RESEARCH

Repeatability and accuracy of a paralleling technique for radiographic evaluation of distal bone healing after impacted third molar surgery

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Objectives: The purpose of this study was to investigate the repeatability and radiographic accuracy of an intraoral paralleling technique to evaluate periodontal bone healing on the distal surface of the second mandibular molar (2 Mm) after impacted third mandibular molar (3 Mm) surgical extraction.

Methods: In order to estimate the variation in different radiographs, three replicas were made, each from 2 Mm, totalling 69 radiographic radicular longitude (RRL) recordings. One operator performed the periapical radiographs in a standard manner, utilizing a modified posterior film holder for the radiographic technique of parallelism, applied on the posterior region with the X-ray beam focused on the centre of 2 Mm. These radiographic recordings of the same region were obtained on three different and separate occasions, over a 12 month evaluation period after surgical extraction of the impacted 3 Mm. The RRL variable was measured and recorded three times by the same operator, with side-by-side comparison of three posterior periapical radiographs, irrespective of when the assessments were performed.

Results: There were no statistically significant differences between the three replica recordings ($p = 0.969$). The correlations between the three sets of measurements were evaluated and found to be highly associated (intraclass correlation reliability coefficient = 0.90) and statistically significant ($p \leq 0.05$). The median and mean error of the radiographic technique evaluated was ± 0.257 mm and ± 0.347 mm, respectively.

Conclusions: The radiographic technique described permits standardization in periapical radiographs with a high repeatability and accuracy in posterior radiographic records (distal surface of 2 Mm) over a postoperative evaluation period of 12 months.

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Introduction

Radiographs are a relevant diagnostic tool because they offer additional information on periodontal disease which is difficult to obtain by other clinical methods

such as probing depth measurements; nonetheless, when radiographs are used their limitations must also be considered. Such limitations include the bidimensional visualization of the interdental bone, and a frequently resulting tendency to underestimate the extent of bone loss.^{1–5}

The gold standard for evaluation of bone defects with the highest degree of accuracy is their intrasurgical

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direct measurement; however, this clinical procedure cannot always be performed due to certain ethical restrictions.^{1–3,5}

There is a disagreement about the accuracy of radiographic measurements as an indicator of real bone loss. Both periapical radiographs and bitewings, made with an intraoral paralleling technique with alignment systems, allow for obtaining more accurate records of crest bone in relation to the tooth root and bone density changes.^{1–3}

Beyond accuracy, the radiographic repeatability is important because it permits reproduction of the targeted region over a short period of time and allows for a comparison of those repeated examinations, which is of great value in assessing and controlling osseous defects over time.^{1,6}

The purpose of this study was to investigate the repeatability and accuracy of an intraoral paralleling technique in a standard way, so as to accurately assess periodontal bone healing on the distal surface of the second mandibular molar (2 Mm) after surgical extraction of an impacted third mandibular molar (3 Mm).

Materials and methods

The sample used was obtained from a prospective clinical study performed over the course of 12 months in 17 healthy patients between the ages of 16 and 35 (mean age of 21.43 ± 5.19 years), with indication of an extracted 3 Mm in contact with the distal aspect of the 2 Mm.

All patients agreed to participate in the study after receiving prior informed consultation and after having signed a waiver of consent, obtaining both the approval of the patient and the Committee on Bioethics at the University of Santiago de Compostela for this study.

Of those patients submitted to mandibular third molar (3 Mm) surgical extraction, periapical radiographs were taken at the posterior area at the distal aspect of 2 Mm, employing a modification of the radiographic technique verified by Kugelberg *et al* in 1986.⁷ The patients were radiographed with a photostimulable phosphor plate (PSP) (31 × 41 mm, Digora® OPTIME, Soredex Orion Corporation, Helsinki, Finland) and with intraoral radiographic equipment (Philips Oralix 65, Philips, Eindhoven, Netherlands) set at 65 kVp, 7.5 mA and 0.2 s. The implemented radiographic technique was a paralleling technique focusing the central ray on the centre of the crown of their 2 Mm. The focus-to-object distance was about 20 cm using an X-ray film positioner for the posterior region (Rinn® XCP Instrument Kit, Dentsply, Elgin, IL), consisting of a ring, an arm and a biteblock. The PSP plates were scanned with a Digora® OPTIME scanner, and then the images were saved. To ensure the stability in the space planes, an additional device was fabricated with modification to the commercial film positioner Rinn® XCP Instrument Kit, in the form of a hollow cylinder adapted to the positioner and the collimator, so that it was attached to the collimator

Figure 1 Radiographic device used to take the periapical radiographs by the intraoral paralleling technique: a hollow cylinder adapted to the X-ray film positioner (posterior system Rinn® XCP Instrument Kit, Dentsply, Elgin, IL) with a biteblock customized with acrylic resin (Pattern Resin®, GC America Inc., Alsip, IL) for each patient

of the X-ray machine to prevent unwanted movements and undesirable angulations (Figure 1). In addition, a biteblock of the positioner was individualized for each patient with an acrylic resin (Pattern Resin®, GC America Inc., Alsip, IL) at the 2 Mm in the maximum intercuspal position in order to ensure the reproducibility of the radiographic technique in the occlusal plane (Figure 1). In this way, the PSP plate was centred and parallel to the longitudinal axis of the 2 Mm, in a reproducible position and perpendicular to the horizontal (occlusal) plane. A specific X-ray gauge pin (millimetre indentations visible radiographically) was used to directly measure the bone defects and obtain a conversion scale depending on the radiographic processing and computerized measuring system used (Figure 1). Therefore, it allowed for comparing different images taken at different times after surgery, verifying the reproducibility of the three-dimensional geometric relationship.⁸

The periapical radiographs were performed by one evaluator (AF) before and after surgical extraction of the 3 Mm, between 3 months and 12 months. This evaluation period has been deemed appropriate for repeated assessments to visualize any radiographic change and analyse the reproducibility of the radiographic technique.^{1–3,6}

Those digital periapical radiographs were used to measure one constant radiographic variable, the radiograph radicular longitude (RRL) of the distal root of the 2 Mm.^{7,8} The computerized lineal measurements were made with a digital measuring program with 1 µm of resolution (Olympus Microimage v.3.0 for Windows 95/NT; Olympus Optical Co., Europe GmbH, Hamburg, Germany), pointing out certain immutable anatomical reference points: the root apex of the distal root (RA) and the cemento-enamel junction (CEJ) of the distal root of the 2 Mm. The RRL was measured from the CEJ to the RA of the distal root of the 2 Mm. Only one evaluator (AF) identified these two immutable anatomical reference points of the distal root of the 2 Mm (CEJ and RA) and measured the

Figure 2 Example of three digital posterior periapical radiographs used to measure the three replicas of the same second mandibular molar (2 Mm), at distinct times of all evaluations of the same tooth. To measure the constant radiographic radicular longitude (RRL) of the distal root of the second mandibular molar (2 Mm) two reference points were selected: radiographic apex (RA) and cemento-enamel junction (CEJ)

linear distance in millimetres between them, comparing the three sets of posterior periapical radiographs side-by-side, registering the three replicas of the RRL, regardless of the time stage at which they were carried out (Figure 2).

Initially, to evaluate the reliability of the radiographic measurements, three repeated measurements were compared using ANOVA for repeated measures, taking into account the dependence between the observations made over the same 2 Mm, and allowing for the detection of any significant differences in radiographic measurements throughout the postoperative period. To check the validity of the assumption of normality, the Kolmogorov–Smirnov statistical test was used. The degree of homogeneity between the three measurements made for each 2 Mm was evaluated utilizing the intraclass correlation reliability coefficient (ICC). All statistical analyses were performed using the SPSS® Statistics 17.0 (SPSS Inc., Chicago, IL), and R 2.12.0 statistical software package,⁹ with $p \leq 0.05$ being deemed statistically significant.

Results

To evaluate the errors of the radiographic technique described, 23 2 Mm with three repeated measures were selected from the main study sample. The three replicas of the RRL variable of each 2 Mm are presented in Figure 3. The differences between measurements were negligible; the mean of the differences between the replicas 1–2, 1–3 and 2–3 were 0.019 ± 0.508 mm, 0.033 ± 0.652 mm and 0.014 ± 0.667 mm, respectively, and statistically insignificant ($p = 0.969$). So, the concordance between the three radiographic measurements was very high. The radiographic reliability was analysed using the ICC. The reliability of the ICC was found to be 0.90, indicating that the error's variance contributed 10% of the total variance. The results of the measurements concerning repeatability of the method are presented in graph form (Figure 4). The mean and median error in millimetres can be calculated as the

mean and median value of the standard deviation, respectively. The mean standard deviation was ± 0.347 mm and the median standard deviation was ± 0.275 mm. The mean and median typical errors of measurements were found to be 0.072 mm and 0.057 mm, respectively.

RADIOGRAPHIC RADICULAR LONGITUDE				
N CASES	THREE REPEATED MEASURES			SD
1	14 991	14 395	15 492	0.549
2	16 849	15 854	15 058	0.897
3	13 002	13 490	13 798	0.401
4	11 741	11 343	13 002	0.866
5	10 680	11 741	10 017	0.870
6	13 068	12 537	12 337	0.378
7	13 068	13 267	13 201	0.101
8	13 864	13 333	13 798	0.289
9	13 731	14 196	13 400	0.400
10	11 960	12 230	11 681	0.275
11	14 130	14 329	14 196	0.101
12	13 798	13 909	14 063	0.133
13	13 201	13 333	13 466	0.133
14	13 267	12 299	12 338	0.548
15	13 997	14 196	14 196	0.115
16	13 068	13 333	13 534	0.234
17	13 094	13 513	13 282	0.210
18	11 941	11 410	11 808	0.276
19	11 675	11 991	12 148	0.241
20	16 252	16 584	16 252	0.192
21	12 405	12 803	13 333	0.466
22	13 798	13 864	13 599	0.138
23	13 731	13 798	14 063	0.176

Figure 3 Table with the three repeated measures (replicas) of radiographic radicular longitude with the standard deviation (SD) of each case

Figure 4 Graph of the three replicas of the radiographic radicular longitude (RRL) variable for each second mandibular molar (2 Mm)

Discussion

The intraoral radiographic technique of parallelism has some limitations, such as small vertical and horizontal angulations of the X-ray beam with respect to the film; less-defined interproximal area of the cervical portion of the tooth, mainly CEJ; an inability to clearly assess the bone defects on buccolingual or palatal surfaces; difficulty in clinical performance; and inexact reproducibility of the technique in further evaluations, mainly in posterior teeth. These limitations should be avoided in order to reduce evaluation and diagnostic errors inherent in all periapical radiographs, like poor identification of anatomical landmarks such as the root apex and CEJ, impossibility of evaluating the buccolingual/palatal bone morphology and distortions of the coronal aspect of the tooth.^{1-4,6,8,10-16}

Commercially available devices for the intraoral paralleling technique provide perpendicularity between the central ray and the film; however, they are not useful in preventing other errors during the clinical performance of the technique.^{1,15-16} Several techniques for radiographic standardization procedures have been described using different X-ray devices and adaptations to meet the ideal radiographic criteria, resulting in an accurate diagnosis.¹³⁻¹⁸

The technique employed was similar to those referred to earlier, using a radiographic device with an occlusal registration for geometric standardization in order to maximize the reproducibility of the radiographic images.⁸ Additionally, the technique was complemented with the introduction of the gauge pin, as utilized by Kugelberg *et al*,⁷ allowing easy calibration between the different radiographs. As a result, the radiographic images taken at different times after surgery could be

compared quantitatively and verified the reproducibility of the three-dimensional geometric relationship. It also permitted an easy side-by-side comparison, allowing the radiographs to be analysed simultaneously, and the direct measurement of RLL to be calculated in millimetres.⁸

For evaluation of the distal bone defects of 2 Mm after 3 Mm surgical extraction, the previous studies did not use the same types of radiographs (some of them used panoramic and others used intraoral radiographs, bitewings or periapical radiographs). The radiographic techniques utilized were also different in those studies. Furthermore, they did not use the same methods of measurement and calibration,¹⁸⁻²⁹ nor did the majority of them evaluate the error of their radiographic technique.¹⁹⁻²⁶

Krausz *et al*²⁷ twice performed linear computerized measures of bone defects in panoramic radiographs, with minutes between them initially and 12 months later; the error between these evaluated measures was about 5% ($r^2 = 95\%$).

To assess the resolution, repeatability and accuracy of the freehand paralleling technique with analogical linear measures with magnification and two different calibrated rules, Kugelberg *et al*⁷ studied the constant length of the distal root of 2 Mm, using two radiographic recordings of the same region, obtained on two separate occasions, 2 and 4 years postoperatively. In order to estimate the variability between examiners, duplicate readings of 25 radiographic recordings were performed, in random order, with 4 days' interval. In this study the error variance due to radiographic reproduction was 3-4% of the total variances. Kugelberg *et al*⁷ found 1% variability intraexaminer when infrabony defects were assessed on the same radiograph. They were able to conclude that repeated radiographic registrations of the 2 Mm region, using their technique, could be performed with accuracy.^{7,28-30}

In this study all of the radiographic measurements were performed three times, for the purpose of statistically validating their accuracy and repeatability. All the measures were made by a single operator (AF) avoiding possible interexaminer error.⁴ The periapical radiographs were taken over the 12 month postoperative period, before and after (3, 6 and 12 months) surgical extraction of the impacted 3 Mm. Three radiographs from these four radiographic recordings of the same region were selected, on three distinct occasions with 3, 6 or 12 month's between them. This evaluation period (up to 12 months after surgery) has been deemed appropriate to assess the radiographic error for repeated assessments, because time increases the probability of committing errors caused by different spatial positions of the radiographic device: the error is greater when there is more time between each repetition of the method.¹⁻³ Other studies have only two repeated measures with intervals of 12-24 months between them.^{7,27}

As in the study by Kugelberg *et al*,⁷ digital periapical radiographs were used to measure one constant

radiographic variable, the RRL of the distal root of the 2 Mm. There were three replicas of the same constant measure over the 12 month postoperative period. This permitted the evaluation of the error of this radiographic method because the distal root length of 2 Mm studied was considered constant throughout the observation period.⁷ Consequently, there were no statistically significant differences between the three radiographic recordings of this variable ($p = 0.969$). The ICC obtained was 0.90 with statistical significance ($p \leq 0.05$), which indicates an excellent grade of homogeneity between the three replicas of the RRL variable. It was suggested by Fleiss³¹ that scores below 0.40 may be taken to represent poor reliability, scores between 0.40 and 0.75 represent fair to good reliability and scores above 0.75 may be taken to represent excellent reliability.³² This study shows that the 10% error represents the combined error of taking serial X-rays and making measurements on these radiographs, including the operator's error. The error variance due to examiner inconsistency was not evaluated, neither was the error variance due to different examiners. The exploratory analysis (Figure 4) suggests a greater variability between the 2 Mm comparatively and the variability between the three measurements of each 2 Mm. Therefore, the majority of the total variability was due to the anatomical heterogeneity of the 2 Mm from different patients included in this study and not due to errors in the radiographic technique utilized.

The reproducibility of the method described in this trial is represented by the respective mean and median standard deviation of a series of replica radiographs, obtained at different times, where no anatomical changes occur (radicular longitude of 2 Mm distal root is constant): ± 0.347 mm and ± 0.275 mm. In order to detect bone loss, the observed measurements must be outside the error limit of the technique.²

This technique presents the same margin of error as others referred to in the literature. Hausmann¹ considered an error of 0.5 mm from the mean standard deviation to be acceptable utilizing the same positioning system (Rinn® XCP Alignment System).

Benn² found a possible error value <1 mm using a standardized radiographic technique. Other studies obtained errors of 0.24 mm,¹³ 0.15 mm,³ 0.1 mm¹⁷ and 0.033 mm¹⁰ between two replicas of measurements with similar intraoral radiographic techniques. Benn³ reported many studies with mean standard deviation errors between ± 0.37 mm and ± 0.45 mm. The paper also presented studies with a lower mean standard deviation error (between ± 0.02 mm and ± 0.16 mm) and discussed some of the causes, such as the selection of cases from the main sample.

A lot of caution was needed when comparing the error values between the different techniques described because the studies presented the error as standard deviation of the mean; the number of cases from a sample varied between the studies, which influenced the final value of each study's error. Thus, to compare error values, it may be preferable to utilize the typical error. As shown before, the obtained mean and median typical error of measurements was 0.072 mm and 0.057 mm, respectively. The studies did not present the typical error, and in a few of them there were no available data to calculate it, which makes it difficult to compare the results.

A future study will be necessary that quantifies the intra- and interexaminer errors of measures throughout the postoperative period and the distortion of radiographs (calculating vertical and horizontal angulations). An estimation of the differences between bone defect measurements is also required, as is the contrast of those radiographic measures with the gold standard (intrasurgical evaluation).

Applying the method detailed in this trial permits obtaining standardized posterior periapical radiographs, and also the verification that there are no significant differences between them, allowing for the maintenance of the same geometric position. In conclusion, as a manner of accurately assessing periodontal bone healing on the distal surface of the 2 Mm after an impacted 3 Mm surgical extraction, the radiographic technique described had a high accuracy and repeatability in posterior radiographic records over a 12 month evaluation period.

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