *Clin Oral Implants Res*. 2011;22(10):1164–1167.

[15] Rosano G, Taschieri S, Gaudy JF, Weinstein T, Del Fabbro M. Maxillary sinus vascular anatomy and its relation to sinus lift surgery. *Clin Oral Implants Res*. 2011;22(7):711–715.

[16] Cho SC, Wallace SS, Froum SJ, Tarnow DP. Influence of anatomy on Schneiderian membrane perforations during sinus elevation surgery: three-dimensional analysis. *Pract Proced Aesthet Dent*. 2001; 13:160–163.

[17] Velloso GR, Vidigal GM, Jr., de Freitas MM, Garcia de Brito OF, Manso MC, Groisman M. Tridimensional analysis of maxillary sinus anatomy related to sinus lift procedure. *Implant Dent*. 2006;15(2): 192–196.

[18] Chan HL, Monje A, Suarez F, Benavides E, Wang HL. Palatonasal recess on medial wall of the maxillary sinus and clinical implications for sinus augmentation via lateral window approach. *J Periodontol*. 2013;84(8):1087–1093.

[19] Jensen OT, Shulman LB, Block MS, Iacono VJ. Report of the sinus consensus conference of 1996. *Int J Oral Maxillofac Implants*. 1998; 13:11–45.

[20] Lundgren S, Cricchio G, Hallman M, Jungner M, Rasmusson L, Sennerby L. Sinus floor elevation procedures to enable implant placement and integration: techniques, biological aspects and clinical outcomes. *Periodontol 2000*. 2017;73(1):103–120.

[21] Wagner F, Dvorak G, Nemec S, et al. Morphometric analysis of sinus depth in the posterior maxilla and proposal of a novel classification. *Sci Rep*. 2017;7:45397.

[22] Chan HL, Suarez F, Monje A, Benavides E, Wang HL. Evaluation of maxillary sinus width on cone-beam computed tomography for sinus augmentation and new sinus classification based on sinus width. *Clin Oral Implants Res*. 2014;25(6):647–652.

[23] Teng M, Cheng Q, Liao J, Zhang X, Mo A, Liang X. Sinus width analysis and new classification with clinical implications for augmentation. *Clin Implant Dent Relat Res*. 2016;18(1):89–96.

[24] Jang HY, Kim HC, Lee SC, Lee JY. Choice of graft material in relation to maxillary sinus width in internal sinus floor augmentation. *J Oral Maxillofac Surg*. 2010;68(8):1859–1868.

[25] Avila G, Wang HL, Galindo-Moreno P, et al. The influence of the bucco-palatal distance on sinus augmentation outcomes. *J Periodontol*. 2010;81(7):1041–1050.

[26] Lombardi T, Stacchi C, Berton F, Traini T, Torelli L, Di Lenarda R. Influence of maxillary sinus width on new bone formation after transcrestal sinus floor elevation: a proof-of-concept prospective cohort study. *Implant Dent*. 2017;26(2):209–216.

[27] Zheng X, Teng M, Zhou F, Ye J, Li G, Mo A. Influence of maxillary sinus width on transcrestal sinus augmentation outcomes: radiographic evaluation based on cone beam CT. *Clin Implant Dent Relat Res*. 2016;18(2):292–300.

[28] Sammartino G, Mariniello M, Scaravilli MS. Benign paroxysmal positional vertigo following closed sinus floor elevation procedure: mallet osteotomes vs. screwable osteotomes. A triple blind randomized controlled trial. *Clin Oral Implants Res*. 2011;22(6):669–672.

How to cite this article: Niu L, Wang J, Yu H, Qiu L. New classification of maxillary sinus contours and its relation to sinus floor elevation surgery. *Clin Implant Dent Relat Res*. 2018;20:493–500. https://doi.org/10.1111/cid.12606