의학 석사 학위논문

Radioanatomic study of the skull base and septum in Asians: implications for using the nasoseptal flap for anterior skull base reconstruction

백인과 비교한 한국인의 두개저 및 비중격 인체 측정학적수치에 대한 방사선 해부학적 연구: 비중격 피판을 이용한 전두개저 결손 재건 시 예상되는 결과 비교

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의학과 이비인후과학 전공

박 성 준

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Abstract

Radioanatomic study of the skull base and septum in Asians: implications for using the nasoseptal flap for anterior skull base reconstruction

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Objectives: To assess the feasibility of using the nasoseptal flap (NSF) for covering the anterior skull base defect in Asians, and to compare the results with Caucasians.

Materials and Methods: A retrospective radioanatomic analysis was conducted in one hundred Korean adult patients. Septal, and skull base dimensions were measured and the feasibility of the NSF in reconstructing a full anterior skull base defect was evaluated according to gender and different age groups. Scans of 49 Caucasian patients were analyzed in the same protocol for a comparative study.

Results: Among various septal dimensions, length of the septum was significantly different in Koreans when compared to Caucasians. Skull base dimensions such as anterior skull base length and width at the level of the anterior ethmoidal artery were different between the two ethnic groups. Individual differences between the anterior width of the hypothetical NSF and the anterior margin of the skull base defect (2.8±3.1 vs 6.4±4.8) and the difference between the hypothetical NSF length and the length of the flap needed for full coverage of the defect were significantly smaller in Korean patients (7.2±3.8 vs 13.1±5.6), leading to a statistically higher chance of flap insufficiency. The insufficiency was more often found in female patients. Additionally, there was significant difference of septum height at the level of the anterior ethmoidal artery for Korean male, female, and as a whole between each age group, while Caucasians did not show any difference in septal dimensions among each age group. For skull base dimensions, Korean male showed significant difference of the length for anterior wall of sella, while Caucasian male and as a whole showed significant difference of skull base width at sphenoethmoidal junction level. However, these results did not significantly affect the feasibility of NSF for reconstruction of anterior skull base defect.

Conclusions: The risk of NSF insufficiency for covering the anterior skull base defect in Koreans is higher relative to Caucasians, and is accentuated in female patients. Efforts to increase the size of the NSF as well as efforts to avoid intraoperative shrinkage of the NSF should be considered to compensate for the relatively small NSF in Asians.

Key words: anterior skull base, endoscopic minimally invasive surgery of the skull base, pedicled nasoseptal flap, skull base reconstruction, radiology

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List of Abbreviations

EEA: endoscopic endonasal approaches

NSF: nasoseptal flap

CSF: cerebrospinal fluid

PNS CT: paranasal sinus computed tomography

Septum height_ANS_Rhinion: the length between anterior nasal spine to rhinion in the midsagittal plane

ANS: anterior nasal spine

Septum height_AEA: the height of the septum at the level of the anterior ethmoidal artery in the coronal plane

AEA: anterior ethmoidal artery

Septum height_SEjxn: the height of the septum at the level of the sphenoethmoidal junction in the coronal plane

SEjnx: sphenoethmoidal junction

Septum length_SPF_ASA: the distance between the point of sphenopalatine foramen projection to the anterior septal angle in the midsagittal plane

SPF: sphenopalatine foramen

SPF_proj: projection of the sphenopalatine foramen

ASA: anterior septal angle

SBD: skull base dimensions

SBD_Cribriform: the length of the cribriform plate in the midsagittal plane

SBD_Planum: the length of the planum sphenoidale in the midsagittal plane

SBD_Sella: the length of the anterior sella wall in the midsagittal plane

ASBL: anterior skull base length in the midsagittal plane

SBD_Width_AEA: the width of the skull base measured at the level of the anterior ethmoidal artery in the coronal plane

SBD_Width_SEjnx: the width of the skull base was measured at the level of the sphenoethmoidal junction in the coronal plane

NSF_AW: the maximum anterior width of the NSF

ASD_AW: the anterior width of the anterior skull base defect

ASD: anterior skull base defect

NSF_PW: the posterior width of the NSF

ASD_PW: the posterior width of the ASD

NSF_LN: NSF length needed

NSF_LP: NSF length possible

Rn: Rhinion

NA: not applicable

Introduction

Recent advances in endoscopic endonasal approaches (EEA) have revolutionized surgical options to the ventral skull base. Among various factors, the innovations in endoscopic skull base reconstruction have been a major driving force that has led to the contemporary EEAs. The task of endoscopic repair has improved dramatically with the implementation of the nasoseptal flap (NSF), lowering the cerebrospinal fluid (CSF) leak rates to less than 5%.[1,2] The high success rate, versatility in design and reach, relative ease of harvest and acceptable donor site morbidity are some of the virtues that has led the vascularized NSF in becoming the workhorse for endoscopic skull base repair.

To achieve a watertight closure, the dimension of the nasoseptal flap must be sufficient to cover the entire skull base defect. Previous studies have validated the NSF to be adequate for reconstruction of a complete anterior skull base defect encountered after an endoscopic craniofacial resection.[3,4] However, validation studies in Asians who tend to have a smaller nose and septum are lacking.[5-7]

This study aimed to analyze septal and skull base dimensions in Koreans, in order to evaluate the feasibility of using the NSF for covering the anterior skull base defect after an endoscopic craniofacial resection. We also compared the results to a separate group comprised of Caucasian subjects.

Materials and Methods

This study was approved by the institutional review board at the Seoul National University Hospital (IRB No. 1207-079-418).

Subjects

A retrospective radioanatomic study was conducted in Korean patients who visited Seoul National University Hospital and underwent a paranasal sinus computed tomography (PNS CT) scan from January 2010 to February 2011. Among 1613 patients, following patients were excluded; patients under 20-years of age, patients with sinonasal pathology, patients with anterior skull base lesions, patients with history of maxillofacial trauma or anomaly, and patients with history of sinonasal or anterior skull base surgery. Finally, the 100 patients consisted of equal number in both sexes with 20 patients from each age decade, such as 20s, 30s, 40s, 50s, and over 60s were randomly selected from the pool of 356 eligible candidates. The mean age of this study group was 44.3 years, ranging from 21 to 67. (Fig. 1) Among foreign national patients who had undergone a PNS CT scan from January 2002 to December 2015, patients with a Caucasian racial trait were selected. Racial identity is self−reported by the patients and included in their medical records. Same exclusion criteria were applied. A total of forty nine Caucasian patients were included for the comparison study. These consisted of 29 male and 20 female patients with a mean age of 40.6 years ranging from 21 to 69. (Fig. 2)

Radioanatomic Study

All patients underwent PNS CT scans with contrast. Axial data was acquired using a 64−slice CT scanner (Philips Medical Systems, Cleveland, OH, USA). The scanning parameters used were detector configuration, 64 × 0.625 mm; slice thickness, 2.0 mm; 200 effective mAs at 120 kVp; and matrix size, 230 × 230. Coronal and sagittal images with slice thickness of 1.0 mm were derived from the reconstruction of the axial data on the Philips workstation. Using the 3−dimensional localization feature (cross reference mode) of the Picture Archiving and Communications System (PACS) workstation (Infinitt PACS version 5.0; Infintt, Seoul, Korea), corresponding anatomical landmarks were identified in the coronal and midsagittal planes. Four septum dimensions were measured. Length between anterior nasal spine to rhinion (Septum height_ANS_Rhinion) (Fig. 3A), and the distance between the point of sphenopalatine foramen projection to the anterior septal angle (Septum length_SPF_ASA) (Fig. 3D) were measured in the midsagittal plane. The height of the septum at the level of the anterior ethmoidal artery (Septum height_AEA) (Fig. 3B) and at the level of the sphenoethmoidal junction (Septum height_SEjxn) (Fig. 3C) were measured in the coronal plane. Skull base dimensions that were measured were as follows. The length of the cribriform plate (SBD_Cribriform) (Fig. 4A), planum sphenoidale (SBD_Planum) (Fig. 4B), anterior sella wall (SBD_Sella) (Fig. 4C) and anterior skull base length (ASBL) (Fig. 4D) were measured in the midsagittal plane. ASBL was defined as the distance from the nasion to the center of the pituitary fossa.[5] In the coronal plane, the width of the skull base was measured at the level of the anterior ethmoidal artery (SBD_Width_AEA) (Fig. 4E) and the sphenoehtmoidal junction (SBD_Width_SEjnx) (Fig. 4F). These measurements were compared between the Korean and Caucasian group according to gender.

To evaluate the sufficiency of the NSF for covering a hypothetical anterior skull base defect we modified the method used in the study by Pinheiro-Neto.[4] The skull base defect included bilateral cribriform and ethmoid roofs, a defect that can be encountered after endoscopic craniofacial resection. The maximum anterior width of the NSF (NSF_AW) was thought to be equivalent to the Septum height_ANS_Rhinion distance. This parameter was compared with SBD Width at AEA (ASD_AW) to evaluate the sufficiency of the anterior width of the NSF. A parallel line was drawn from the skull base to the base of the nasal cavity after a distance equivalent to the cribriform plate and perpendicular to Septum height_ANS_Rhinion, which represented the posterior width of the NSF (NSF_PW). This parameter was compared to the SBD Width at SEjxn (ASD_PW) to evaluate the sufficiency of the posterior width of the NSF (Fig. 5A). The length of the nasoseptal flap needed to cover the anterior skull base defect (NSF_length needed, NSF_LN) was determined as the sum of the length of the cribriform plate and the length from the SPF projection to the SEjxn (Fig. 5B). The maximum length of the NSF was calculated as the sum of the Septum Length_SPF_ASA and the distance from the SPF to the septum in the axial view at the level of the SP foramen and was designated as the NSF length possible (NSF_LP) (Fig. 5C). We compared the two values to assess the sufficiency of the length of the NSF. Feasibility was determined in each of the three dimensions by subtracting the individual defect size or the flap dimension needed for coverage from the largest possible NSF dimension, representing the amount of flap excess. The results were tiered into three categories, more than 0mm, more than 5mm, and more than 10mm, for comparison.

Statistical Analysis

Data were analyzed using IBM SPSS statistics 20.0 (SPSS Inc., Chicago, IL). Statistical significance was considered in the P value < 0.05. Independent t test was used to compare the means of the dimensions measured between sexes and Koreans and Caucasians. Kruskal-Wallis test was used to compare the means of the dimensions measured between each age group in both Koreans and Caucasians. Chi-square test was used to compare feasibility of the NSF in reconstructing the anterior skull base defect between race, gender, and each age group.

Results

Measurements of the nasal septal dimensions of Koreans and Caucasians are shown in Table 1 and the skull base dimensions in Table 2. Additionally, comparative results of nasal septal dimensions and skull base dimensions according to each age group in Koreans and Caucasians are shown in Table 3 and 4. The comparative results of the feasibility of the NSF between gender and each ethnic group are shown in Table 5 and results according to each age group and gender within each ethnic group are shown in Table 6.

When the septal measurement values were compared between male and female Korean subjects, there were significant differences in all of the measured dimensions. Septum height_ANS_Rhinion (31.56±2.02 mm vs 28.54±2.48 mm, $p<0.001$), Septum height_AEA (43.95±2.93 mm vs 42.43±3.59 mm, $p<0.001$), Septum height_SEjnx (43.05±3.14 mm vs 40.88±2.36 mm, $p<0.001$), and Septum length_SPF_ASA (66.69±3.72 mm vs 60.89±4.09 mm, $p<0.001$) were significantly greater in male subjects. When compared to Caucasians, all parameters except for the Septum height_AEA and Septum height_SEJnx showed significant difference. Septum height_ANS_Rhinion, and Septum length_SPF_ASA were greater in Caucasians (30.05±2.72 mm vs 32.11±2.88 mm, p<0.001; 63.79±4.86 mm vs 70.74±5.81mm, p<0.001) (Table 1).

Regarding skull base dimensions, the mean length of the cribriform plate (SBD Cribriform), planum sphenoidale (SBD Planum), anterior wall of sella (SBD Sella), and anterior skull base length (ASBL) in Koreans were 28.69±4.23 mm, 12.67±3.32 mm, 9.31±1.41 mm, and 64.83±2.99 mm, respectively. The mean widths of the skull base were 27.21±2.35 mm (SBD Width at AEA) and 27.51±2.46 mm (SBD Width at SEjnx). SBD Cribriform was significantly larger in female subjects (27.78±3.72 mm vs 29.61±4.55 mm, p=0.03) while SBD Planum (13.64±3.09 mm vs 11.70±3.29 mm, p=0.003), ASBL (65.90±2.85 mm vs 63.76±2.75 mm, p<0.001), SBD Width at AEA (27.70±2.14 mm vs 26.71±2.45 mm, p=0.034), and SBD Width at SEjnx (28.12±2.47 mm vs 26.86±2.31 mm, p=0.011) were significantly larger in male subjects. When these skull base parameters were compared to Caucasians, two parameters showed significant difference. The ASBL

(64.83±2.99 mm vs 69.51±3.74 mm, $p<0.001$) was significantly shorter and SBD Width at AEA (27.21±2.35 mm vs 25.77±3.42 mm, $p=0.003$) was significantly larger in Koreans when compared to Caucasians (Table 2).

When septal measurement values were compared in each age group within each ethnic group, Koreans showed significant difference in Septum height_ANS_Rhinion ($p=0.042$) and Septum height_AEA ($p<0.001$) while Caucasians did not show any significant difference. Further analysis conducted within each ethnic group and within each gender demonstrated Septum height_AEA showing significant difference between each age group of Korean male ($p=0.010$) and female ($p<0.001$), while Caucasians did not show any significant difference. Same analysis conducted with the skull base measurement showed difference between each age group only for SBD Sella in Korean male group ($p=0.014$) and SBD Width at SEjnx in Caucasians ($p=0.016$) and Caucasian male group ($p=0.031$). (Table 3 and 4)

The value calculated by subtracting the flap dimension needed from the possible dimensions for the anterior width (NSF_AW−ASD_AW), posterior width (NSF_PW−ASD_PW) and length of the flap (NSF_LP−NSF_LN) were 2.84±3.12 mm (−5.64 to 8.10), 15.63±5.51 mm (−4.62 to 29.70), and 7.21±3.84 mm (−4.01 to 19.17) respectively in Koreans. When these differences were compared between male and female within Koreans, there were significant difference in NSF_AW−ASD_AW (3.86±2.50 mm vs 1.82±3.36 mm, p=0.002) and NSF_LP−NSF_LN (8.29±3.61 mm vs 6.12±3.78 mm, p=0.004). When these differences for flap sufficiency were compared between Koreans and Caucasians NSF_AW−ASD_AW (2.84±3.12 mm vs 6.38±4.84 mm, p<0.001) and NSF_LP−NSF_LN (7.21±3.84 mm vs 13.15±5.64 mm, p<0.001) in Koreans showed significantly smaller values. When the number of individuals were tiered by the amount of flap excess, the proportion of Koreans who had had more than 5 and 10 mm was significantly smaller compared to Caucasians regarding anterior width (p<0.001 and p<0.001) and length (p=0.010 and p<0.001). There was no significant difference among the two groups in regards to the posterior flap width. The entire comparative result for flap sufficiency between the gender and the two ethnic groups are shown in Table 5.

The comparative results of NSF sufficiency in each age group and gender is shown in Table 6. In Koreans, the percentages of people with more than 5mm in anterior width of the NSF in all gender ($p=0.041$) and the mean value for sufficiency of NSF in posterior width showed significant difference between each age group for all gender ($p=0.003$) and male ($p=0.010$). However, this result did not significantly affect the sufficiency of NSF for overall Koreans. Additionally, Korean male group showed significant difference mean values regarding the sufficiency of NSF in length ($p=0.031$), but did not show any difference in percentages of population with additional length more than 0mm, 5mm, and 10mm in length. In Caucasian group, only the percentages of people with more than 5mm in anterior width of the NSF showed significant difference in each age group ($p=0.039$), but did not did not significantly affect the sufficiency of NSF for overall Caucasians.

Discussion

To our knowledge this is the first study that analyzed and compared septal and skull base dimensions in two different racial groups, Asians and Caucasians. Previous studies that have compared nasal dimensions have mainly focused on aesthetic parameters.[5,7−9] Asians have a relatively lower dorsum and radix,[5] and less projection in the nasion and tip compared to Caucasians.[8] They also have a smaller septal cartilage and shorter nasal bones,[8] and significantly larger nasofrontal angle.[9] Our study has focused on septal dimensions, which showed a significantly smaller height and length in Koreans.

Skull base dimensions of Asians and Caucasians have also been compared in different occasions, but these have been limited to a few anterior−posterior measurements. Collectively they have shown that the anterior cranial base length of Asians, measured from the nasion to the center of the pituitary, were shorter compared to Caucasians.[6] Our results have also confirmed that the anterior skull base length is shorter in Koreans compared to Caucasians. An interesting additional finding was that when the anterior skull base parameters were broken down and analyzed starting from the cristae galli, none of the parameters showed significant difference between the two races. Hence we can conclude that the difference in the length of the antero−posterior skull base is mainly attributable to frontal sinus aeration, thickness of the bone in the nasion area, and nasal dorsum projection, and not to differences in the actual length of the cranial base.

With the expanding indications of endoscopic endonasal approaches for ventral skull base lesions, a consistent and reliable reconstruction method is in high demand. The septal flap has met these needs by proving an efficient way of repair with an acceptable nasal morbidity.[1−2,4,10−11,14] While the clinical feasibility, in terms of sufficiency, of using the septal flap for covering a full anterior skull base defect has been demonstrated,4 this is the first sufficiency study in Asians. We have calculated sufficiency in three dimensions which were the anterior width, posterior width and length. To interpret the results in a more clinically relevant manner we have tiered the individual differences of the flap and ASB measurements into three categories > 0 mm, > 5mm, and >10mm. The flap excess accounts for some degree of overlap in the margins and foreshortening of the nasoseptal flap that usually occurs after elevation. A bigger difference or excess will allow for a more relaxed coverage of the defect, while a smaller difference will theoretically increase the risk of flap shortage. Our results showed that the individual differences were significantly smaller in the anterior width and length of the NSF in Koreans. For the anterior width difference, the percentage of patients with an excess of more than 5mm was only 27% (63.3% in Caucasians, p<0.001) and none of the patients in our study showed an excess of 10mm (22.4% in Caucasians, p<0.001). For the length difference, the percentage of patients with an excess of more than 5mm was 71% (89.8% in Caucasians, p=0.010) and only 21% (73.5% in Caucasians, p<0.001) showed an excess of 10 mm. The posterior width difference showed similar values in both races. Another important finding was that the radiologically observed shortage of the septal flap was pronounced in female subjects. When an excess of 5mm of flap sufficiency was considered, the anterior width (18% vs 36, p=0.043) and length of the septal flap (62% vs 80%, p=0.041) was more often insufficient in the Korean female patients. Our results are in accordance with previous radioanatomic studies in which the anterior width showed a higher risk of flap shortage.[3,10] Koreans having a smaller septal dimension and yet having similar skull base dimensions are at a higher risk of shortage of the NSF when a big defect needs to be repaired. The shortage is accentuated in the anterior width and length.

In view of our results, extra efforts should be made when designing and elevating the NSF to avoid shortage in Asian patients undergoing anterior skull base resection, especially in female patients. The vulnerable dimensions, as highlighted in our study, will most likely be the anterior width and length of the flap. Efforts include incorporating the mucoperiosteum of the nasal floor and/or lateral wall anteriorly up to the vestibular skin junction to increase the anterior width and including the membranous septum to gain length. It is also important to avoid or minimize intraoperative shrinkage of the flap. Surgical tips employed by the authors include the use of a cold knife for the septal incisions and applying tagging sutures on the caudal margin of the flap to maintaining an anterior tension instead of pushing it into the nasopharynx.[10] Finally, the surgeon must be familiar with tactics to augment the NSF in the event of a shortage. These include free mucosal grafts from the middle turbinate or nasal floor,[10,12] and the use of local and regional flaps such as the middle or inferior turbinate flaps and the pericranial flap.[13−15]

Even though our study suggests that the posterior width of the NSF has the least chance of insufficiency, we should be aware of the limitations of our study. The methodology used in our study may not accurately represent the real intraoperative events since we did not take into account the distortion of the soft tissue flap created by the rotation of the flap on its pedicle. In our experience, this distortion will frequently create a shortening or pulling effect in the posterior lateral margin opposite the side of the pedicle.[10] Incorporation of the mucosa in the nasal floor up to the lateral wall below the inferior turbinate can add to the posterior width of the flap. In spite of the fact that the author measured all the radioanatomical parameters by himself, these results might not represent the actual value of the septal and skull base dimensions.

Additionally, despite the effort to randomly select the subjects included in this study, so that the results of this study can represent the general population in each ethnic group, there is a possibility of presence of selection bias regarding this study population.

Although we have focused on the sufficiency of the NSF for reconstructing the anterior skull base, we acknowledge that the NSF is only a part of the reconstruction process, which is usually done in a multilayered fashion. Thus the success of the reconstruction does not depend solely on the sufficient coverage of the NSF, but also on various factors including materials and technique used for the inlay, and host factors.[1,4,10-15] However it is intuitive to hypothesize that if other factors are adjusted for, sufficient coverage will lead to better outcomes.

Conclusion

The relatively smaller nasal septum in Koreans increases the risk of nasoseptal flap insufficiency for covering a large anterior skull base defect compared to Caucasians. The insufficiency is accentuated in female patients. Efforts to enlarge the size of the NSF, as well as efforts to avoid intraoperative shrinkage of the flap should be considered.

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Table 1. Septal Parameters; Comparative results of Race and Gender

Septal Parameters	Koreans (mm)	Caucasians (mm)	*P* value
Septum height ANS_Rhinion			
Total	30.05±2.72	32.11±2.88	***<0.001***
Male / Female	31.56±2.02/28.54±2.48 †	33.33±2.24/30.34±2.81 †	***0.001 / 0.018***
Septum height AEA			
Total	43.19±3.34	43.75±4.13	*0.410*
Male / Female	43.95±2.93/42.43±3.59 †	44.95±4.17/42.02±3.47 †	*0.214 / 0.654*
Septum height SEjnx			
Total	41.96±2.97	41.93±4.55	*0.965*
Male / Female	43.05±3.14/40.88±2.36 †	42.69±4.36/40.84±4.71	*0.698 / 0.968*
Septum Length SPF_ASA			
Total	63.79±4.86	70.74±5.81	***<0.001***
Male / Female	66.69±3.72/60.89±4.09 †	73.09±5.07/67.34±5.18 †	***<0.001 / <0.001***

† Significant difference between Male vs Female ; $P < 0.05$

Table 2. Skull Base Parameters; Comparative results of Race and Gender

Parameters	Koreans (mm)	Caucasians (mm)	*P* value
SBD_Cribriform			
Total	28.69±4.23	29.74±4.22	*0.160*
Male / Female	27.78±3.72 / 29.61±4.55 †	30.08±4.30 / 29.25±4.16	***0.020*** */ 0.751*
SBD_Planum			
Total	12.67±3.32	13.36±3.34	*0.240*
Male / Female	13.64±3.09 / 11.70±3.29 †	14.56±3.10 / 11.62±2.94 †	*0.208 / 0.915*
SBD_Sella			
Total	9.31±1.41	9.41±1.68	*0.711*
Male / Female	9.12±1.35 / 9.49±1.45	9.31±1.30 / 9.56±2.14	*0.542 / 0.888*
ASBL			
Total	64.83±2.99	69.51±3.74	***<0.001***
Male / Female	65.90±2.85 / 63.76±2.75 †	71.31±2.94 / 66.90±3.23 †	***<0.001 / 0.001***
SBD Width_AEA			
Total	27.21±2.35	25.77±3.42	***0.003***
Male / Female	27.70±2.14 / 26.71±2.45 †	26.36±3.37 / 24.90±3.40	***0.034 / 0.039***
SBD Width_SEjnx			
Total	27.51±2.46	27.06±3.49	*0.364*
Male / Female	28.12±2.47 / 26.89±2.31 †	27.74±3.16 / 26.07±3.79	*0.576 / 0.271*

† Significant difference between Male vs Female ; $P < 0.05$

Table 3. Septal Parameters; Comparative results of Age Groups and Gender

Septal Parameters	Koreans (mm)			Caucasians (mm)		
	Male	Female	Total	Male	Female	Total
Septum height ANS_Rhinion	*0.069*	*0.252*	***0.042*** †	*0.962*	*0.313*	*0.363*
Age group 1 (20s)	32.39±1.40	28.97±2.22	30.68±2.52	33.19±2.59	34.08±0.00	33.29±2.44
Age group 2 (30s)	32.85±1.29	29.92±2.28	31.39±2.34	33.39±1.92	30.68±1.35	32.71±2.13
Age group 3 (40s)	31.17±2.22	28.08±1.95	29.62±2.58	34.00±3.09	29.41±2.98	30.72±3.61
Age group 4 (50s)	30.99±1.88	28.11±3.25	29.55±3.13	32.91±4.49	31.65±3.36	32.07±3.35
Age group 5 (over 60)	31.56±2.02	27.61±2.31	29.01±2.51	32.89±2.24	29.3±0.00	31.99±1.97
Septum height AEA	***0.010*** †	***<0.001*** †	***<0.001*** †	*0.545*	*0.835*	*0.813*
Age group 1 (20s)	36.47±2.69	36.25±2.35	36.36±2.46	35.40±4.42	29.13±0.00	34.71±4.64
Age group 2 (30s)	33.73±2.51	33.80±2.67	33.77±2.52	33.65±4.90	31.14±4.32	33.02±4.76
Age group 3 (40s)	33.04±1.52	31.50±3.63	32.27±2.82	35.98±1.74	32.75±3.85	33.67±3.64
Age group 4 (50s)	31.91±2.43	30.45±3.60	31.18±3.08	37.59±5.32	32.23±2.51	34.02±4.13
Age group 5 (over 60)	34.59±3.44	30.18±3.59	32.38±3.42	35.80±1.78	30.22±0.00	34.40±3.14
Septum height SEjnx	*0.380*	*0.218*	*0.213*	*0.559*	*0.980*	*0.894*
Age group 1 (20s)	34.79±3.72	32.32±2.93	33.56±3.50	32.37±4.28	28.47±0.00	31.93±4.21
Age group 2 (30s)	31.81±2.86	31.31±1.21	31.56±2.15	31.73±5.17	31.33±8.05	31.63±5.71
Age group 3 (40s)	32.57±2.52	30.54±2.11	31.56±2.49	33.27±2.74	31.08±4.81	31.70±4.34
Age group 4 (50s)	32.68±2.83	29.43±2.58	31.06±3.12	36.34±5.64	30.25±1.87	32.28±4.28
Age group 5	33.39±3.43	30.77±2.05	32.08±3.06	34.18±2.10	31.27±0.00	33.45±2.25

(over 60)						
Septum Length SPF_ASA	*0.154*	*0.537*	*0.205*	*0.582*	*0.844*	*0.504*
Age group 1 (20s)	64.38±3.76	58.60±5.45	61.49±5.44	71.23±0.78	69.94±0.00	71.08±0.85
Age group 2 (30s)	66.49±2.77	60.92±4.51	63.71±4.63	72.50±3.52	66.31±8.19	70.95±5.49
Age group 3 (40s)	67.46±2.17	61.65±2.83	64.56±3.86	73.90±3.42	68.04±5.21	69.72±5.39
Age group 4 (50s)	66.37±4.29	60.76±3.73	63.56±4.86	75.33±11.21	66.51±3.67	69.45±7.34
Age group 5 (over 60)	68.74±4.36	62.50±3.07	65.62±4.87	77.89±12.36	65.09±0.00	74.69±11.95

† Kruskal-Wallis test; $P < 0.05$

Table 4. Skull Base Parameters; Comparative results of Age Groups and Gender

Parameters	Koreans (mm)			Caucasians (mm)		
	Male	Female	Total	Male	Female	Total
SBD_Cribriform	*0.648*	*0.801*	*0.576*	*0.746*	*0.856*	*0.712*
Age group 1 (20s)	26.42±3.73	28.90±3.68	27.66±3.83	29.99±5.09	31.69±0.00	30.18±4.80
Age group 2 (30s)	27.95±2.99	28.60±6.61	28.28±5.00	29.76±4.55	30.40±6.25	29.92±4.80
Age group 3 (40s)	28.80±2.54	30.37±4.18	29.58±3.47	29.52±4.01	29.10±4.14	29.22±3.95
Age group 4 (50s)	26.85±4.01	29.08±3.70	27.96±3.92	29.13±3.21	28.01±3.63	28.38±3.21
Age group 5 (over 60)	28.89±4.93	31.10±4.38	29.99±4.68	32.95±3.15	28.69±0.00	31.89±3.34
SBD_Planum	*0.378*	*0.211*	*0.184*	*0.501*	*0.373*	*0.051*
Age group 1 (20s)	15.18±2.81	11.98±2.81	13.58±3.19	14.75±3.80	9.40±0.00	14.15±3.98
Age group 2 (30s)	13.81±3.88	12.70±4.95	13.25±4.37	15.28±2.45	9.42±3.46	13.81±3.70
Age group 3 (40s)	13.22±2.89	11.81±2.37	12.51±2.67	12.13±2.50	12.1±3.04	12.11±2.80
Age group 4 (50s)	13.40±2.83	12.45±2.82	12.92±2.79	13.15±5.66	13.31±1.49	13.26±2.79
Age group 5 (over 60)	12.60±2.90	9.58±2.52	11.09±3.06	15.36±2.68	11.04±0.00	14.28±3.07
SBD_Sella	***0.014*** †	*0.636*	*0.347*	*0.779*	*0.322*	*0.284*
Age group 1 (20s)	9.00±1.18	9.13±1.03	9.07±1.08	9.11±1.05	9.75±0.00	9.18±1.01
Age group 2 (30s)	9.56±0.83	9.57±1.60	9.57±1.24	9.42±1.23	11.30±2.35	9.89±1.70
Age group 3 (40s)	9.88±1.32	9.52±1.68	9.70±1.48	8.93±1.79	8.84±2.27	8.87±2.07
Age group 4 (50s)	8.98±1.35	9.09±1.29	9.04±1.29	10.27±0.11	9.97±1.04	10.07±0.82
Age group 5 (over 60)	8.20±1.57	10.15±1.57	9.17±1.83	9.27±2.29	7.87±0.00	8.92±2.00
ASBL	*0.566*	*0.116*	*0.110*	*0.361*	*0.885*	*0.197*

Age group 1 (20s)	66.36±3.24	64.76±2.70	65.56±3.01	70.46±2.73	64.99±0.00	69.85±3.14
Age group 2 (30s)	65.63±3.63	62.24±3.59	63.93±3.92	71.37±2.65	66.19±2.85	70.07±3.48
Age group 3 (40s)	66.65±2.05	64.11±1.99	65.38±2.36	70.19±3.98	66.90±3.97	67.84±4.11
Age group 4 (50s)	64.72±2.37	63.02±1.46	63.87±2.10	71.93±4.86	67.91±2.72	69.25±3.67
Age group 5 (over 60)	66.16±2.88	64.67±3.08	65.41±3.00	74.43±0.62	67.71±0.00	72.75±3.40
SBD Width_AEA	*0.494*	*0.990*	*0.783*	*0.462*	*0.116*	*0.303*
Age group 1 (20s)	27.71±2.26	26.37±1.94	27.04±2.16	24.79±2.31	21.64±0.00	24.44±2.40
Age group 2 (30s)	28.17±2.09	26.83±2.82	27.50±2.51	26.54±3.68	23.23±3.09	25.71±3.75
Age group 3 (40s)	28.44±2.74	27.05±2.63	27.75±2.70	28.18±3.63	26.69±3.55	27.12±3.50
Age group 4 (50s)	27.08±2.06	26.58±2.71	26.83±2.36	25.46±2.32	23.92±0.92	24.44±1.49
Age group 5 (over 60)	27.11±1.46	26.75±2.56	26.93±2.03	28.06±4.60	20.82±0.00	26.25±5.22
SBD Width_SEjnx	*0.818*	*0.812*	*0.741*	***0.031*** †	*0.058*	***0.016*** †
Age group 1 (20s)	27.98±2.95	26.81±3.09	27.39±3.00	27.32±2.22	20.99±0.00	26.62±2.96
Age group 2 (30s)	27.93±2.39	26.67±1.64	27.30±2.10	27.07±3.36	24.68±1.84	26.47±3.18
Age group 3 (40s)	28.85±2.17	26.98±2.00	27.92±2.24	30.59±2.34	28.27±3.75	28.93±3.49
Age group 4 (50s)	27.93±2.72	27.64±2.54	27.78±2.56	23.34±0.29	23.84±3.06	23.67±2.39
Age group 5 (over 60)	27.92±2.45	26.36±2.31	27.14±2.45	30.68±0.31	23.61±0.00	28.91±3.54

† Kruskal-Wallis test; $P < 0.05$

Table 5. Flap sufficiency; Comparative results of Race and Gender

Differences	Koreans (mm)	Caucasians (mm)	*P value*
NSF_AW - ASD_AW	2.84±3.12	6.38±4.84	***<0.001***
Male / Female	3.86 ±2.50 / 1.82±3.36 †	7.06±4.54 / 5.41±5.20	***<0.001/ 0.001***
> 0mm, Total	82%	89.8%	*0.216*
Male / Female	94% / 70% †	89.7% / 90%	*0.482 / 0.078*
≥ 5mm, Total	27%	63.3%	***<0.001***
Male / Female	36% / 18% †	69% / 55%	***0.005 / 0.002***
≥ 10mm, Total	0%	22.4%	***<0.001***
Male / Female	0% / 0%	27.6% / 15%	***<0.001 / 0.005***
NSF_PW - ASD_PW	15.63±5.51	15.81±5.05	*0.839*
Male / Female	17.04±5.36 / 14.21±5.34 †	15.83±5.19 / 15.78±4.98	*0.329 / 0.251*
≥ 0mm, Total	97%	100%	*0.221*
Male / Female	98% / 96%	100% / 100%	*0.443 / 0.364*
≥ 5mm, Total	96%	98%	*0.533*
Male / Female	96% / 96%	96.6% / 100%	*0.902 / 0.364*
≥ 10mm, Total	90%	91.8%	*0.718*
Male / Female	94% / 86%	93.1% / 90%	*0.875 / 0.652*
NSF_LP - NSF_LN	7.21±3.84	13.15±5.64	***<0.001***
Male / Female	8.29±3.61 / 6.12±3.78 †	14.69±5.32 / 10.91±5.46 †	***<0.001 / <0.001***
≥ 0mm, Total	96%	100%	*0.156*
Male / Female	100% / 92% †	100% / 100%	*NA / 0.193*
≥ 5mm, Total	71%	89.8%	***0.010***
Male / Female	80% / 62% †	93.1% / 85%	*0.118 / 0.061*
≥ 10mm, Total	21%	73.5%	***<0.001***
Male / Female	20% / 22%	86.2% / 55% †	***<0.001 / 0.007***

† Significant difference between Male vs Female ; $P < 0.05$

Table 6. Flap sufficiency; Comparative results of Age Groups and Gender

Differences	Koreans (mm)			Caucasians (mm)		
	Male	Female	Total	Male	Female	Total
NSF_AW - ASD_AW	*0.369*	*0.638*	*0.187*	*0.655*	*0.148*	*0.095*
Age group 1 (20s)	4.67±2.13	2.60±2.77	3.64±2.63	8.73±1.82	12.44±0.00	9.14±2.10
Age group 2 (30s)	4.68±2.02	3.10±3.35	3.89±2.81	6.85±5.15	7.30±2.24	6.96±4.53
Age group 3 (40s)	2.73±3.16	1.03±2.89	1.88±3.07	5.82±6.58	2.71±5.71	3.60±5.89
Age group 4 (50s)	3.90±2.65	1.54±3.97	2.72±3.50	7.45±6.81	7.73±3.55	7.63±4.10
Age group 5 (over 60)	3.31±2.27	0.86±3.75	2.09±3.27	4.83±4.51	8.48±0.00	5.75±4.11
> 0mm	*0.225*	*0.753*	*0.539*	*0.428*	*0.695*	*0.302*
Age group 1 (20s)	100%	80%	90%	100%	100%	100%
Age group 2 (30s)	*100%*	*80%*	*90%*	*91.7%*	100%	93.8%
Age group 3 (40s)	80%	70%	75%	75%	80%	78.6%
Age group 4 (50s)	90%	60%	75%	100%	100%	100%
Age group 5 (over 60)	100%	60%	80%	66.7%	100%	75%
≥ 5mm	*0.302*	*0.202*	***0.041**** [a]	*0.263*	*0.244*	***0.039**** [b]
Age group 1 (20s)	40%	*20%*	30%	100%	100%	100%
Age group 2 (30s)	60%	40%	50%	58.3%	75%	62.5%
Age group 3 (40s)	20%	0%	10%	50%	30%	35.7%
Age group 4 (50s)	40%	20%	30%	50%	75%	66.7%
Age group 5 (over 60)	20%	10%	15%	66.7%	100%	75%
≥ 10mm	*NA*	*NA*	*NA*	*0.719*	*0.133*	*0.316*

Age group 1 (20s)	0%	0%	0%	37.5%	100%	44.4%
Age group 2 (30s)	0%	0%	0%	25%	0%	18.8%
Age group 3 (40s)	0%	0%	0%	25%	10%	14.3%
Age group 4 (50s)	0%	0%	0%	50%	25%	33.3%
Age group 5 (over 60)	0%	0%	0%	0%	0%	0%
NSF_PW - ASD_PW	***0.010*** †	*0.056*	***0.003*** †	*0.376*	*0.460*	*0.219*
Age group 1 (20s)	21.27±2.79	16.33±3.52	18.80±4.00	14.88±4.38	18.85±0.00	15.32±4.31
Age group 2 (30s)	16.36±7.74	16.26±4.15	16.31±6.05	15.31±5.94	17.77±5.86	15.93±5.83
Age group 3 (40s)	16.27±2.48	15.59±3.78	15.93±3.13	14.66±4.04	13.97±4.00	14.17±3.86
Age group 4 (50s)	14.40±6.16	13.67±3.44	14.03±4.87	21.96±2.08	17.43±7.19	18.94±6.11
Age group 5 (over 60)	16.92±3.94	9.20±7.71	13.06±7.16	17.95±6.11	16.18±0.00	17.51±5.06
≥ 0mm	*0.395*	*0.080*	*0.240*	*NA*	*NA*	*NA*
Age group 1 (20s)	100%	100%	100%	100%	100%	100%
Age group 2 (30s)	90%	100%	95%	100%	100%	100%
Age group 3 (40s)	100%	100%	100%	100%	100%	100%
Age group 4 (50s)	100%	100%	100%	100%	100%	100%
Age group 5 (over 60)	100%	80%	90%	100%	100%	100%
≥ 5mm, Total	*0.537*	*0.080*	*0.456*	*0.832*	*NA*	*0.716*
Age group 1 (20s)	100%	100%	100%	100%	100%	100%
Age group 2 (30s)	90%	100%	95%	91.7%	100%	93.8%

Age group 3 (40s)	100%	100%	100%	100%	100%	100%
Age group 4 (50s)	90%	100%	95%	100%	100%	100%
Age group 5 (over 60)	100%	80%	90%	100%	100%	100%
≥ 10mm	*0.225*	*0.106*	*0.349*	*0.895*	*0.797*	*0.888*
Age group 1 (20s)	100%	90%	95%	87.5%	100%	88.9%
Age group 2 (30s)	90%	100%	95%	91.7%	100%	93.8%
Age group 3 (40s)	100%	90%	95%	100%	90%	92.9%
Age group 4 (50s)	80%	90%	85%	100%	*75%*	83.3%
Age group 5 (over 60)	100%	60%	80%	100%	100%	100%
NSF_LP - NSF_LN	***0.031***†	*0.507*	*0.224*	*0.681*	*0.556*	*0.653*
Age group 1 (20s)	7.04±4.96	4.72±4.66	5.88±4.83	14.32±5.88	14.36±0.00	14.33±5.50
Age group 2 (30s)	10.89±2.87	4.89±5.00	7.89±5.02	14.39±5.59	11.16±6.07	13.59±5.69
Age group 3 (40s)	8.17±2.15	7.11±2.80	7.64±2.49	13.68±4.23	10.19±5.51	11.19±5.27
Age group 4 (50s)	8.61±2.60	7.26±3.31	7.94±2.98	13.91±8.41	13.32±5.61	13.52±5.75
Age group 5 (over 60)	6.75±3.84	6.64±2.38	6.69±3.11	18.73±3.57	3.96±0.00	15.04±7.94
≥ 0mm	*NA*	*0.055*	*0.065*	*NA*	*NA*	*NA*
Age group 1 (20s)	100%	70%	85%	100%	100%	100%
Age group 2 (30s)	100%	90%	95%	100%	100%	100%
Age group 3 (40s)	100%	100%	100%	100%	100%	100%
Age group 4 (50s)	100%	100%	100%	100%	100%	100%
Age group 5	100%	100%	100%	100%	100%	100%

(over 60)						
≥ 5mm	*0.068*	*0.577*	*0.464*	*0.895*	*0.114*	*0.704*
Age group 1 (20s)	60%	50%	55%	87.5%	*100%*	88.9%
Age group 2 (30s)	100%	50%	75%	91.7%	*100%*	93.8%
Age group 3 (40s)	90%	60%	75%	100%	*80%*	85.7%
Age group 4 (50s)	90%	70%	80%	100%	*100%*	100%
Age group 5 (over 60)	60%	80%	70%	100%	*0%*	75%
≥ 10mm	*0.068*	*0.977*	*0.347*	*0.490*	*0.587*	*0.454*
Age group 1 (20s)	10%	20%	15%	87.5%	100%	88.9%
Age group 2 (30s)	50%	20%	35%	91.7%	50%	81.2%
Age group 3 (40s)	0%	*20%*	*10%*	*75%*	*50%*	*57.1%*
Age group 4 (50s)	20%	30%	25%	50%	75%	66.7%
Age group 5 (over 60)	20%	20%	20%	100%	0%	75%

† Kruskal-Wallis test; $P < 0.05$

∗Pearson Chi-Square test; $P<0.05$, a. Phi and Cramer’s V value = 0.315, $P=0.041$, b. Phi and Cramer’s V value = 0.453, $P=0.039$

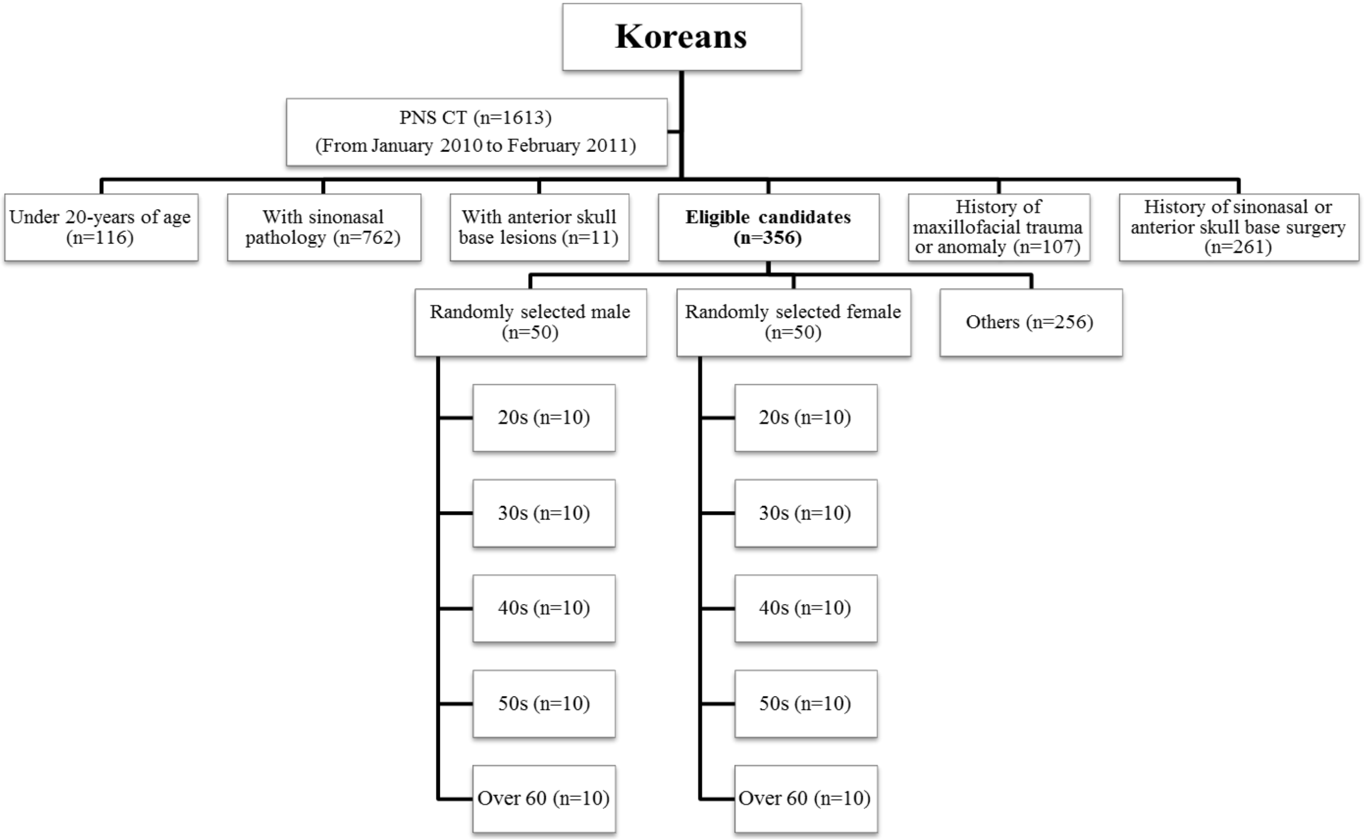

Figure 1. Flow chart of exclusion and inclusion of Korean participants. The 100 patients consisted of equal number in both sexes with 20 patients from each age decade, such as 20s, 30s, 40s, 50s, and over 60s were randomly selected from the pool of 356 eligible candidates.

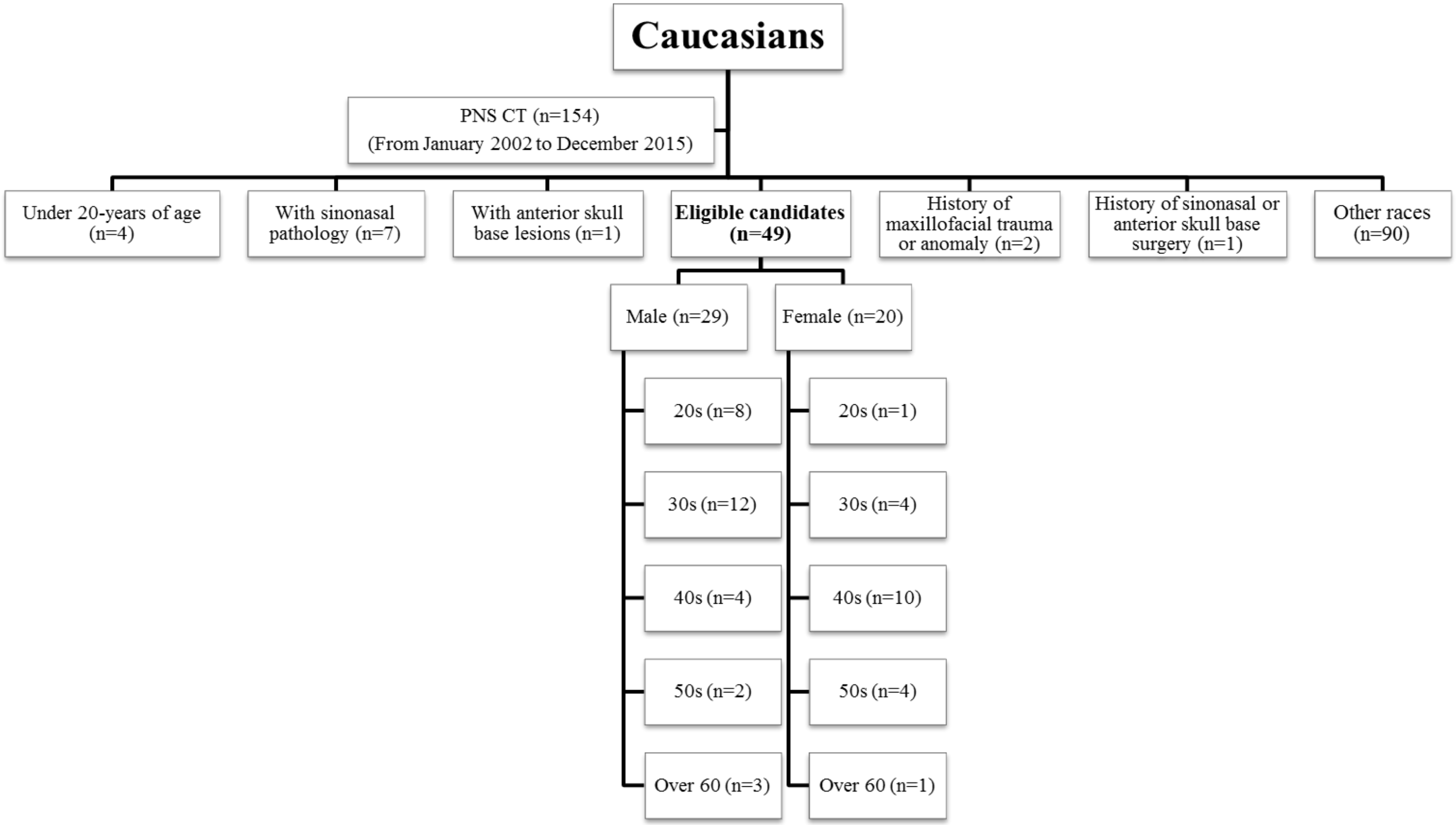

Figure 2. Flow chart of exclusion and inclusion of Caucasian participants. A total of 49 Caucasian patients were included, which consisted of 29 male and 20 female patients.

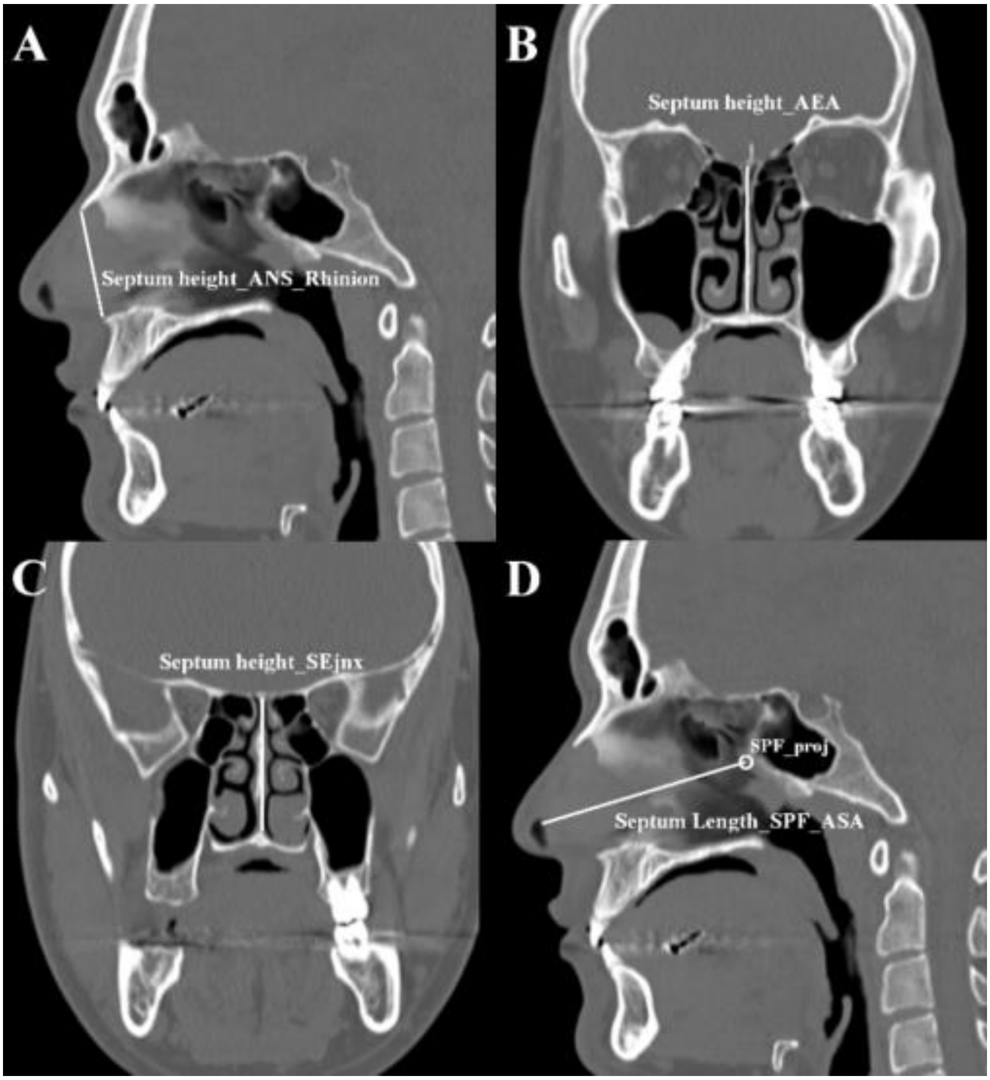

Figure 3. Radioanatomic measurement of the septum. A. Septal height was measured from the anterior nasal spine to rhinion (Septum height_ANS_Rhinion), B. Septum height at anterior ethmoid artery level (Septum height_AEA), C. Septum height at sphenoethmoidal junction (Septum height_SEjnx), D. Length of the septum was measured from the projection of the sphenopalatine foramen to the anterior septal angle.

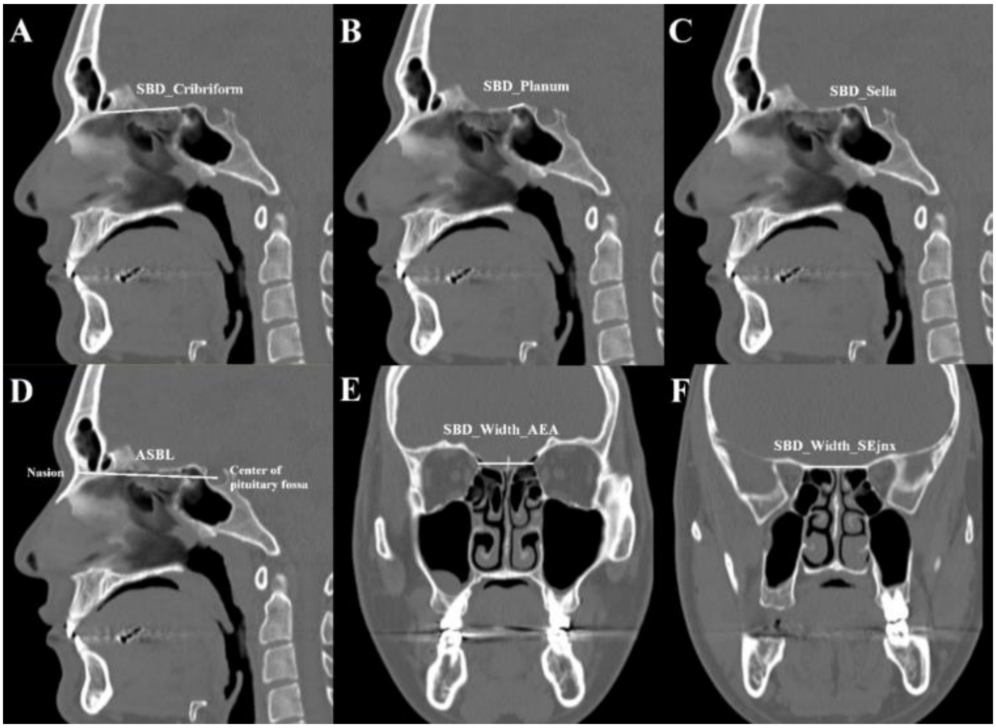

Figure 4. Radioanatomic measurement of skull base dimensions. A. Length of the cribriform, B. Length of the planum, C. Length of the anterior wall of the sella, D. Anterior skull base length, E. Width of the skull base at the anterior ethmoidal artery, F. Width of the skull base at the sphenoethmoidal junction.

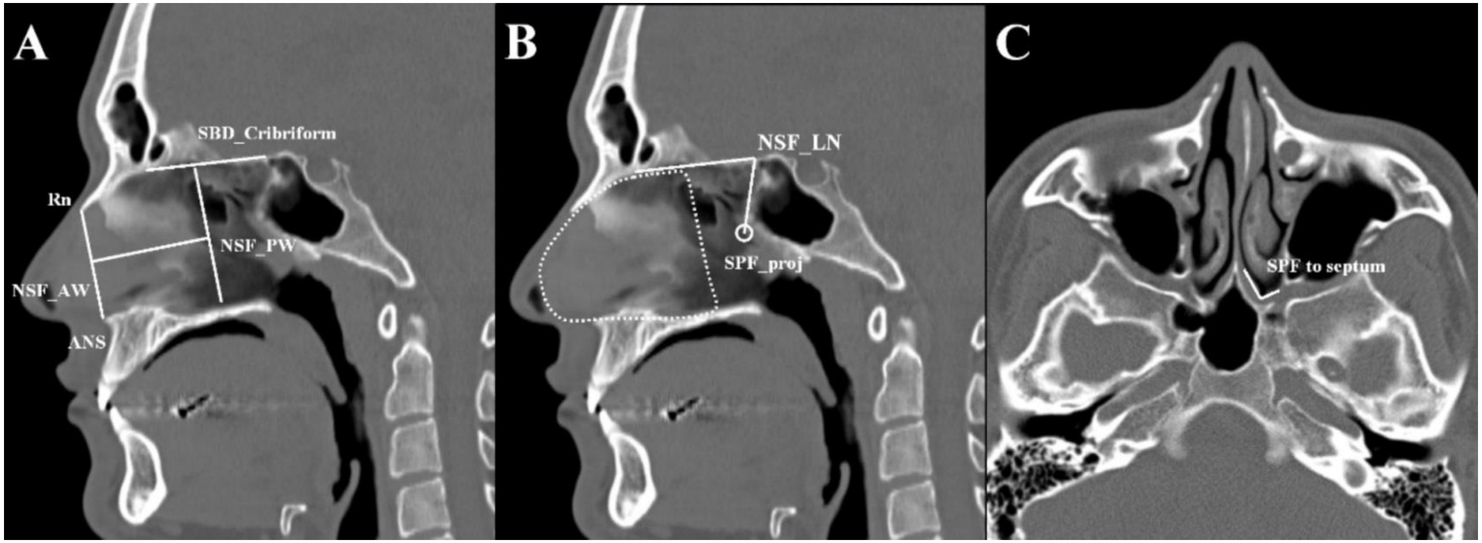

Figure 5. Radioanatomic measurement of the dimensions of the nasoseptal flap (NSF) needed for reconstruction of the anterior skull base defect. A. The anterior width of the NSF (NSF_AW) corresponded to the Septum height_ANS_Rhinion distance. A parallel line drawn from the skull base to the base of the nasal cavity after a distance equivalent to the length of the cribriform plate and perpendicular to the anterior width, represented the posterior width of the NSF (NSF_PW). B. The length of the nasoseptal flap needed to cover the anterior skull base defect (NSF_LN) was determined by the sum of the length of the cribriform plate and the distance from the SPF_proj (white circle) to the sphenoethmoid junction. The dotted area depicts the reconstructive area of the septum. C. The maximum length of the NSF was calculated as the sum of the septum length and the distance from the SPF to the septum in the axial view at the level of the SPF.

요약 (국문 초록)

목적: 아시아인에서 비중격피판을 활용한 전두개골 기저부 결손 재건술의 타당성을 평가하고 그 결과를 백인 집단에서의 결과와 비교하고자 함.

대상 및 연구 방법: 정상 단층화 촬영 영상 결과를 보인 한국인 성인 환자 100 명을 대상으로 후향적 방사선해부학적 분석을 시행하였다. 비중격 및 두개골 기저부의 치수를 측정하였고, 성별과 연령군에 따른 비중격피판을 활용한 전두개골 기저부 재건술의 타당성을 비교 분석 하였다. 마지막으로 한국인에서 측정한 수치들과 타당성 결과를, 49 명의 정상 단층화 촬영 영상 결과를 보이는 백인들을 대상으로 시행한 동일한 치수 측정 및 타당성 평가 결과와 비교 분석하였다.

결과: 측정한 여러 비중격 치수들 중 비중격의 길이가 백인에서 측정한 수치과 비교했을 때 한국인에서 유의한 차이를 보였다. 전두개 기저부 길이와 전사골 동맥의 비강내 기시부 수준에서 전두개골 기저부 폭과 같은 두개골 기저부 치수는 두 인종 집단 사이에서 유의한 차이를 보였다. 비중격피판의 이론적인 앞쪽 넓이와 전두개골 기저부의 방사선해부학적인 전방 결손 폭 간의 차이(2.8 ± 3.1 대 6.4 ± 4.8)와

비중격피판의 이론적인 길이와 전두개골 기저부 재건을 위해 필요한 비중격피판 길이의 차이(7.2 ± 3.8 vs 13.1 ± 5.6)는 한국인에서 유의하게 작은 결과를 보여 비중격피판을 활용한 전두개골 기저부 재건이 타당하지 못할 가능성이 통계적으로 한국인에서 더 높은 결과로 이어졌다. 이러한 비중격피판의 부족 현상은 여성에서 더 높은 정도 및 빈도로 발견되었다. 또한 연령군 별로 비교하였을 때, 백인군에서는 비중격 수치들에서 차이를 보이지 않았으나 한국인에서는 남자군내 및 여자군내 그리고 성별과 무관하게 전사골 동맥의 비강내 기시부 수준에서 측정한 비중격의 높이가 통계적으로 유의한 차이를 보이는 것으로 나타났다. 두개골 기저부의 치수는 한국인 남성군 내에서 터어키안 전벽의 길이가 연령군별 유의한 차이를 보였고, 백인은 남성군 및 성별과 무관하게 접형사골 경계부 수준에서 측정한 두 개저의 폭이 연령군별 유의한 차이를 보였다. 그러나 이와 같은 연령군별 차이를 보이는 결과는 비중격피판을 활용한 전두개골 기저부 결손부위 재건의 타당성 결과에 유의한 영향을 미치지 않았다.

결론: 전두개 기저부 결손 재건을 위한 비중격 피판의 타당성 분석 결과 한국인에서 백인과 비교하여 전방 전두개 기저부 결손 재건에 위험성이 높다는 결과를 보였고, 남성군 보다는 여성군에서 더 두드러지게

나타났다. 비중격 피판의 크기를 증가시키기 위한 노력과 수술 중 비중격 피판의 수축을 피하기 위한 노력은 아시아인에서 상대적으로 작은 비중격 피판을 보완하기 위해 항상 고려되어야 한다.

주요어: 전두개골 기저부, 내시경적 최소 침습 두개골 기저부 수술, 비중격 유경피판, 두개골 기저부 재건술, 방사선학적 연구

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