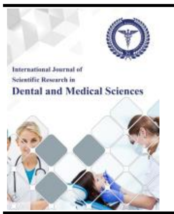

International Journal of Scientific Research in Dental and Medical Sciences

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Evaluation Outcome of Cone Beam Computed Tomography for Treatment Plan Success and Failure: A Systematic Review

Monica Aponte Mendez[a], Gözde Kayasöken[b,*], Bahareh Afjeh Soleymani[c], Benjamin Ravanbakhsh[d]

[a] *Depaerment of Implantology, School of Dentistry, San Sebastián University, Santiago, Chile*
[b] *Department of Endodontics, School of Dentistry, Marmara University, Istanbul, Turkey*
[c] *School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran*
[d] *School of Dentistry, Student Research Committee, Ahvaz Jundishapour University of Medical Sciences, Ahvaz, Iran*

ARTICLE INFO

Article history:
Received 02 April 2020
Received in revised form 21 May 2020
Accepted 29 May 2020
Available online 02 June 2020

Keywords:
Cephalometry
Cone-Beam Computed Tomography
Three-Dimensional

ABSTRACT

Background and aim: It is worth noting that cone beam computed tomography (CBCT) can differentiate between success and failure of treatment plans. Therefore, the main objective of this systematic review was to fulfil an outcome evaluation of CBCT for treatment plan success and failure.

Materials and methods: For this purpose, the databases of Embase, PubMed, Cochrane Library, MEDLINE, Google Scholar, and the Institute for Scientific Information (ISI) were searched to perform a systematic review of the related literature on the subject matter published up to May 2020. To manage the study titles electronically, the EndNote x8 software was further utilized. Employing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), this systematic review was accordingly completed. Two reviewers then assessed the quality of the selected studies using the Methodological Index for Non-Randomized Studies (MINORS) tool.

Results: A total number of 354 relevant titles and abstracts were retrieved during the electronic searches into the subject-matter literature. Ultimately, six studies were in line with the inclusion criteria in this systematic review. As well, the sample size in all studies was found to be 388 cases, and CBCT had been exercised in each one. Moreover, the follow-up timing of CBCT scans was not the same in the selected studies.

Conclusion: CBCT can be useful in successful treatment, CBCT systems have highly efficient for reconstructing the 3D image of the cortical bone with a thickness of more than 1 mm vs less than 0.5 mm thickness.

1. Introduction

Thus far, cephalometry has been utilized in longitudinal studies and a variety of orthodontic procedures. The given method is frequently being exercised to diagnose and evaluate craniofacial growth and to plan for its related treatments.[1] Given this, it is of utmost importance to identify some specific landmarks and to analyze several angular and linear variables.[2] It is of note that cephalometric analysis has been principally designed for patients in need of maxillofacial surgeries.[3] Accordingly, among the drawbacks of two-dimensional (2D), projection radiographs are more extensive and even unequal ratios of the left and right sides of the skull, their disproportionate superimposition, and distorted structures of the midface.[4] On recent years, cone beam computed tomography (CBCT) has been much appreciated since axial slices can be yielded through three-dimensional (3D) reconstruction of the whole craniofacial skeleton.[5] Regarding numerous studies in this field, CBCT has been so far practiced in orthodontics and maxillofacial surgeries.[6-8] Moreover, clinical and pathological diagnoses can be measured through this medical imaging technique in an accurate manner.[9] Accordingly, particular and less traumatic surgical exposures in consort with more efficient and fitting orthodontic traction are among the positive points of CBCT scans. They correspondingly contribute to better resolution and enhanced tooth prognosis.[8, 10] Traditional imaging techniques used for such purposes have also been suspected of errors occurring during the identification of landmarks or hand-traced measurements.[11] Studies have further confirmed the success of programs performing a digitized evaluation of cephalograms through manual tracking methods, to make linear and angular measurements in an efficient manner.[12-17] Nevertheless, such results have been contradictory in the related literature.[18, 19]

Since cephalometric analyzes are bound by human judgment and errors such as landmark identification, measurement methods, and quality of radiographic examinations arise in various sizes,[15, 20] new technologies are recently emerging to enhance such assessments and to minimize inaccuracies. Despite the benefits of existing programs, the best way to move from manual

* *Corresponding author. Gözde Kayasöken*
E-mail address: gozde.kayasoken@gmail.com
Department of Endodontics, School of Dentistry, Marmara University, Istanbul, Turkey
http://doi.org/ 10.30485/IJSRDMS.2020.233140.1061

towards digital tracing is not still known. As changes in digital methods are outstanding, the transfer takes place in the safest possible way, and specialists need to be prepared in this respect.[21-23] Before implementing new techniques, their efficiency must also be verified. Likewise, it is necessary to compare traditional digital images and those from CBCT scans to have a transition from 2D to 3D methods. It is of note that CBCT scans can differentiate between success and failure of treatment plans. Therefore, the main objective of this systematic review was to perform an outcome evaluation of CBCT for treatment plan success and failure.

2. Materials and methods

Search Strategy

The databases of Embase, PubMed, Cochrane Library, MEDLINE, Google Scholar, and the Institute for Scientific Information (ISI) were searched for a systematic review of the related literature concerning this subject matter published up to May 2020. To manage the study titles electronically, the EndNote x8 software was further utilized. The search was also accomplished using Mesh (Medical Subject Headings) terms including ((("Cone Beam Computed Tomography/methods" [Mesh]) AND ("Cephalometry / instrumentation" [Mesh] OR "cephalometry / methods" [Mesh])) AND ("imaging, three-dimensional / instrumentation" Mesh] OR "imaging, three-dimensional / methods" [Mesh])) AND "image processing, computer-assisted" [Mesh]. Employing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), this systematic review was ultimately performed.[24]

Selection Criteria

The inclusion criteria in this systematic review were as follows:

1. Randomized controlled trials (RCTs), prospective and retrospective cohort studies, as well as in vitro and in vivo studies.
2. Studies focused on outcome evaluation of CBCT scans.
3. Studies comparing CBCT outcomes.
4. Studies reporting sample sizes.
5. Studies wrote in all languages.

As well, case studies, case reports, and reviews were excluded from this systematic review.

Data Extraction and Analysis

The data extracted from the selected studies consisted of study title, year of publication, study design, study objectives, and imaging techniques implemented. Two reviewers then assessed the quality of the given studies through the Methodological Index for Non-Randomized Studies (MINORS) tool.[25] The scoring method was further based on this tool, evaluating eight and twelve domains for non-comparative and comparative studies; respectively. Accordingly, scores of zero, one, and two were assigned to "not reported", "insufficiently reported", and "sufficiently reported"; respectively. The ideal scores were also 16 for non-comparative studies and 24 for similar ones.

Given that, a higher score could indicate a lower risk of bias of the study. Besides, the domains were scored as zero for "not reported" and 1 and 2 if they were "insufficiently reported" and "sufficiently reported"; respectively. It should be noted that two independent reviewers performed scoring. Moreover, disagreements were settled through further discussions.

3. Results

A total number of 354 titles and abstracts were retrieved during electronic searches. At the first phase of study selection, 254 studies were removed based on their titles and abstracts. Then, the full-texts of the remaining 68 cases were assessed entirely. A total number of 62 studies were also excluded at this phase since they failed to meet the inclusion criteria in this systematic review. Finally, six studies meeting the inclusion criteria were reviewed (Figure 1).

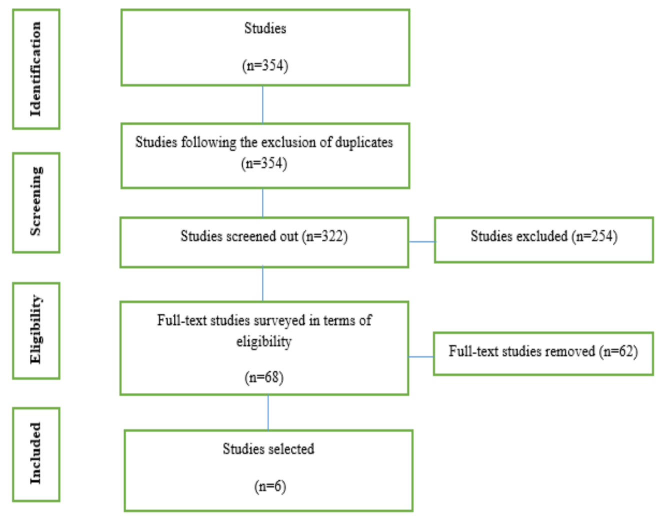

Figure 1. Study attrition.

Sample Size

In total, six in vitro studies were selected for this systematic review (Table 1). The sample size was also equal to 388 cases, chosen from 6 dry human skulls,[26] 27 bone blocks,[27] 24 rib bones of a freshly slaughtered cow,[28] 300 CBCT scans,[29] 20 maxillary first molars,[30] and 11 human dry mandibles[31] (Table 2).

Image Acquisition

CBCT had been exercised in all studies. The follow-up timing of CBCT scans was not also the same in the selected studies. Imaging technique employed in three studies[26, 28, 29] was NewTom, three studies[27, 28, 31] had implemented CRANEX 3D, and Micro-CT scanner had been utilized in one study[30] (Table 2).

Bias Assessment

As illustrated in Table 1, all the studies had moderate risk of bias.

Findings of the Selected Studies

In a study by Shokri et al. (2014), the reliability and accuracy of linear measurements in lateral cephalometric analysis acquired from CBCT scans had been assessed. Then, measurements between digital lateral cephalometric images and lateral cephalograms from CBCT scans had been compared in detail. Before scanning, landmarks had also been identified using barium sulfate as a medium. The gold standard had been further obtained for each linear measurement through physical measurements, using a digital caliper with the accuracy equal to 0.01 mm. Cephalometric radiographic adjustments of 66 kV, 10 mA, and 0.6 s had been correspondingly taken into account. The images had been then seen in a softly lit room using 17-inch LG monitor with 32-bit color depth and resolution of 1440×900 pixels. The results had revealed that the CBCT measurements could be compared in the planes and they were reliable compared with cephalometric ones. In most parameters, significant changes had been additionally observed in actual anatomical measurements.[26]

In one other investigation in this line, Shokri et al. 2019 had shed light on the effect of CBCT exposure parameters on a metal artifact of dental implants. All CBCT scans had been further reconstructed by OnDemand3D software, and then the traced arch for each sample had been modified to take an accurate image of each implant. The region of interest (ROI) had also been selected to ascertain the mean gray following implant cavity preparation. Also, the remaining bone around the cavity had been wholly used in upper and lower directions together with buccolingual areas to fix the ROI. Upon implant placement, the area surrounding the implant had been reselected via choosing the central cut, and consequently, the mean gray value had been calculated. Finally, the results had demonstrated that the field of view (FOV) size and bone density had influenced the metal products neighbouring the dental implant. Accordingly, smaller FOV could be employed to decline metal products.[27]

Table 1. Study objectives and risk of bias assessment of selected studies.

Year of publication	Study design	Study objectives	Risk of bias assessment
Shokri et al. 2014[26]	In vitro study	Evaluating linear measurement accuracy regarding digital lateral cephalograms from CBCT scans.	14/16
Shokri et al. 2019[27]	In vitro study	Investigating effects of CBCT exposure parameters on the reduction of metal artifact surrounding dental implants within bone densities.	13/16
Shokri et al. 2018[28]	In vitro study	Conducting an in vitro study on CBCT performance in the visualization of the cortical plate in reconstructed 3D images.	14/16
Nikkerdar et al. 2018[29]	In vitro study	Assessing the ability of CBCT systems, i.e., NewTom 3G, Cranex 3D, and 3D Promax for the reconstruction of a 3D image of cortical plates in different thicknesses.	12/16
Naseri et al. 2013[30]	In vitro study	Comparing the quality of different root canal obturation procedures, namely, warm vertical condensation, cold lateral condensation (CLC), GuttaFlow, and Obtura II using micro-CT scanner.	11/16
Shokri et al. 2015[31]	In vitro study	Examining the influence of head orientation in linear measurement for implant planning in CBCT.	11/16

Table 2. Outcomes of studies selected for systematic review.

Year of publication	Sample size	Imaging techniques
Shokri et al. 2014[26]	Six dry human skulls	NewTom 3G CBCT software (QR NNT v2.0.4, Quantitative Radiology)
Shokri et al. 2019[27]	27 bone blocks	Cranex 3D (Soredex, Tuusula, Finland)
Shokri et al. 2018[28]	24 rib bones of a freshly slaughtered cow	Cranex 3D (Soredex, Tuusula, Finland) CBCT system NewTom 3G 3D Promax
Nikkerdar et al. 2018[29]	300 CBCT scans	NewTom VGi CBCT system (QR SRL Co., Verona, Italy)
Naseri et al. 2013[30]	20 extracted maxillary first molars	Micro-CT scanner (SkyScan-1072, Kontich, Belgium)
Shokri et al. 2015[31]	11 human dry mandibles	Cranex 3D X-ray machine

As well, Shokri et al. (2018) had estimated the ability of three CBCT scans of the cortical plate having varying thicknesses. To this end, the samples had been allocated to three groups with thicknesses of less than or equal to 0.5 mm, 0.6-1 mm, and 1.1-1.5 mm for the bone marrow texture. Each CBCT scan had also been performed using all three models. Relevant FOVs and 3D scans had been further reconstructed via related software programs. The capacity of each system for 3D reconstruction of different thicknesses of the cortical bone had been correspondingly specified based on its visualization. The results had suggested that the thickness of >1 mm could be right for CBCT to reconstruct the 3D images of the cortical bone. Slight effects had been similarly observed for the thickness of <0.5 mm. As a result, systems with smaller FOVs and wax sizes had been selected for accurate visualization of anatomical structures.[28]

Moreover, Nikkerdar et al. (2018) had reflected on CBCT outcomes and the possible relationship between anatomical variations of the nasopalatine canal and age/gender. For this purpose, the length and the shape of the nasopalatine canal in the sagittal and coronal planes, the diameter of the nasal and oral openings of the canal, and the angle and the number of canals had been thus established in the sagittal plane. Then their correlation with age and gender had been explored. The results had highlighted the significance of the nasopalatine canal as well as the high incidence of anatomical and morphological variations.[29]

Naseri et al. (2013) had similarly assessed the quality of root canal obturation procedures. To this end, the sample size had been randomly apportioned into four groups, and a Micro-CT scanner had been utilized to calculate the internal volume associated with the root canals. The results had revealed that GuttaFlow and CLC had the highest and the lowest vapor pressure (VP) of the saturated materials; respectively.[30] Furthermore, Shokri et al. (2015) had examined the influence of head orientation in linear measurement on CBCT. For this purpose, using digital calipers and CBCT images with and without ReAxis, the width and the height of the bone at the central, molar, and canine tooth areas had been computed on the left and right sides of the skull. The results had indicated that ReAxis had not affected the measurement of bone width, but it could make a significant difference as an option in height measurement.[31]

4. Discussion

The selected studies included in this systematic review were not homogeneous about their objectives. CBCT had also been assumed as a valuable tool for craniofacial region assessment, whose radiation dose was lower than medical CT scan; in other words, it was within the range of conventional dental radiographic.[32, 33] Using CBCT, a rotating surface or gantry could thus carry an X-ray source and detector. Cone-shaped divergent radiation could accordingly radiate from the area, and the remaining attenuated beam could be depicted on the opposite side of the beam detector. The X-ray source and the detector could then rotate around a center. This rotation center was fixed within the center of the ROI.[34] Besides, cephalometric radiographs resembled the base image, and each one had shifted to some extent relative to the other.

Additionally, most of the volume images had been calculated and reconstructed from a few hundred 2D base images, whose full series had been called "projection data". As the entire area had been covered by the CBCT exponent, rotating about 180-360 degrees through the gantry scan could occur only once to restore the volume and to receive enough data.[34, 35] X-ray production, image reconstruction, and radiation detection had been consequently introduced as three main components in CBCT.[36] Depending on the size and the shape of the detector, the scanning size or the FOV dimensions as well as the geometry of the irradiated beam, and the ability to irradiate the beam had been determined. The scan volume could also be cylindrical or spherical. Primary X-ray collimation could further limit the radiation exposure to the target area.

Moreover, the size of the field needed to be limited to the smallest volume representing the area. This field size had to be chosen based on patient needs. Also, patients' unnecessary exposure could be reduced, and the best images could be generated by mitigating scattered radiation to diminish image quality.[37] According to Shokri et al. (2014), CBCT measurements were similar in the planes, and they were reliable to a greater extent compared with cephalometric ones.[26] As well, Navarro et al. had compared manual and digital CBCT cephalometric analyses as well as lateral ones, suggesting that all the evaluated methodologies were reliable and valid for scientific evidence.[38] Correspondingly, Lin et al. had reported significant measurement errors using 2D cephalogram synthesis, in terms of minimizing mandibular dimensions and their monthly changes in the early growth stages as well as overall annual growth. In general, it was concluded that linear measurement accuracy was acceptable in CBCT.

Moreover, FOV size and bone density could influence the metal products surrounding the dental implant,[39] so that smaller FOV could be used to reduce such products.[27, 40, 41]

Furthermore, the 3D image related to the cortical bone characterized with a thickness less than 1 mm was apt for CBCT. Uncertain effects had been additionally observed for thicknesses lower than 0.5 mm. These results had been validated in other studies.[28, 42-44]

5. Conclusion

Present systematic review finding showed;

1. Compared to measurements obtained from CBCT images with cephalometric measurements, the CBCT method was more reliable to comparable with direct skull measurements.

2. Size of FOV of CBCT and bone density affect the metal artifacts around dental implants

3. CBCT systems have highly efficient for reconstructing the 3D image of the cortical bone with a thickness of more than 1 mm vs less than 0.5 mm thickness.

4. CBCT systems with smaller FOVs are preferred.

5. To evaluate the premaxilla on CBCT scans used before surgical procedures.

In general, the use of CBCT can be useful in successful treatment.

Conflict of Interest

The authors declared that there is no conflict of interest.

Acknowledgments

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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How to Cite this Article: Aponte Mendez MA, Kayasöken G, Afjeh Soleymani B, Ravanbakhsh B, Evaluation Outcome of Cone Beam Computed Tomography Between the Success and Failure of Treatment Plan: A Systematic Review. International Journal of Scientific Research in Dental and Medical Sciences, 2020;2(2):46-51. doi: 10.30485/IJSRDMS.2020.233140.1061.