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Depth determination of artificial periodontal pockets using cone-beam tomography and radio-opaque material

An in vitro feasibility study

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Radiology,
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SUMMARY

In general, periodontal tissues are clinically assessed using calibrated periodontal probes and radiographs. Due to technical developments and the availability of cone-beam computed tomography (CBCT), 3-D imaging has become feasible and offers some advantages and potential for the evaluation of complex anatomical structures. The present pilot study illustrates and validates the possibility of radiographically visualizing and metrically assessing hard and soft tissue. Artificial periodontal pockets were created in porcine mandibles and measured by clinical

(i.e. pocket probing) and radiographic means (CBCT). For the latter method, pockets were filled with a radiopaque material allowing visualization by CBCT. Clinically simulated pocket depth probing and CBCT measurements were compared. The results showed no statistically significant differences between the two methods. Thus, the CBCT visualization approach points towards the development of a new and promising radiographic all-in-one evaluation system of the periodontal status. However, more research and development is required.

Introduction

Metrical assessment is considered central for the diagnosis of periodontal hard and soft tissue as well as during the planning and monitoring of therapeutic strategies (WINDISCH ET AL. 2007).

Traditionally, periodontal tissues are meticulously clinically assessed using calibrated periodontal probes. The most useful parameters in the clinical context are pocket depth and recession (distance between *margo gingivae* and the enamel-cement interface) as well as the attachment loss calculated from these factors.

Periodontal probes have been described as far back as 1925 by Simonton. They still represent the most important and simple

instrument for clinical examination (SCHMIDLIN 2011). The validity of the measurement is determined by various factors, such as the geometry of the probe, the force applied as well as the angle of application. Additionally, biological factors such as inflammation of the tissue influence the degree of probe penetration. The clinical level of attachment does not necessarily correspond with the histologic level of attachment (VAN DER VELDEN & JANSSEN 1980, CATON ET AL. 1981). Various automated probes have been introduced to the market in order to increase the accuracy of the measurements as well as making them reproducible. Examples are the so-called Florida probe (GIBBS ET AL. 1988) and the Toronto probe (BIREK ET AL. 1987), which provide simultane-

ous computer-assisted measurements for factors such as probing depth and the degree of gingival recession. These instruments are particularly useful for (longitudinal) studies, as they provide measurements with an accuracy of 0.2 mm. However, automated measurement devices also have disadvantages: due to higher costs and the necessary computer assistance they are not ideal for daily routine in the practice (PIHLSTROM 1992).

Radiographs complement the clinical diagnosis by probe. They mainly serve to visualize the bony structures of the periodontium and the degree of marginal bone loss. Conventional radiographs provide two-dimensional imaging only and require accurate projection (parallel technique) to avoid distortion. As a matter of fact, radiographs are generally characterized by low sensitivity, on the one hand, and high specificity, on the other hand. Especially non-standardized radiographs tend to underestimate bone loss as a loss of 30–50% of all mineralized tissue is necessary to render bone loss visible (JEFFCOAT 1992).

Radiograph technology in dentistry has made large progress in the last few years, particularly in the area of cone-beam computed tomography (CBCT). This new technology introduces the third dimension to dental imaging along with previously unknown diagnostic possibilities. CBCT is able to provide three-dimensional images to assess periodontal defects. Because the extent of defect can be determined by a single image, CBCT is particularly useful in the planning stage of severe generalized cases of periodontitis. Especially with complex anatomical situations, CBCT, in combination with clinical assessment, enables more reliable tooth prognosis and therapeutic planning (WALTER ET AL. 2009, WALTER ET AL. 2012).

Imaging and the quantification of gingival tissue morphology continue to provide an increasingly important focus to complement the visualization of periodontal bone defects. The thickness and volume of the gingiva are important for the diagnosis and the choice of therapeutic strategy based on both functional and aesthetic considerations (RONAY ET AL. 2011). The simultaneous depiction of surface morphology and pocket imaging would be a desirable option (NKENKE ET AL. 2007).

The goal of this pilot study was to test in vitro the feasibility of the use of CBCT in accurately providing optical measurements of pockets. A radiopaque material (flowable light-curing composite) was introduced into artificial pockets, measured with CBCT and the resulting values compared with clinically obtained data. The study is based on the assumption that the material is able to depict the pocket fundus and that the measurements will lead to values comparable with clinical probing.

Materials and Methods

The study was conducted on six porcine mandibles (Fig. 1). To simulate periodontal lesions, artificial periodontal pockets were prepared on the first molars of both mandibular quadrants by using scalpels (single-use scalpel, Martin, Solingen, Germany). The scalpel was applied parallel to the tooth with intrasulcular incisions until bone contact.

For clinical and radiographic orientation, six markers made of radiopaque flowable composite (Teric Flow, Ivoclar Vivadent, Schaan, Liechtenstein) were applied and light-cured (Blue-phase, Ivoclar Vivadent, Schaan, Liechtenstein) on the enamel of each tooth (buccal and oral, each side with a mesial, buccal/oral and distal marker). Subsequently, the following measurements were obtained for all 72 markers: first, the artificial pocket depth was assessed and documented with a periodontal probe calibrated at 3 mm (CP 12, Deppeler, Rolle, Switzerland),

applied with a pressure of 0.2 N. Values were rounded up to the next millimeter. The measurements were performed by two separate researchers. The results were compared and values differing by more than 1 mm were re-measured and discussed.

Subsequently, the same composite which had previously been used to provide the markers was used as contrast medium in the pockets. Excess material was carefully removed and the remaining material light-cured for 15 seconds with a polymerization light. This prevents leaking of the material from the sulcus, and simultaneously provides the outline of the soft tissue attached to the marginal mucous membrane. A CBCT (Orthophos XG 3D, Sirona, Bensheim, Germany) was then produced for each quadrant, and the DICOM files assessed as follows (Simplant®, Materialise Dental, Gilching, Germany): first, a bucco-oral reference line was laid through the mesial, distal and bucco-lingual marker pairs. Pocket depth was determined by the software. Measurements were performed by two separate researchers which were unaware of the clinical measurements and results.

Statistics

Power analysis was performed with the software nQuery Advisor 6.0. A sample size of 21 will achieve 99% power to detect a relevant difference in means of 1 mm, assuming a standard deviation of difference of 0.985 mm using a paired t-test with a 0.05 two-sided significance level.

The data was coded in Excel and analyzed with SPSS version 19. Normality testing was performed with both the Kolmogorov-Smirnov- and the Shapiro-Wilk tests. Parametric (mean and standard deviation) as well as non-parametric/robust (median and interquartile range) descriptive statistics were calculated. Robust boxplots were used for visualisation of data. Paired non-parametric Wilcoxon- and Sign tests for CBCT and clinical measurements were calculated separately for each of the three groups (mesial, oral/buccal and distal). The results of the statistical analysis was interpreted as statistically significant with a p-value of <0.05.

Results

The results of the difference between clinical (probing depth with probe) and radiographic (CBCT) measurements at the three measurement points are presented in Figure 2.

The difference between clinical measurements and the results of the CBCT analysis presented largest at the buccal/oral markers with a standard deviation of maximally 0.985 mm, therefore below the required tolerance of maximally 1 mm.

Standard deviation of the three groups was ± 0.751 mm (mesial), ± 0.985 mm (buccal/oral) and ± 0.740 mm (distal), where the given minimal sample size of 21 provided a power of 99%, using a paired t-test with a two-sided significance level of 0.05.

At each of the three marker points, clinical measurements (probing depth with probe) and radiographic measurements (CBCT) were compared and no significant differences were found within the groups. Kolmogorov-Smirnov- as well as Shapiro-Wilk tests indicated violation of the normality assumption ($p < 0.001$). Consequently, the data was analyzed with robust methods. The non-parametric paired-sample Wilcoxon test for each of the three groups (mesial, buccal/oral and distal) provided the following results for asymptotic significance (two-tailed): 0.071, 0.116, 0.763. The paired non-parametric Sign test within the three groups provided the following results for exact significance (two-tailed): 0.146, 0.180, 0.727. In gen-

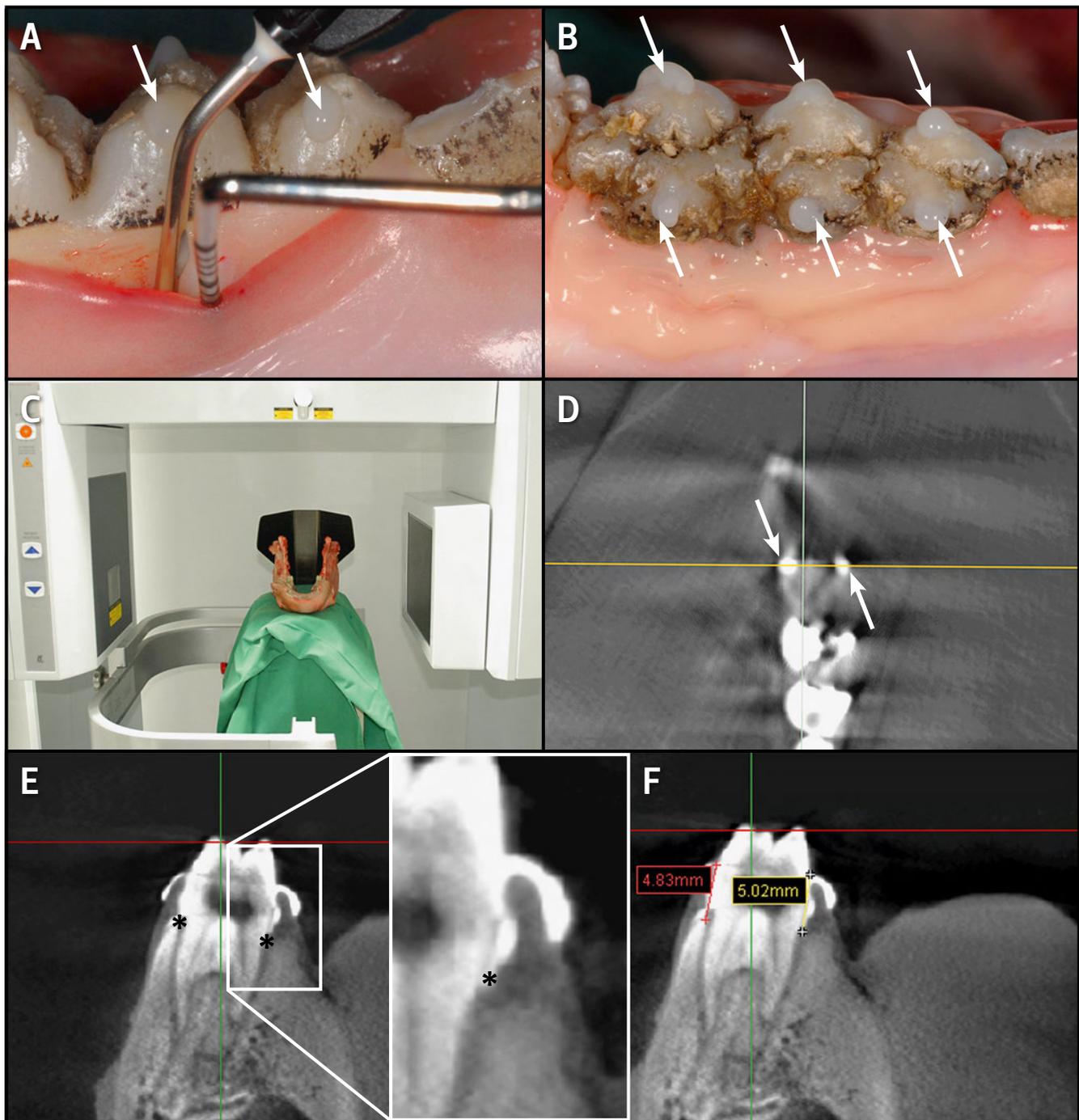


Fig. 1 After artificial pockets were produced with a scalpel and composite markers were applied for orientation (arrows), the flowable composite was applied with a blunt cannula (A) and immediately cured. Excess material served to illustrate the marginal outline of free gingiva (B). A CBCT was produced of the mandible (C), a reference line was laid through the marker pairs (D) and pocket depth was measured digitally (E/F; the star indicating the pocket fundus).

eral, the difference between the measuring methods (clinical-CBCT) tended to be positive (statistically non-significant), meaning that clinical measurements provided slightly higher values than radiographic measurements.

Discussion

The study's goal was to evaluate the feasibility and measurement accuracy of an optical survey of pockets with the use of CBCT. This feasibility study showed that digital measurements of pockets prepared with a radiopaque material provided values comparable to those acquired with clinical measurements.

It needs to be noted that this study did not investigate periodontal pockets but artificially created soft tissue defects which differ from the clinical reality with respect to tissue turgor as well as their internal soft tissue surfaces and connections. Additionally, these artificial lesions were prepared on porcine mandibles. In clinical conditions, pockets are generally not empty spaces or split flaps, but are filled with exudate such as blood/pus/cells which might affect penetration ability and the stability of any medium being introduced. It remains to be shown in vivo whether imaging is still possible after in situ curing or extrasulcular marginal material stabilization to avoid leakage

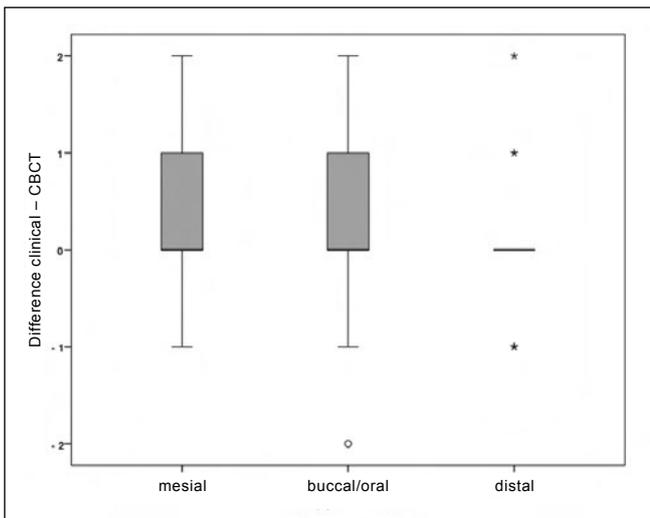


Fig. 2 Difference between clinical and radiographic measurements (all groups have medians 0 and interquartile ranges at 1).

(Fig. 3). Furthermore, it remains unclear whether defects (e.g. vertical bone fractures or furcations) filled with granulation tissue (RONAY ET AL. 2013) will not provide too much resistance to displacement by the chosen medium to guarantee adequate imaging and readability. Within those limitations of the study design, however, the hypothesis that calculable measurement based on pocket imaging is comparable to clinical measurements was verified.

For this study, a flowable composite was selected, as the material has a proven a high degree of opacity, is easy to manipulate and apply and is quickly stabilized by polymerization. Alternatively, the use of dual-curing materials might be considered, which would present the advantage of hardening in deeper areas which are not accessible for polymerization lights.

Disadvantages of this alternative are the potential toxicity of certain matrix components (SCHWEIKL ET AL. 2007, GUPTA ET AL. 2012) and, especially in its non-polymerized state, the danger of residue in undercuts or areas which are difficult to clean and rinse. Another alternative might be the use of biocompatible radiopaque media mixed with substances ensuring flowability for application in pockets and hardening at body temperature. Prestudies showed promising results with respect to radiopacity and hardening. This material was however not chosen for the present in vitro study due to a lack of control in humidity and temperature.

Further issues to consider while interpreting pocket depth values and standard deviations are the presence of CBCT-specific palpation and hard spot artifacts appearing at the interface between substances featuring different degree of density (composite and organic tissues) as well as the distribution of the generated data in Voxel (SCHULZE ET AL. 2011). The choice of biocompatible radiopaque media used in vivo should therefore consider adequate density to minimize hard spot artifacts.

Imaging techniques, possibly in combination with CAD/CAM technology, will play a central role in research and development of diagnostic possibilities (STREBEL ET AL. 2009, RONAY ET AL. 2011). Ethical considerations with respect to radiation with the use of radiopaque materials for periodontal diagnosis will have to be discussed critically on a case-by-case basis. The interpretation of a two-dimensional image into the third dimension provides valuable information, the accuracy of which is to date unsurpassed by any CBCT imaging.

The results of this study confirm the feasibility of the idea to visualize pockets and soft tissue with radiopaque media in order to receive automated periodontal findings simplifying diagnosis and therapeutic planning in complex cases. However, further questions regarding material and technical issues need to be clarified as well as the method requiring in vivo validation.

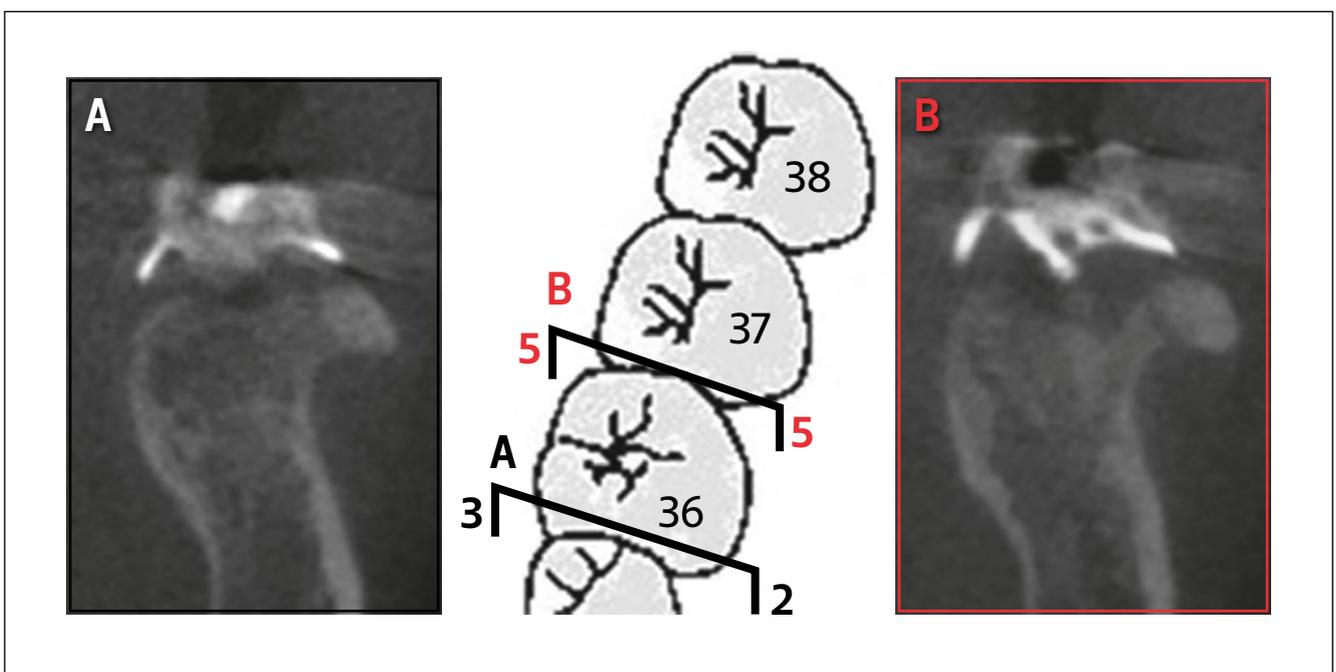


Fig. 3 Radiographic example of a patient requiring CBCT before wisdom tooth extraction. Informed consent was obtained to apply CBCT to pockets present in the vicinity of the area in question. Less material is visible in the pockets in healthy tissue (A), but the marginal soft tissues are distinctly visible. The interdental pockets at 36/37 are represented in the interproximal area (B, a torus mandibularis is visible lingually).

Résumé

Les tissus parodontaux sont classiquement évalués avec une sonde parodontale graduée et avec des radiographies. Avec la tomographie volumétrique numérique (TV), la troisième dimension trouve de plus en plus sa place dans l'imagerie et peut offrir une représentation des caractéristiques anatomiques complexes.

La présente étude pilote démontre et valide la capacité de visualiser et mesurer radiologiquement aussi bien les tissus durs que mous.

Des poches parodontales artificielles ont été préparées sur une mandibule de porc et mesurées avec une sonde parodontale

graduée, puis remplies d'un agent de contraste pour la prise d'une tomographie volumétrique. Les mesures de poche par TV ont été comparées à celles par sondage clinique. Les résultats n'ont montré aucune différence significative entre les deux méthodes de mesure en ce qui concerne la profondeur des poches en acceptant la supposition d'une erreur de mesure de 1 mm. Dans les conditions *in vitro* décrites, les mesures de poche par TV sont possibles. Cette méthode radiologique offrira peut-être à l'avenir une nouvelle perspective d'évaluation tout-en-un de l'état parodontal, mais d'autres études sont nécessaires.

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