Computed Densitometry of Panoramic Radiographs in Evaluation of Bone Healing after Enucleation of Mandibular Odontogenic Keratocysts

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Objective: *To investigate bone formation after enucleation of mandibular odontogenic keratocysts (keratocystic odontogenic tumours) by computed densitometry of preoperative and post-operative panoramic radiographs.*
Methods: *Fifty-eight patients with mandibular keratocysts were treated by surgical enucleation and primarily closed without grafting. The largest diameters of the cysts were 3.5 cm to 7.1 cm. Post-operative clinical and radiographic examinations were performed at 1, 3, 6 and 12 months. Bone density of the residual cavity was measured on the preoperative and post-operative panoramic radiographs with Digora® through a greyscale of 254 tonalities. Student* t *test was used for comparison of bone density values of different time periods.*
Results: *Progressive bone formation in the residual cavity was observed after enucleation of mandibular odontogenic keratocysts. The mean increase of bone density was 6.85% at post-operative 1 month, 22.61% at 3 months, 49.45% at 6 months and 71.77% at 12 months in comparison with that of the preoperative radiograph. Although increase in bone density was not significantly different between the post-operative first 3 months and second 3 months, this increase was significantly higher in the first 6 months than that in the later 6 months ($P < 0.05$). No significant correlation was found between increase of bone density and patient gender or the maximal diameter of the cysts.*
Conclusion: *Bone regeneration could progressively occur in the defect area without grafting materials after enucleation of mandibular odontogenic keratocysts, with significant increase of bone density at 6 months post-operatively.*

Key words: *bone healing, computerised analysis, enucleation, odontogenic keratocyst, panoramic radiographs*

Odontogenic keratocyst, also known as keratocystic odontogenic tumour[1], is a common developmental cyst, representing 10.2% of all jaw cysts[2]. The mandible is involved far more frequently than the maxilla, with a higher frequency in the mandibular molar-ramus area. Cyst enucleation with Carnoy's solution treatment is a commonly used method for management of these lesions[3,4]. Radiopacity changes are usually used to evaluate bone healing of the residual cavity after surgery. A variety of grafting materials are used to reduce the risk of mandibular fracture and to shorten the healing period of bone defects after cyst enucleation[5-10]. However, their application may increase post-operative complications. Horowitz and Bodner[6] reported that 20% failure is associated with the use of autogenous bone in combination with a xenograft of Kiel bone, most concentrated in the group of large defects. Allogeneic graft or xenograft increases the post-operative healing period[7]. Chiapasco et al[11] reported that spontaneous regeneration of bone

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was obtained in 27 mandibular cysts exceeding 40 mm in diameter after enucleation. A subjective evaluation of panoramic radiographs to assess the healing process of cystic lesions may be quite imprecise and can introduce a significant bias[12,13], but the results obtained with a computed analysis of panoramic radiographs is more reliable for evaluating this healing process[11].

In the present study, bone formation after enucleation of mandibular odontogenic keratocysts was investigated using a computed analysis of bone density on pre- and post-operative panoramic radiographs to determine the healing progression of this bone defect.

Patients and methods

The study was approved by the institutional review board of the hospital and performed according to its guidelines. It included 58 consecutive patients who underwent enucleation of mandibular odontogenic keratocysts and had a follow-up of more than 6 months within a 10-year period from 1999 to 2008 in the Department of Oral and Maxillofacial Surgery, Hospital of Stomatology, Wuhan University. There were 36 males and 22 females, aged between 18 and 69 years, enrolled in the study. The dimensions of the cysts were evaluated on panoramic radiographs taken just before surgical treatment. Recurrent cysts were not included in the study. Follow-up was based on clinical and radiographic examinations at 1, 3, 6 and 12 months after surgical treatment. All panoramic radiographs were obtained with Promax (Planmeca, Helsinki, Finland), and converted into digital images using the computed radiography system Regius (Konica Minolta, Tokyo, Japan). Bone density of the residual cavity was measured on the preoperative and post-operative panoramic radiographs with Digora® (Soredex, Orion, Helsinki, Finland) through a greyscale of 254 tonalities. Measurements were taken both on the central part of the cystic region and on the healthy bone from the corresponding region on the contralateral side, on the same panoramic radiographs (Fig 1). The central part of the cystic region was defined as the intersection point between the midpoint of the longitudinal line and the vertical line. The mean density measurement of each lesion was subtracted from the mean density measurement of the corresponding bone on the contralateral side. The bone density at four follow-up periods was compared with that from the preoperative panoramic radiographs.

The data set was further analysed with the aid of the SPSS 13.0 package (SPSS, Chicago, IL USA), and a Student *t* test was used for comparison between bone density values of different time periods. Results were considered significant at $P < 0.05$.

Results

All the cysts were diagnosed histopathologically as odontogenic keratocysts[14]. The largest diameters of the cysts were 3.5 cm to 7.1 cm. The post-operative radiographs demonstrated a progressive increase of radiopacity of the residual cavities at four post-operative follow-up periods (Table 1). The post-operative radiographs showed gradual reduction of the residual cavity in all cases, with significant bone regeneration and reconstitution of normal anatomical structures in the affected mandible at post-operative 3 to 6 months. Figure 2 shows a representative case of a large cyst occupying the left mandibular body to ramus region, significantly increasing bone density in the cystic site 6 months post-operatively. The mean greyscale values measured preoperatively were 99.4 on the cyst region and 144.5 on the corresponding bone region on the contralateral side. The mean increase in bone density was 49.45% on the 6-month post-operative radiograph and 71.77 % on the 12-month post-operative radiograph, in comparison with the bone density on the preoperative radiograph. Although increase in bone density was not significantly different between the post-operative first 3 months and second 3 months, the bone density was significantly higher in the first 6 months than that in the second 6 months ($P < 0.05$). No significant difference was found between males and females, and between cysts ≤ 5 cm in diameter and those > 5 cm in diameter. The preoperative mean bone density in the cyst site was 67.75% of the contralateral healthy bone, and post-operative bone density in the residual cavity increased to 82.56% of the healthy bone at 6 months and 90.11% at 12 months.

Discussion

Residual cavity after enucleation of jaw cysts is a common bone defect. Osteogenesis of a bone defect in the jaws begins with formation of a blood clot, which is later replaced by osteogenic granulation tissue[9]. Some studies on spontaneous bone regeneration after cyst enucleation have been performed before, and most of the evaluations made on panoramic radiographs are subjective and do not contain measurable values.

In the present study, the authors investigated the progress of the bone healing using a computer-assisted method, to evaluate osseous regeneration by measuring bone density. In a study by Chiapasco et al[11], 27 cases with large mandibular cysts were treated with enucleation and no grafting material was used. They evaluated bone regeneration and reduction of the residual cavities by a computed analysis of preoperative and post-

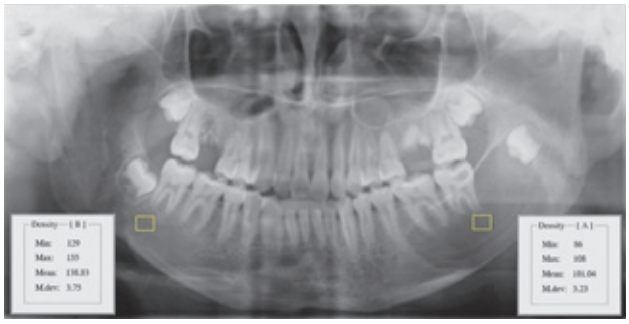

Fig 1 Preoperative radiograph of the patient shows the sites for measuring bone density in the affected side (A) and in the healthy side (B).The bone density in the cyst site was 72.8% of that of the contralateral bone.

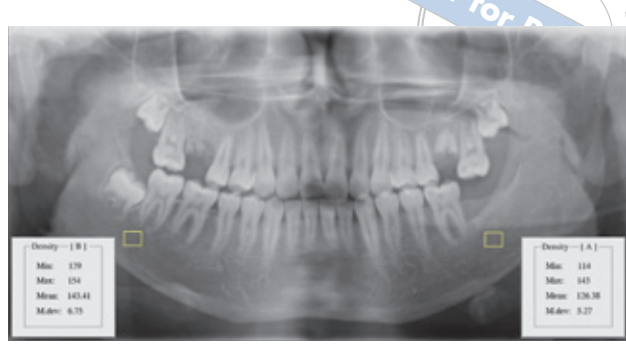

Fig 2 Radiograph of the patient in Figure 1, 6 months post-operatively, shows that the bone density in the affected area significantly increased, up to 88.1% of that of the contralateral bone.

Table 1 Changes of differences in greyscale values between cyst site and contralateral bone after enucleation of mandibular keratocysts (mean ± SD)

Pre-operation	Post-operation				*P*
	1 month	3 months	6 months	12 months	
(n = 58)	(n = 58)	(n = 58)	(n = 45)	(n = 37)	
47.95 ± 26.16	45.04 ± 28.06	37.42 ± 30.93	24.42 ± 30.35	13.62 ± 15.88	<0.05*
Decrease (%)	6.85	22.61	49.45	71.77	

* The difference was significant between the post-operative 6-month and 12-month results

operative panoramic radiographs, and found that mean bone density in the residual cavities was increased by 37% after 6 months, and 48.27% after 12 months as compared with the immediate post-operative values.

Ihan Hren and Miljavec[15] studied spontaneous bone healing of the bone defects with a computer analysis of panoramic radiographs in 33 patients with mandibular odontogenic cysts and benign lesions, and demonstrated that the mean final bone density in bone defects was 88% of that of the surrounding bone. In cases of smaller bone defects (20–30 mm), the final bone density was 97%, while in bone defects of 30–50 mm, the bone density of surrounding bone was 84% after 1 year.

The present results agreed with previous studies that bone cavities are able to regenerate in large cysts after enucleation without any bone grafting[8,11]. If the cystic area is going to be rehabilitated with a removable denture, the length of the healing process or the quality of the regenerated bone is probably not very important[11]. However, if the cystic area is planned as a site for an osseointegrated implant, the quantity and the quality (bone density) of the regenerated bone, as well as the rate of regeneration, are of utmost importance[11]. The present results show that post-operative bone density in the residual cavity was significantly increased at 6 months post-operatively, to over 80% of the bone density of the contralateral healthy bone. Therefore, even the large cystic lesions of the mandible are worth considering when planning for further rehabilitation after enucleation.

Radiography is the major non-surgical method for detecting bone formation in a healing osseous defect. Thus it is useful in clinical situations because of its speed, continuity of measurements, and non-invasive nature. Bone healing is radiographically expressed as an increase in radiopacity, resulting in a higher optical density of the bone image. Computed tomography is a more precise method to evaluate the bone healing process after cyst enucleation, but it produces a relatively high cost for routine follow-up examinations[11]. The only objective method for determining absolute bone mass is dual energy X-ray absorptiometry (DXA) of the maxilla

and mandible[16]. It remains clinically inapplicable for the follow-up of the healing of bone defects because of the high costs. The measurement of bone density of the defect area and surrounding healthy bone on the same radiograph may avoid the mistakes arising from comparing the bone density from different radiographs. The method of relative densitometry can be performed on standard or digitalised panoramic radiographs, and can be used to monitor bone healing regularly, with low costs and reduced irradiation hazards.

Conclusion

With computer-assisted analysis of bone density on pre- and post-operative panoramic radiographs, bone density of the cystic site significantly increased 6 months post-operatively compared with before the operation.

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