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Bone resorption after maxillary reconstruction with the vascularized free iliac flap

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Abstract. The aim of this study was to evaluate the resorption of the iliac bone after maxillary reconstruction with a vascularized free iliac flap. Twenty-seven patients with maxillary defects who underwent maxillary reconstruction with the vascularized free iliac flap between January 2017 and January 2021 were included. Computed tomography (CT) images taken at 1 week, approximately 6 months, and 1 year after the surgery were used for evaluation. The total iliac bone thickness and height, cortical bone thickness, and cancellous bone density were measured in the CT images. Compared with 1 week after the surgery, the total thickness and height of the iliac bone were reduced significantly 1 year after the surgery, and the cortical bone thickness and cancellous bone density were reduced significantly at 6 months and 1 year after the surgery. Compared with 6 months after the surgery, cancellous bone density was reduced significantly 1 year after the surgery. In conclusion, during the first year after maxillary reconstruction with a vascularized free iliac flap, there was significant resorption of iliac bone, including the total iliac bone thickness and height, the cortical bone thickness, and the cancellous bone density.

Keywords: Maxilla; Ilium; Cortical bone; Cancellous bone; Bone resorption.

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Maxillary defects after tumour resection or trauma in the head and neck region can cause severe functional and cosmetic deformities.[1] The free iliac flap based on the deep circumflex iliac artery was first proposed for use in mandibular reconstruction and is well described. It is also well suited to maxillary reconstruction, as the natural curvature of the iliac crest corresponds well to that of the maxilla.[2]

The use of a vascularized iliac free flap combined with dental implant placement can restore and provide good long-term maxillofacial appearance and function[3]. A sufficient bone volume and bone quality, which includes cortical bone thickness and cancellous bone density, are crucial factors for ensuring dental implant success, and these substantially influence the survival rate of implants.[4–7]

Mertens et al.[8] and Wilkman et al.[9] demonstrated bone resorption in patients who had undergone mandibular reconstruction with a vascularized free iliac flap. Studies on bone resorption in vascularized free iliac flaps after maxillary reconstruction are rare. The aim of the present study was to evaluate the resorption of the iliac bone after maxillary reconstruction with a vascularized free iliac flap, in order to determine the changes in the total iliac bone thickness and height, cortical bone thickness, and cancellous bone density.

Materials and methods

This study included patients who had undergone maxillary reconstruction with a vascularized free iliac flap in the Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China, between January 2017 and January 2021. The inclusion criteria were (1) maxillary defect after tumour resection requiring restoration with a vascularized free iliac flap, (2) the use of at least one iliac crest segment to reconstruct the maxillary alveolus, (3) no postoperative exposure of the titanium plates or infection, and (4) computed tomography (CT) images taken at 1 week, approximately 6 months, and 1 year after the surgery. The exclusion criteria were (1) failure of the flap to survive, (2) any bone metabolism disease in the patient, and (3) radiotherapy or chemotherapy before and after the operation. This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Institutional Ethics Committee, Peking University School and Hospital of Stomatology (PKUSSIRB – 202164070).

Imaging analysis

CT images (120 kV, 25 mA, section width 1.25 mm) that were obtained at 1 week, approximately 6 months, and 1 year following the reconstruction were used to evaluate iliac bone resorption. The iliac bone was viewed in a bone window (800 Hounsfield units (HU)) and measured manually using PACS software (Carestream Health Inc., Rochester, NY, USA).

The observation planes were adjusted so that the transverse plane was parallel to the occlusal plane and 10 mm above the lowest point of the iliac segment. The exterior and interior sides were then measured in the transverse plane (Fig. 1). The sagittal plane was perpendicular to the selected transverse plane, and coincided with the middle long axis of the iliac segment. The inferior side was measured in the sagittal plane (Fig. 1). The total iliac bone thickness was measured in the transverse plane, along the vertical line making a tangent at points corresponding to 25% (S1), 50% (S2), and 75% (S3) of the maximum length of the interior side (Fig. 2A). The total iliac bone height was measured in the sagittal plane, along the vertical line making a tangent at points corresponding to 25% (S1), 50% (S2), and 75% (S3) of the maximum length of the inferior side (Fig. 2B). Cortical bone thickness was measured in three cross-sections at 25% (S1), 50% (S2), and 75% (S3) of the maximum length of the iliac segment, respectively, in the transverse plane and sagittal plane (Fig. 2C, D). Cancellous bone density was evaluated quantitatively using the Hounsfield units value, which is often used to evaluate bone density changes in many medical fields including dentistry and maxillofacial surgery. Three circular areas with a diameter of 6 mm each were selected for determining the Hounsfield unit values in the middle of the iliac segment at 25% (S1), 50% (S2), and 75% (S3) of its maximum length (Fig. 2E). Three circular areas of the same size, whose circle centres were 8 mm vertically above the lower line of the cortical bone, were selected at 25% (S1), 50% (S2), and 75% (S3) of the maximum length of the iliac segment in the sagittal plane (Fig. 2F). The images were assessed independently by two investigators.

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics, version 20.0 (IBM Corp., Armonk, NY, USA). The intra-class correlation coefficient (ICC) was used to evaluate inter-observer reliability. Data are presented as the mean ± standard deviation (SD), and two-way analysis of variance was used to evaluate the differences in total iliac bone thickness and height, cortical bone thickness, and cancellous bone Hounsfield unit values among the measurement time points (1 week, 6 months, and 1 year after the surgery). The resorption rate was expressed as the percentage reduction in the total thickness and height of the iliac bone, cortical bone thickness, and cancellous bone Hounsfield unit values at 6 months and at 1 year after the surgery in comparison to the values at 1 week after the surgery. Sex (female or male), age (> 25 years or ≤25 years), tumour type (benign or malignant), defect type (Brown class II or class III[10]), and number of segments (one or two) were examined by logistic regression analysis to determine the factors associated with cortical bone and cancellous bone resorption. *P*-values of less than 0.05 were considered to indicate statistical significance.

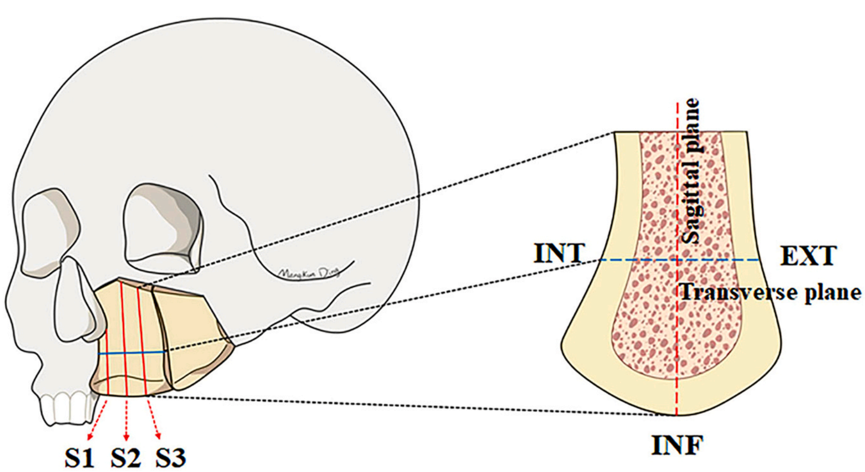

Fig. 1. Schematic diagram of the planes in the CT images used for measurement of the iliac bone. S1, S2, and S3 represent the positions at 25%, 50%, and 75% of the iliac segment length, respectively. (INT, interior side; EXT, exterior side; INF, inferior side).

Results

Out of an initial 41 patients who had undergone maxillary reconstruction with a vascularized free iliac flap, 27 (16 female and 11 male) treated with 33 iliac segments were included in this study. The mean patient age was 32.4 ± 8.9 years (range 17–49 years). Twenty-two patients had benign tumour resections and five patients had malignant tumour resections. Twenty patients had Brown class II defects and seven patients had Brown class III defects. The average follow-up time was 10.9 ± 0.8 months (range 10–13 months) (Table 1). Nine patients had implant surgery for reconstruction of

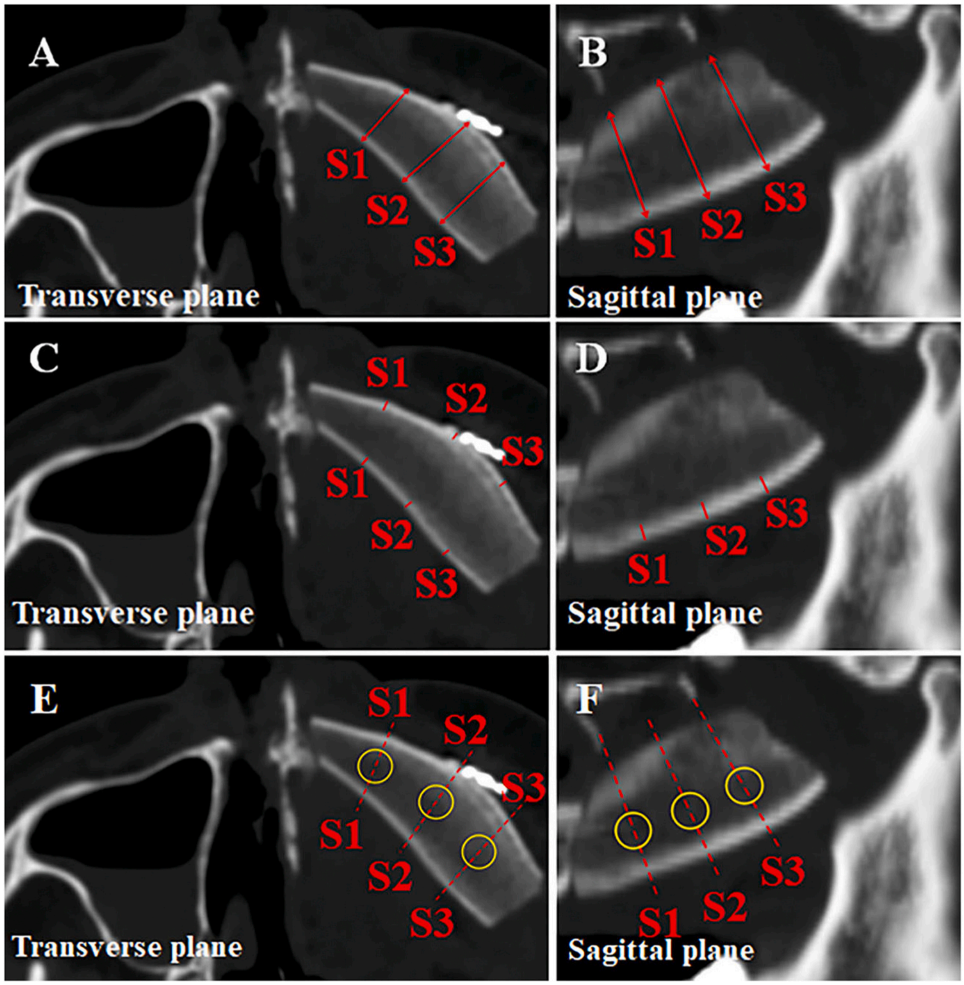

Fig. 2. Measurements of the iliac bone in the transverse and sagittal planes. A and B: measurements of the entire thickness and height of the iliac bone. C and D: measurements of cortical bone thickness. E and F: measurements of cancellous bone density.

the occlusion between 1 year and 2 years after the maxillary reconstruction surgery; the other 18 patients had no reconstruction of the occlusion of any type. Inter-observer reliability was good (ICC = 0.83).

Table 1. Patient characteristics.

Variable	
Number of patients	27
Sex, *n*	
Female	16
Male	11
Age (years), mean ± SD (range)	32.4 ± 8.9 (17–49)
Disease, *n*	
Benign tumour	22
Malignant tumour	5
Defect, *n*	
Brown class II	20
Brown class III	7
Follow-up time (months), mean ± SD (range)	10.9 ± 0.8 (10–13)

SD, standard deviation.

The total thickness and height of the iliac bone at 1 week after the surgery were 13.45 ± 3.21 mm and 22.23 ± 3.92 mm, respectively. One year after the surgery, the total thickness and height of the iliac bone had decreased by 9.1% and 6.5%, respectively (thickness, $P < 0.001$; height, $P < 0.003$ (Table 2, Fig. 3).

Cortical bone thickness of the exterior, interior, and inferior sides at 1 week after the surgery were 1.62 ± 0.46 mm, 1.21 ± 0.19 mm, and 2.76 ± 0.67 mm, respectively. Six months after the surgery, cortical bone thickness of the exterior, interior, and inferior sides had decreased by 26.5%, 20.7%, and 28.3%, respectively (exterior, $P < 0.008$; interior, $P < 0.001$; and inferior, $P < 0.001$). At 1 year after the surgery, cortical bone thickness of the exterior, interior, and inferior sides had decreased by 34.6%, 24.0%, and 39.5%, respectively (exterior, $P < 0.001$; interior, $P < 0.001$; and inferior, $P < 0.001$) (Table 2, Fig. 3).

Cancellous bone density (Hounsfield unit values) at 1 week after the surgery was 308.77 ± 113.56 HU in the transverse plane and 304.26 ± 108.22 HU in the sagittal plane. Six months after the surgery, the values had decreased by 63.3% in the transverse plane and 61.9% in sagittal plane (transverse, $P < 0.001$; sagittal $P < 0.001$). One year after the surgery, the values had decreased by 75.7% in the transverse plane and 75.8% in the sagittal plane (transverse, $P < 0.001$; sagittal $P < 0.001$). The values at 1 year after surgery had also decreased significantly when compared to those at 6 months after the surgery (transverse, $P < 0.026$; sagittal $P < 0.048$) (Figs. 3 and 4).

Logistic regression analysis showed that none of the five examined variables (sex, age, tumour type, defect type, and number of segments) were associated with

Table 2. Changes in the iliac bone across the three time points after surgery.

		1 week (mm)	6 months (mm)	1 year (mm)
Total bone	Thickness	13.45 ± 3.21	13.02 ± 3.36	12.23 ± 3.23**
	Height	22.23 ± 3.92	21.78 ± 3.75	20.78 ± 3.28**
Cortical bone	Exterior side	1.62 ± 0.46	1.19 ± 0.23**	1.06 ± 0.26**
	Interior side	1.21 ± 0.19	0.96 ± 0.13**	0.92 ± 0.22**
	Inferior side	2.76 ± 0.67	1.98 ± 0.55**	1.67 ± 0.79**

Data are presented as the mean ± standard deviation.
**Significant difference compared with 1 week after the surgery, $P < 0.01$.

the resorption of total iliac bone, cortical bone, or cancellous bone ($P > 0.05$).

Discussion

Maxillectomy defects may be extensive and complex, and the goals of maxillary reconstruction are to obliterate the defect, restore function, particularly speech and mastication, and provide structural support for the reconstruction of facial features.[11] The use of a free iliac flap based on the deep circumflex iliac artery is one of the methods that are available to achieve these aims.[2,12–14]

Mertens et al.[8] studied iliac bone changes after mandibular reconstruction with the iliac flap, using digital panoramic radiographs, and reported that the vertical bone height reduction was 6.79% after 6 months, 10.20% after 11 months, and 12.58% after 17 months. Wilkman et al.[9] measured

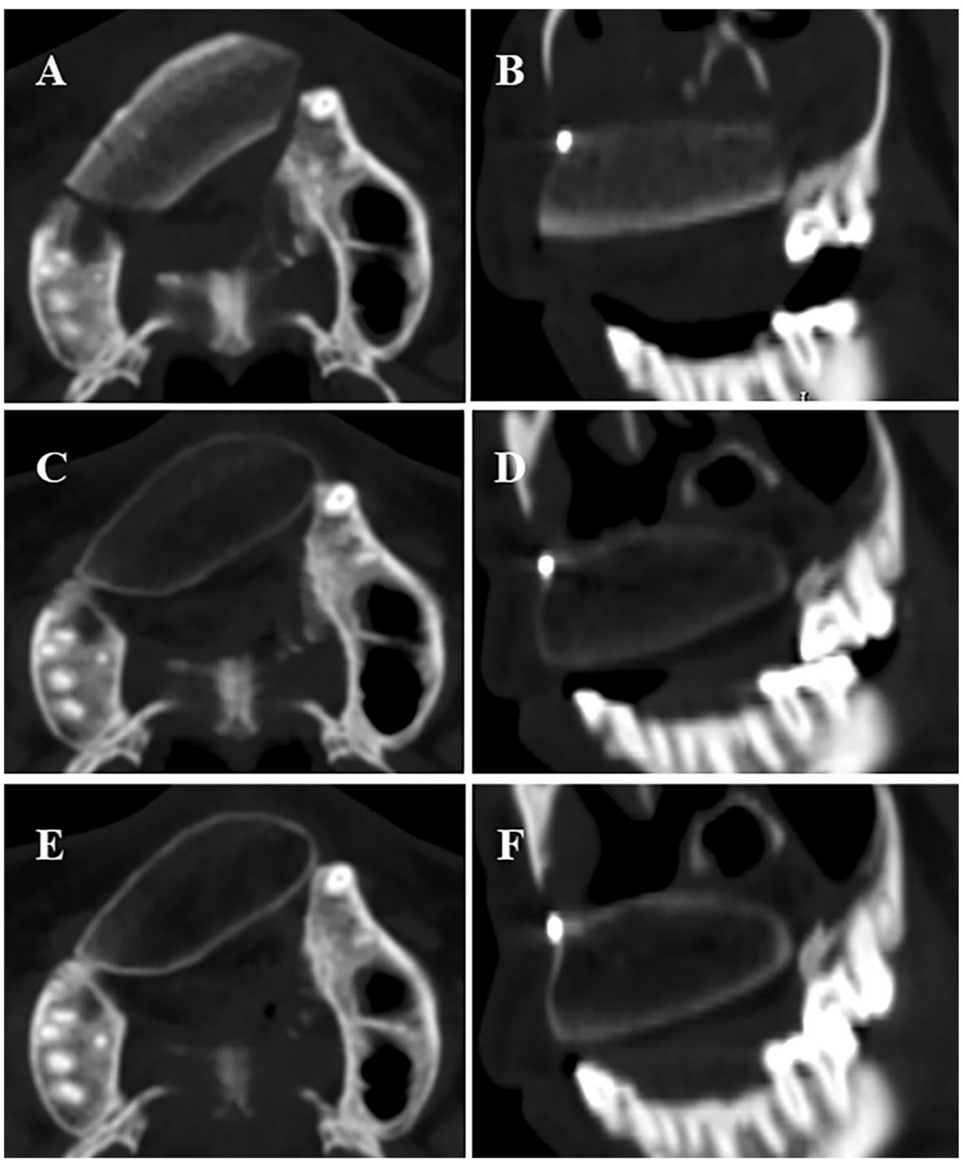

Fig. 3. CT images showing changes in the iliac bone of the vascularized free iliac flap after maxillary reconstruction in a male patient aged 36 years. A and B: 1 week after the surgery; C and D: 6 months after the surgery; E and F: 1 year after the surgery.

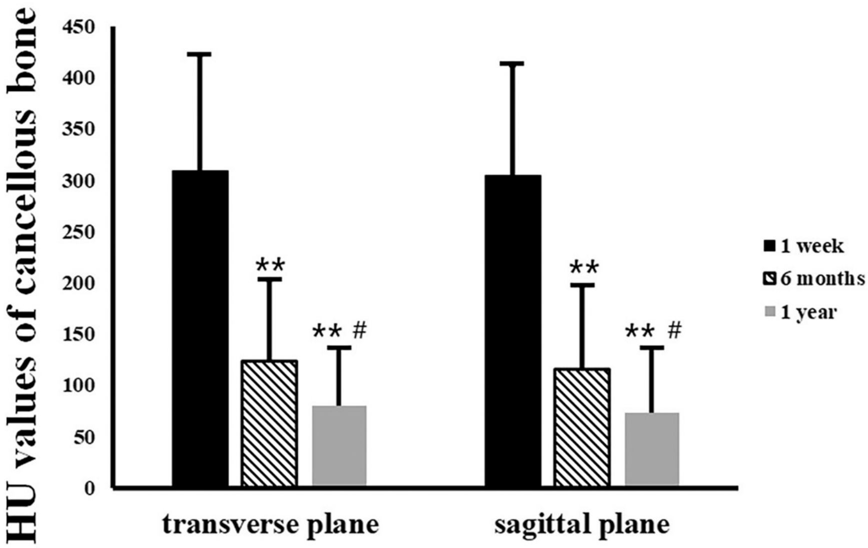

Fig. 4. Changes in cancellous bone density in the transverse and sagittal planes at three time points after the surgery. **Significant difference compared with 1 week after the surgery, $P < 0.01$. #Significant difference compared with 6 months after the surgery, $P < 0.05$.

bone height and thickness reductions in multi-slice computed tomography (MSCT) images and observed a 3% volume loss in iliac bone at 2 years after mandibular reconstruction with the iliac flap. In the long axis of the iliac bone, regenerative new bone can join the iliac bone and maxillary bone together 6 months after the surgery, so the present study focused on the changes in total thickness and height of the iliac bone. It was observed that the total thickness of the iliac bone was reduced by 3.2% after 6 months and 9.1% after 1 year, and the total height of the iliac bone was reduced by 2.0% after 6 months and 6.5% after 1 year. This confirms that the bone volume shows a persistent but non-significant decrease after maxillary reconstruction with the vascularized free iliac flap.

The thickness of the cortical bone has an important role in the primary stability of implants.[4] Currently, the direct measurement of cortical bone thickness on CT images is the best option,[15] and new approaches are needed to evaluate cortical bone thickness more easily and objectively. Kang et al.[15] evaluated the change in cortical bone thickness of fibula bone after maxillary reconstruction with a fibula free flap in CT images, and found cortical bone loss of 21%, 17%, 10%, and 31% for the exterior, interior, superior, and inferior sides, respectively, at 1 year after the surgery. In the present study, the iliac cortical bone loss after maxillary reconstruction was considerably greater, at 34.6%, 24.0%, and 39.5% for the exterior, interior, and inferior sides, respectively, at 1 year after the surgery.

Bone density has an important role in the survival rate of implants.[5] Dual-energy X-ray absorptiometry (DXA) and quantitative computed tomography (QCT) are two important methods for the measurement of bone density, but MSCT without quantitation is used more widely as an examination method before and after surgery in clinical practice. The measurement of Hounsfield unit values in CT images is a feasible tool to assess bone quality, with good sensitivity compared with DXA, and many studies have used Hounsfield units to evaluate bone density changes across various medical fields, including dentistry and maxillofacial surgery.[16–19] Up to now, there have been few studies on cancellous bone density changes in the vascularized bone flap used for maxillofacial reconstruction. In the present study, during the 1-year period after surgery, the Hounsfield unit values of the cancellous bone decreased significantly to around 70 HU, which is equivalent to the Hounsfield unit value of haematomas.

Considering that a sufficient bone volume and bone quality are crucial factors for ensuring dental implant success,[4–7] and the resorption of the total iliac bone, cortical bone, and cancellous bone detected in this study, it is assumed that the iliac bone resorption may have an adverse impact on dental implants. Further studies on this topic are needed in the future.

There are several possible reasons for bone resorption. Without the dentition and occlusion, the fixated iliac bone receives very little stress and is merely used to support the soft tissues over the bone. Frost[20] demonstrated that bone was resorbed when the microstrain was less than 50–100 or stress was less than 1–2 MPa. Accordingly, a reduction in the strain and stress acting on the iliac bone is suggested to be one possible reason for bone resorption. Bone innervation has been shown to play a crucial role in maintaining bone homeostasis.[21] Wang et al.[22] found that at the 12-month follow-up, the density loss of iliac bone used to reconstruct the mandibular bone defect in the non-innervated group was significantly higher than that in the innervated group. Therefore, non-innervation is suggested to be another possible reason.

The sample size and retrospective design are two of the limitations of this study. Although only 27 patients treated with 33 iliac segments were included in this study, the sample size is still larger than that of most previous studies on maxillary reconstruction with the vascularized free iliac flap. In the future, studies with a larger sample size and a prospective design, and more holistic and objective measurements are required to obtain more precise findings about the characteristics of iliac bone resorption after maxillary reconstruction.

In conclusion, the total iliac bone thickness and height, iliac cortical bone thickness, and cancellous bone density were found to decrease significantly during the 1 year period after maxillary reconstruction with a vascularized free iliac flap. Moreover, no relationship between bone resorption and sex, age, tumour type, defect type, or number of segments was found in the patients included in this study.

Ethical approval

Peking University School and Hospital of Stomatology Institutional Ethics Committee (PKUSSIRB – 202164070).

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Competing interests

None.

Patient consent

Not required.

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