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THE ROLE OF ITK-SNAP SOFTWARE IN THE DIAGNOSIS AND MONITORING OF HEALING AFTER APICOECTOMY

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ABSTRACT

Objective: To evaluate the role of ITK-SNAP software in the diagnosis and monitoring of healing after apicoectomy.

Methods: A descriptive case series was conducted on 30 patients with 41 teeth and 36 lesions undergoing apicoectomy at the Institute of Odonto-Stomatology, Hanoi Medical University, from August 2020 to July 2021. Cone-beam computed tomography (CBCT) scans were obtained preoperatively, immediately postoperatively, and at 6 months. Preoperative lesion volumes were segmented and quantified using ITK-SNAP and subsequently categorized using a threshold of 247 mm^3. In cases with 6-month follow-up CBCT, postoperative bone defect volumes were also measured immediately after surgery and at 6 months to assess bone regeneration. Healing was evaluated clinically at 1 week and 3 months. Radiographic healing was assessed at 6 months using the PENN 3D criteria.

Results: The mean age of the patients was 34.37 ± 14.55 years, and 56.7% were male. Maxillary teeth accounted for 70.7% of cases. Periapical cysts represented 30.6% (11/36) of the lesions. Of lesions with a preoperative volume above 247 mm^3, 76.9% were diagnosed as periapical cysts. In contrast, only 4.3% of lesions with a volume up to 247 mm^3 were cystic ($p<0.001$). Favorable healing was observed in 66.7% of cases after 1 week and in 91.3% after 3 months. At 6 months (n=11), complete bone healing according to the PENN 3D criteria was observed in 18.2% of cases, whereas 81.8% showed incomplete healing. The mean postoperative bone defect volume decreased from 355.37 mm^3 immediately after surgery to 74.76 mm^3 at 6 months, representing a 78.96% reduction.

Conclusion: ITK-SNAP is a free and practical tool for CBCT-based segmentation and volumetric assessment. It may serve as a practical adjunct for lesion assessment, postoperative monitoring of healing, and prognostic evaluation after apicoectomy.

Keywords: ITK-SNAP; cone-beam computed tomography; periapical cyst; apicoectomy; three-dimensional segmentation; lesion volume.

1. INTRODUCTION

Chronic periapical lesions are common pathological entities that may develop into periapical granulomas or cysts, leading to bone destruction and compromised oral function. When nonsurgical endodontic retreatment fails due to technical limitations, apicoectomy with curettage and retrograde filling is indicated to remove infection and support healing[1].

Assessment of periapical lesions and postoperative healing after apicoectomy has traditionally relied on two-dimensional imaging, such as periapical or panoramic radiographs. These are limited by anatomical superimposition, reduced accuracy, and variation in projection angle. More recently, cone-beam computed tomography (CBCT) has enabled three-dimensional evaluation of lesion extent, anatomy, and volumetric changes, providing a more reliable basis for healing assessment [2].

Several software platforms are available for lesion segmentation, three-dimensional reconstruction, and volumetric analysis. Among them, ITK-SNAP is a free, open-source software that supports both manual and semi-automatic segmentation. It allows direct volume calculation from DICOM datasets [3,4]. Previous studies have used ITK-SNAP to evaluate periapical lesion volume and to monitor healing after endodontic surgery. This approach contributes to more standardized three-dimensional assessment using criteria such as PENN [5].

In Vietnam, free 3D tools for standardized evaluation of periapical lesions are rarely used. This study aimed to evaluate the practical utility of ITK-SNAP in the assessment and monitoring of healing in periapical lesions treated by apicoectomy.

2. MATERIALS AND METHODS

2.1. Study design

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This was a descriptive case series.

2.2. Study setting and period

The study was conducted at the Institute of Odonto-Stomatology, Hanoi Medical University. Data were collected from August 2020 to July 2021.

2.3. Study participants

The study included patients diagnosed with chronic periapical lesions who were treated at the study center.

2.4. Sample size and sampling

All patients meeting the eligibility criteria were included. A total of 30 patients with 41 teeth (44 root apices) underwent apicoectomy. After surgery, 36 lesions were collected and submitted for histopathological classification.

- *Inclusion criteria:* Patients were eligible if apicoectomy was indicated because of large apical lesions, endodontic complications such as fractured instruments or deeply located foreign bodies, failed or difficult nonsurgical retreatment, or lesions requiring biopsy. Additional criteria included complete clinical records, willingness to participate, and planned postoperative follow-up.

- *Exclusion criteria:* Poor cooperation; severe systemic disease or contraindications to surgery; use of anticoagulant therapy; prior irradiation to the jaws; pregnancy; severe non-restorable periodontal disease; excessively short roots; or anatomical conditions that prevented use of the surgical guide.

2.5. Variables and outcome measures

The main variables included lesion volume (mm^3) measured on CBCT using ITK-SNAP, lesion morphology, histopathologic diagnosis (inflammatory tissue, periapical granuloma, or periapical cyst), and healing outcomes.

At 6 months, radiographic healing was assessed on CBCT according to the PENN 3D criteria. Healing was classified as complete, incomplete (scar tissue), or unsatisfactory/non-healing.

2.6. Study procedures and data collection

Patients underwent clinical examination and preoperative CBCT imaging. Treatment planning included the design of a surgical guide for apicoectomy. Apicoectomy was then performed with lesion curettage and retrograde filling using mineral trioxide aggregate (MTA). Postoperative follow-up included clinical evaluation at 1 week and 3 months, and radiographic assessment of bone healing at 6 months.

CBCT acquisition and image processing

CBCT scans were obtained using a RAYSCAN α+ unit (Ray Co., Ltd., Korea). The image data were stored in DICOM format. Three-dimensional visualization and volumetric analysis were done using ITK-SNAP version 3.8.0.

Segmentation and volumetric measurement using ITK-SNAP

The segmentation workflow in ITK-SNAP version 3.8.0 included: (1) importing the CBCT DICOM dataset and verifying image orientation and voxel dimensions; (2) defining the region of interest around the lesion to reduce noise and processing time; (3) selecting semi-automatic segmentation and adjusting threshold values and seed points according to the density of the radiolucent area; (4) running the segmentation algorithm followed by manual refinement on axial, coronal, and sagittal slices; and (5) calculating lesion volume using the software's statistical tools and reconstructing the three-dimensional lesion model. Each measurement was performed twice, and the mean value was used for analysis.

2.7. Statistical analysis

Data were coded and analyzed using SPSS version 20. Descriptive statistics were presented as mean ± standard deviation, frequency, and percentage. Group comparisons were performed using appropriate statistical tests according to variable type, including the Chi-square test or Fisher's exact test for categorical variables and the t-test or ANOVA for continuous variables. A p-value <0.05 was considered statistically significant.

2.8. Ethical approval

The study was approved by the Ethics Committee in Biomedical Research of Hanoi Medical University (No. 406/GCN-HĐĐĐNCYSH – ĐHYHN).

3. RESULTS

From August 2020 to July 2021, 30 patients with 41 teeth and 44 root apices underwent surgical treatment.

3.1. General characteristics of the study population

The mean age of the patients was 34.37 ± 14.55 years, with the 19- to 40-year age group accounting for the highest proportion (50%). The male-to-female ratio was 17:13, corresponding to 56.7% and 43.3%, respectively.

Table 1. Distribution of affected teeth by jaw and tooth group (n=41)

Jaw	Tooth group	Number (%)	Number (%)
Maxilla	Anterior teeth	22 (53.7%)	29 (70.7%)
	Premolars	4 (9.8%)	29 (70.7%)
	Molars	3 (7.3%)	29 (70.7%)
Mandible	Anterior teeth	5 (12.2%)	12 (29.3%)
	Premolars	1 (2.4%)	12 (29.3%)
	Molars	6 (14.6%)	12 (29.3%)
Total		41 (100%)	41 (100%)

Maxillary anterior teeth were the most frequently affected, accounting for 53.7% of cases. Molars in both arches accounted for 21.9% (9 cases).

3.2. Lesion classification and its relationship with lesion volume and morphology

After surgery, 36 lesions were collected and examined histopathologically.

Table 2. Distribution of histopathologic lesion types (n=36)

Lesion type	n	%
Inflammatory tissue	13	36.1
Periapical granuloma	12	33.3
Periapical cyst	11	30.6
Total	36	100

The distribution of lesion types was relatively balanced, although inflammatory tissue was slightly more common than the other two categories.

Figure 1. Three-dimensional reconstruction of a periapical lesion generated from CBCT data using ITK-SNAP 3.8.0, enabling evaluation of lesion morphology, boundaries, and volume.

Table 3. Association between lesion type and preoperative volume measured using ITK-SNAP (n=36)

Volume group (mm^3)	Inflammatory tissue/ granuloma n (%)	Periapical cyst n (%)	Total n (%)
≤ 247	22 (95.7%)	1 (4.3%)	23 (100%)
> 247	3 (23.1%)	10 (76.9%)	13 (100%)
Total	25 (69.4%)	11 (30.6%)	36 (100%)

When lesion volume was categorized using a threshold of 247 mm^3, 95.7% of lesions with a volume ≤247 mm^3 were classified as inflammatory tissue or granuloma, whereas 76.9% of lesions with a volume >247 mm^3 were diagnosed as periapical cysts.

Table 4. Association between lesion type and preoperative morphology on ITK-SNAP (n=36)

Morphology	Inflammatory tissue/ granuloma n(%)	Periapical cyst n (%)	Total n (%)
Round/Oval	4 (26.7%)	11 (73.3%)	15 (41.7%)
Crescent-shaped	16 (100%)	0 (0%)	16 (44.4%)
Indistinct	5 (100%)	0 (0%)	5 (13.9%)
Total	25 (69.4%)	11 (30.6%)	36 (100%)

All crescent-shaped and indistinct lesions were classified as inflammatory tissue or granuloma. In contrast, 73.3% of round or oval lesions were diagnosed as periapical cysts.

3.3. Healing outcomes over time and volumetric changes

Healing was evaluated at 1 week, 3 months, and 6 months. At 6 months, 11 patients underwent CBCT evaluation of bone healing according to the PENN 3D criteria.

Table 5. Healing outcomes over time based on the PENN 3D criteria

Time point	Good n (%)	Fair n (%)	Poor n (%)
1 week (n=30)	20 (66.7%)	9 (30.0%)	1 (3.3%)
3 months (n=23)	21 (91.3%)	2 (8.7%)	0 (0%)
6 months (n=11)	2 (18.2%)	9 (81.8%)	0 (0%)

At 6 months, CBCT-based assessment according to the PENN 3D criteria showed complete healing in 18.2% of cases and incomplete healing in 81.8%.

Among the 11 cases with 6-month CBCT follow-up, the mean postoperative bone defect volume, measured with ITK-SNAP, decreased from 355.37 mm^3 immediately after surgery to 74.76 mm^3 at 6 months, representing a 78.96% reduction.

4. DISCUSSION

The findings of this study demonstrate the feasibility of using ITK-SNAP, a free software platform, for segmentation and three-dimensional reconstruction based on CBCT data in the diagnosis and follow-up of healing after surgical treatment of periapical lesions, particularly periapical cysts.

ITK-SNAP allows image evaluation to move beyond a purely qualitative approach toward quantitative assessment. Based on lesion volume data, ROC curve analysis was used to determine the discriminatory value of lesion volume and identify an optimal cut-off point. The results indicated that 247 mm^3 was the optimal threshold, reflecting the best balance between sensitivity and specificity. This value may therefore serve as a useful reference point in the diagnostic assessment of chronic periapical lesions. Using a threshold of 247 mm^3, 95.7% of lesions with a volume ≤247 mm^3 were classified as inflammatory tissue or granuloma, whereas 76.9% of lesions with a volume >247 mm^3 were histopathologically confirmed as periapical cysts.. This is consistent with the clinical observation that cystic lesions are often larger and more well-defined. Previous international studies have similarly used CBCT characteristics, including lesion volume, to support the preoperative differentiation of periapical cysts.

Postoperative healing assessment based on two-dimensional radiographs may overestimate healing due to anatomical superimposition and variability in radiographic angulation. By contrast, CBCT combined with volumetric segmentation provides a more accurate evaluation of bone regeneration over time. In the subgroup with 6-month CBCT follow-up, the mean reduction in lesion volume was 78.96%, comparable to previous reports using CBCT for postoperative endodontic assessment. Schloss et al. reported a mean volumetric reduction of 83.7% after endodontic surgery, using OsiriX and ITK-SNAP for segmentation. These findings suggest that three-dimensional volumetric measurement may serve as a sensitive indicator of healing progression[5].

ITK-SNAP is fully free, open-source software that has demonstrated reliable segmentation performance across multiple imaging applications. Gomes et al. reported high accuracy of ITK-SNAP in measuring the volume of irregularly shaped structures on CBCT. In resource-

constrained settings, this represents a major practical advantage for wider implementation in both clinical care and training.

Limitations. First, it was designed as a case series and did not include a control group. Second, the 6-month follow-up period remains shorter than the minimum 1-year period commonly recommended for evaluating bone healing after apicoectomy. Third, only 11 of the 30 patients underwent CBCT follow-up at 6 months, which limits the strength of the conclusions regarding final healing outcomes. Future studies with larger samples, longer follow-up periods, and comparative designs are needed to validate and extend these findings.

5. CONCLUSION

In conclusion, ITK-SNAP is a free, open-source software tool with substantial practical value for segmentation, volumetric quantification, and three-dimensional reconstruction of periapical lesions on CBCT. Lesion volume and morphology derived from ITK-SNAP may assist in the preoperative assessment of periapical cysts, while postoperative volumetric monitoring may provide useful information on healing progression after apicoectomy

RECOMMENDATION

ITK-SNAP should be considered as a supportive tool in the preoperative assessment and postoperative follow-up workflow for apicoectomy in centers equipped with CBCT.

DECLARATIONS

Ethical approval: This study was approved by the Ethics Committee in Biomedical Research of Hanoi Medical University (406/GCN-HĐĐĐNCYSH – ĐHYHN).

Conflict of interest: The authors declare no conflicts of interest related to this study.

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