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Original Article

Designing a Radiographic Index for Periodontitis Evaluation

Martin Lange[1], Berit Hackenberg[1]*, Max Marian[1]

[1]Department of Preventive Dentistry, Periodontology and Cariology, University Medical Centre Goettingen, Germany.

***E-mail** ✉ Berithackenberg47@yahoo.com

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ABSTRACT

Radiographic indices are currently underutilized, primarily due to their complexity and inconsistent standardization. This study aimed to propose a new radiographic index to assist clinicians in evaluating interproximal alveolar bone loss (iABL) in relation to root length among periodontitis patients. A retrospective analysis was conducted on 50 anonymized dental panoramic tomograms (DPTs) from patients diagnosed with periodontitis. The most affected site in each quintet was visually assessed by one investigator and 20 volunteer clinicians, and the results were compared against a gold standard measurement. Intra-examiner reliability was quantified using the Kappa coefficient, while inter-examiner reliability employed the intra-class correlation coefficient; validity was examined with Cramér's V test. The mean intra-examiner agreement for iABL severity and pattern was 0.808 (K) and 0.802 (K), respectively. Inter-examiner agreement was higher when evaluating iABL severity compared to pattern or furcation involvement, with mean correlation values of 0.892 and 0.739, respectively. A strong correspondence was observed between the visual assessments and gold standard measurements. Within the study's limitations, the newly proposed radiographic index shows promise as a straightforward, reliable, and valid tool to aid clinicians in assessing the extent and severity of iABL in patients with periodontitis.

Keywords: Bone loss, Schei technique, Radiographic index, Periodontitis, Panoramic radiographs

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Introduction

Periodontitis is one of the most widespread chronic diseases affecting populations worldwide. Its inflammatory nature results in notable destruction of connective tissue and alveolar bone, accompanied by diverse clinical signs that adversely affect patients' quality of life, highlighting the importance of comprehensive periodontium assessment for proper patient care [1]. Accurate diagnosis, prognosis, and treatment planning rely on a combination of meticulous clinical evaluation and radiographic imaging.

Over the years, various indices have been introduced to improve understanding of periodontitis, primarily using visual examination, periodontal probing, or radiographic assessment. A robust index should quantify disease severity with sufficient precision and reproducibility to allow meaningful statistical analysis in clinical, epidemiological, or combined study settings [2].

One of the key outcomes of developing these indices has been the creation of practical screening tools, such as the Basic Periodontal Examination (BPE), which has been widely used in the United Kingdom since 1986. The BPE remains the standard method for quickly assessing the need for detailed periodontal examination and providing preliminary guidance for treatment [3].

Despite these advantages, most existing indices depend heavily on periodontal probing, a method subject to multiple sources of variability. Factors such as operator technique, tissue health, probe design, local anatomical differences, junctional epithelium length, and the presence of calculus or over-contoured restorations all influence probing accuracy [4]. Precise probing requires consistent angulation, controlled force, accurate CEJ localization, and exact reading of probe measurements [5], in addition to managing patient discomfort during the procedure [6].

Radiography, while not perfect, offers a complementary tool for evaluating alveolar bone loss, supporting diagnosis, treatment planning, prognostic assessments, and longitudinal monitoring of bone changes. Historical radiographic indices, including Sheppard's Index (1936), the Gingival-Bone Count Index (Dunning and Leach, 1960), and Teeuw's Bone Loss Index (2009), have attempted to quantify alveolar bone changes in periodontitis. However, their complexity and lack of standardization have limited their routine application in research and clinical practice.

In light of these limitations, this study introduces a new radiographic index designed to measure interproximal alveolar bone loss (iABL) relative to the total root length of individual teeth. Combining this index with clinical screening tools, such as the BPE, could enhance clinicians' ability to assess disease severity accurately. The study aims to evaluate the validity and reliability of the proposed index and present it as a practical tool for determining iABL extent and severity in periodontitis patients. It is proposed that this radiographic index could become a straightforward, reliable adjunct for both clinical assessment and epidemiological studies.

Materials and Methods

A cross-sectional study was performed to examine the reliability and validity of the newly proposed radiographic index. The sample consisted of 50 anonymized dental panoramic tomograms (DPTs) obtained through convenience sampling from adult patients previously diagnosed with periodontitis who attended consultant or postgraduate periodontal clinics at Charles Clifford Dental Hospital (CCDH) between March 2018 and March 2019. All images were captured using an Instrumentarium Dental Orthopantomograph® OP200 D (Instrumentarium Dental, Nahkelantie, Finland).

Following ethical approval from The University of Sheffield, School of Clinical Dentistry (Ref. No. 025305, approved 23 December 2019) and authorization from Sheffield Teaching Hospitals NHS Foundation Trust (STH20877), the DPTs were processed with PACS software to enhance visualization of alveolar bone levels and root apices. The images were standardized in size and orientation, anonymized, and printed on Grade A A4 paper using an HP LaserJet M5035xs MFP printer.

For intra-examiner reliability, a single investigator (ZS) assessed alveolar bone loss severity and extent in relation to root length on all 50 DPTs on two separate occasions spaced one month apart. To determine inter-examiner reliability, 30 volunteers with varying clinical experience—including eight dental undergraduates (UG), twenty postgraduate dental students (PGT), and two restorative dentistry consultants—evaluated the same 50 DPTs in two equal batches, one month apart, under proper lighting conditions. A 67% participation rate resulted in 20 sets of visual interpretations being analyzed **(Figure 1)**.

Figure 1. Flowchart of participants.

A sample size estimation for this study was based on a pilot study involving 10 participants. Preliminary results from the pilot indicated a certain level of agreement, and it was anticipated that higher agreement would be observed in the larger study. Considering that 50 observations per participant would be evaluated, and aiming for statistical significance with an alpha of 0.05 and a minimum power of 80%, the calculated minimum number of subjects needed was 19 [7] **(Table 1)**.

Table 1. Sample size requirement for intra-class correlation for R0 ≠ 0 versus R1 (R0 = 0.5 versus R1 = 0.7) and alpha = 0.05.

[R_0 = 0.5] vs. [R_1 = 0.7]		
Observation per Subject	**Number of Subjects (Power = 80%)**	**Number of Subjects (Power = 90%)**

2	63	87
3	39	55
4	32	45
5	28	40
6	26	37
7	25	35
8	24	33
9	23	32
10	22	32
20	20	28
30	19	27
40	19	27
→ 50	19	26
60	19	26
70	18	26
80	18	26
90	18	26
100	18	26

An orientation session was held for all volunteer participants to explain the study's purpose, objectives, and methodology. During this session, the system for assessing interproximal alveolar bone loss (iABL) on dental panoramic tomograms (DPTs) was presented, and participants were provided with the following materials:

- Information Sheet for Participants
- Consent Form
- Detailed Instructions
- Fifty anonymized DPTs, divided into two batches (1–25 and 26–50)
- A Scoring Grid for documenting assessments, to be returned to investigator ZS

The visual evaluations, including both intra-examiner and inter-examiner results, were compared with a reference standard using the Schei Technique to determine the validity of the proposed index. This method calculates alveolar bone height as a fraction of the tooth's radiographic root length, employing a plastic "Schei ruler." Sites were considered to exhibit bone loss if the distance from the cemento–enamel junction (CEJ) to the alveolar crest (AC) exceeded 1 mm. When restorations obscured the CEJ, the cervical margin of the restoration was used, unless it was clearly positioned apical to the expected CEJ [8]. The following anatomical landmarks were used for measurement:

- CEJ: the radiographic endpoint of enamel on mesial and distal crown surfaces
- Alveolar crest: the coronal-most point of the periodontal ligament with normal width (0.2–0.4 mm) [9]
- Radiographic apex: the radiographic tip of the root [10]

The proposed radiographic index was applied using these steps:

1. The dentition was segmented into five maxillary and five mandibular quintets **(Table 2a)**.
2. For each quintet, the highest (worst) score for bone loss was recorded, following the scoring codes and descriptions in **Tables 2b and 2c**.
3. All teeth within a quintet were evaluated, excluding third molars unless first or second molars were absent.
4. Quintets were scored only if they contained at least one tooth.

Table 2. a) Teeth allocation in different quintets for the radiographic index. (b) The proposed scoring codes for the radiographic index. (c) The proposed additional descriptors.

(a)

UPPER RIGHT MOLARS (#17–#16)	**UPPER RIGHT PREMOLARS** (#15–#14)	**UPPER ANTERIORS** (#13–#23)	**UPPER LEFT PREMOLARS** (#24–#25)	**UPPER LEFT MOLARS** (#26–#27)
LOWER RIGHT MOLARS (#47–#46)	**LOWER RIGHT PREMOLARS** (#45–#44)	**LOWER ANTERIORS** (#43–#33)	**LOWER LEFT PREMOLARS** (#34–#35)	**LOWER LEFT MOLARS** (#36–#37)

(b)

CODE	DEFINITION	PERCENTAGES (%) Interproximal Alveolar Bone Loss
0	No Bone Loss	0
1	Mild Bone Loss	1–15
2	Moderate Bone Loss	16–33
3	Severe Bone Loss	34–66

(c)

CODE	DEFINITION
*	Furcation Involvement
H	Horizontal Pattern of Bone Loss
V	Vertical Pattern of Bone Loss
-	Teeth Absent in Quintet

Figures 2 and 3 illustrate the suggested methods for visually and radiographically assessing the severity and distribution of iABL.

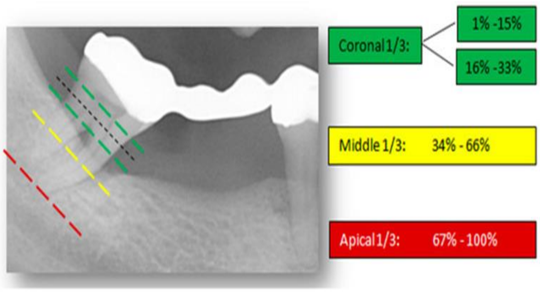
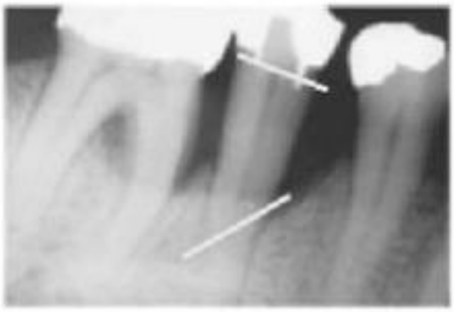


Figure 2. Assessment of bone loss severity through visual inspection. For each quintet, the tooth exhibiting the greatest loss is divided into coronal, middle, and apical thirds, and the extent of alveolar bone loss is estimated as a percentage within these sections.

a)



b)

Figure 3. Patterns of periodontal bone loss as observed radiographically, classified into (a) horizontal and (b) vertical types.

Given that the collected data were categorical, intra-examiner consistency was evaluated using Cohen's Kappa (K), chosen for its ability to adjust for chance agreement, with interpretation following the recent framework by McHugh [11].

To address possible quantitative discrepancies among the 20 examiners, the intra-class correlation coefficient (ICC) was applied to examine reproducibility, consistency, and absolute agreement between groups. ICC values were interpreted according to established guidelines: <0.5 indicates poor reliability, 0.5–0.75 moderate, 0.75–0.9 good, and >0.9 excellent reliability [12].

The validity of the proposed radiographic index was further tested using Cramér's V to quantify the association between two categorical variables related to iABL severity:

- Visual scores assigned by participants using the proposed coding system
- Reference measurements obtained via the Schei method

Cramér's V interpretation followed the criteria outlined by Akoglu [13]. All analyses—including Kappa, ICC (95% confidence interval, average-rating, absolute-agreement, two-way random-effects model), and Cramér's V—were performed using IBM® SPSS Statistics 26.0 (IBM, Portsmouth, UK).

Results and Discussion

Intra-examiner reliability

Across all 10 quintets, the average intra-examiner Kappa for iABL severity was 0.808, indicating strong agreement. Agreement varied by site, with lower right premolars showing moderate agreement (K = 0.679) and lower anterior teeth demonstrating strong agreement (K = 0.877).

For the iABL pattern across the dentition and posterior furcation involvement, the mean Kappa was 0.802, again reflecting strong reliability. Agreement was weaker in upper left molars (K = 0.527), whereas certain quintets—including the lower left premolars, lower right premolars, and lower right molars—achieved perfect concordance (K = 1.000). All findings were statistically significant (p = 0.000) **(Table 3)**.

Table 3. Intra-examiner agreement scores (site-specific).

Site (Quintet)	iABL Severity (κ)	iABL Pattern/Furcation (κ)	*p*-Value
UR Molars (1)	0.847	0.718	0.000
UR Premolars (2)	0.762	0.849	0.000
U Anteriors (3)	0.839	0.642	0.000
UL Premolars (4)	0.735	0.849	0.000
UL Molars (5)	0.844	0.527	0.000
LL Molars (6)	0.824	0.788	0.000
LL Premolars (7)	0.809	1.000	0.000
L Anteriors (8)	0.877	0.645	0.000
LR Premolars (9)	0.679	1.000	0.000
LR Molars (10)	0.862	1.000	0.000
Mean Agreement (κ)	0.808	0.802	0.000

Inter-examiner reliability

Among the senior clinicians, including restorative dentistry consultants and postgraduate trainees (PGTs), assessment of iABL severity across all quintets yielded a high mean inter-examiner consistency, with an ICC of 0.915. Agreement varied by location, with the upper anterior teeth showing the lowest concordance at 0.830, while the lower right (LR) and lower left (LL) molars demonstrated near-perfect agreement at 0.968 and 0.970, respectively.

When considering both the overall iABL pattern across all quintets and the evaluation of posterior furcation involvement, the mean inter-examiner ICC decreased to 0.778, reflecting moderate agreement. These results were highly statistically significant (p = 0.000) **(Table 4a)**.

Table 4. Intra-examiner agreement scores (site-specific).

(a)

Site (Quintet)	iABL Severity (ICC)	iABL Pattern/Furcation (ICC)	*p*-Value
UR Molars (1)	UR Molars (1)	UR Molars (1)	UR Molars (1)
UR Premolars (2)	UR Premolars (2)	UR Premolars (2)	UR Premolars (2)
U Anteriors (3)	U Anteriors (3)	U Anteriors (3)	U Anteriors (3)
UL Premolars (4)	UL Premolars (4)	UL Premolars (4)	UL Premolars (4)
UL Molars (5)	UL Molars (5)	UL Molars (5)	UL Molars (5)
LL Molars (6)	LL Molars (6)	LL Molars (6)	LL Molars (6)

LL Premolars (7)	LL Premolars (7)	LL Premolars (7)	LL Premolars (7)
L Anteriors (8)	L Anteriors (8)	L Anteriors (8)	L Anteriors (8)
LR Premolars (9)	LR Premolars (9)	LR Premolars (9)	LR Premolars (9)
LR Molars (10)	LR Molars (10)	LR Molars (10)	LR Molars (10)
Mean Agreement ICC	Mean Agreement ICC	Mean Agreement ICC	Mean Agreement ICC

(b)

Site (Quintet)	**iABL Severity (ICC)**	**iABL Pattern/Furcation (ICC)**	***p*-Value**
UR Molars (1)	UR Molars (1)	UR Molars (1)	UR Molars (1)
UR Premolars (2)	UR Premolars (2)	UR Premolars (2)	UR Premolars (2)
U Anteriors (3)	U Anteriors (3)	U Anteriors (3)	U Anteriors (3)
UL Premolars (4)	UL Premolars (4)	UL Premolars (4)	UL Premolars (4)
UL Molars (5)	UL Molars (5)	UL Molars (5)	UL Molars (5)
LL Molars (6)	LL Molars (6)	LL Molars (6)	LL Molars (6)
LL Premolars (7)	LL Premolars (7)	LL Premolars (7)	LL Premolars (7)
L Anteriors (8)	L Anteriors (8)	L Anteriors (8)	L Anteriors (8)
LR Premolars (9)	LR Premolars (9)	LR Premolars (9)	LR Premolars (9)
LR Molars (10)	LR Molars (10)	LR Molars (10)	LR Molars (10)
Mean Agreement ICC	Mean Agreement ICC	Mean Agreement ICC	Mean Agreement ICC

Dental undergraduate students also demonstrated substantial inter-examiner consistency, achieving a mean ICC of 0.868 for the evaluation of iABL severity across all quintets. Compared to their more experienced counterparts, site-specific agreement among UGs showed less variation. However, when assessing the iABL pattern across all quintets along with posterior furcation involvement, their mean inter-examiner agreement dropped to a moderate level of 0.699 (ICC). These observations were statistically significant (p = 0.000) **(Table 4b)**.

When considering all study participants collectively, inter-examiner agreement was higher for iABL severity than for its pattern and the presence or absence of furcation involvement. The overall mean ICC values for these measures were 0.892 and 0.739, respectively, both reaching statistical significance (p = 0.000) **(Table 5)**.

Table 5. Mean inter-examiner agreement scores for all participants (n = 20).

Participants (n = 20)	**iABL Severity (ICC)**	**iABL Pattern/Furcation (ICC)**	***p*-Value**
PGT & Consultants (n = 14)	0.915	0.778	0.000
UGs (n = 6)	0.868	0.699	0.000
Total Mean Agreement ICC	0.892	0.739	0.000

Validity

Cramér's V analysis was employed to examine the relationship between participants' visual assessments and the gold standard measurements. Individual associations across all 20 participants ranged from 0.286 to 0.513, with the weakest correlation observed in a postgraduate dental student and the strongest in an undergraduate dental student. Notably, intra-examiner comparisons revealed even higher correlations, with the first and second assessments showing Cramér's V values of 0.631 and 0.685, respectively. When combining intra- and inter-examiner data, the overall mean Cramér's V was 0.447, a result that reached statistical significance (p = 0.000).

Radiographic evaluation of periodontal status has long faced limitations, including the two-dimensional representation of alveolar bone and uncertainties regarding measurement validity, precision, and accuracy [14]. Recent literature emphasizes the need for standardized guidelines to calibrate alveolar bone level assessments [15]. Conventional dental radiographs, such as panoramic and periapical images, are limited in depicting bone quality and mineralization, as well as in quantifying circumferential alveolar bone loss due to their inability to capture the sagittal plane.

Despite advances in imaging, few new technologies have sufficiently addressed these diagnostic challenges. While digital radiography has been promoted as a solution, evidence suggests its benefits in clinical practice are mostly practical, with diagnostic accuracy often comparable to conventional film radiographs [16]. Conversely, some studies indicate that digital radiographs may provide a more precise representation of alveolar bone loss than traditional imaging [17].

According to Faculty of General Dental Practice (FGDP) recommendations [18], the gold standard for assessing periodontal status includes either a full-mouth series of periapical radiographs using the long-cone paralleling technique or panoramic radiographs supplemented with selected periapical images. Panoramic imaging may reduce radiation exposure and save time and costs, but intraoral radiographs have been shown to underestimate bone loss, whereas severe osseous destruction may be overestimated on radiographs [19].

Panoramic radiography also has inherent limitations due to its projection geometry, resulting in artifacts such as ghost images, superimpositions, and magnification, which reduce image detail, especially for structures outside the focal trough [20]. These limitations likely contributed to the lower clarity of anterior teeth reported by participants, corresponding to a higher number of unreadable sites and weaker inter-examiner agreement in anterior and premolar regions compared with premolars and molars **(Tables 4a and 4b)**.

Validating the proposed radiographic index required identifying the most effective technique for alveolar bone level quantification. Albandar *et al*. [21] compared various methods, assessing baseline and 2-year changes in periapical radiographs. While intra-examiner reliability was similar across methods, inter-examiner reliability was not evaluated. Regression analyses indicated that the Schei technique had superior sensitivity for detecting bone level changes, whereas the Björn method showed the lowest detectability. Regarding readability, the absolute method had the fewest unreadable sites for most teeth, except mandibular incisors, where differences with the Schei method were minimal. In contrast, the Björn technique produced the highest number of unreadable sites. Overall, these findings suggest that, among relative quantification approaches, the Schei method reliably captures radiographic changes in alveolar bone. This conclusion is further supported by laboratory studies on dried human mandibles with simulated progressive interdental bone loss [22].

Additionally, while the Fixot–Everett grid method may offer greater convenience for routine clinical application compared with the Schei technique, its use is limited to periapical radiographs, whereas the Schei method can also be applied to panoramic images [19]. Although Teeuw *et al*. [23] reported promising results using a novice image analysis tool for detecting alveolar bone loss compared with the Schei technique, these findings may reflect minor visual distortions of landmarks caused by the printing process inherent in the conventional method. The study also demonstrated excellent inter-examiner reliability between the two approaches. The authors concluded that aside from the convenience offered by the new tool, both methods provide comparable measurements of bone loss. The inclusion of additional parameters—such as angular bone defects, furcation involvement, and periapical radiolucencies—into the tool could further enhance its clinical utility and potentially make it superior to traditional techniques if cost considerations were secondary. For these reasons, the present study adopted the Schei technique as the reference standard for quantifying alveolar bone loss on panoramic radiographs.

To improve the specificity of periodontitis screening, the dentition was divided into five quintets per arch, rather than the traditional sextant division. This grouping allows similar tooth types to be assessed together (molars, premolars, and anteriors), making patterns such as the molar-incisor distribution of periodontitis more easily identifiable. This method also facilitated distinct analysis of inter- and intra-examiner agreement, revealing stronger concordance for lower molars compared with upper molars in evaluating iABL severity and pattern, which aligns with recent literature [24]. These differences are likely influenced by the complex anatomy of maxillary molars, including potential superimposition of palatal roots over mesiobuccal and distobuccal roots, combined with the limited sensitivity of panoramic radiographs in detecting furcation involvement and angular bone defects. Notably, better agreement was observed when assessing iABL severity rather than its pattern or furcation involvement, likely reflecting these anatomical and imaging limitations.

The iABL percentages used in this study were selected to correspond with the coronal, middle, and apical thirds of the root, in line with the staging framework of the new periodontal classification system [25].

Conclusion

Despite inherent limitations of panoramic radiography, the proposed radiographic index demonstrated simplicity, reliability, and validity. It can complement clinical screening tools to assist clinicians with varying experience levels in prognostic assessment of periodontally affected teeth. Future studies applying this index to intraoral periapical radiographs could further validate its utility and underscore its potential in both clinical practice and population-level epidemiological research.

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