

## CONFIABILIDADE DA TOMOGRAFIA COMPUTADORIZADA DE FEIXE CÔNICO E DA TOMOGRAFIA COMPUTADORIZADA DE FEIXE EM LEQUE EM MEDIDAS LINEARES DO ESPAÇO AÉREO FARÍNGEO

**Kleber Vinicius Rodrigues dos Santos**  
PhD student, Department of Oral Sciences, School  
of Dentistry, Federal University of Goiás,  
Goiânia, Brazil  
klebervinicius@usp.br.

**Ananda Amaral Santos**  
PhD student, Department of Oral Sciences, School  
of Dentistry, Federal University of Goiás, Goiânia,  
Brazil.

**Hianne Miranda de Torres**  
PhD, Assistant Professor, D Department of Oral  
Rehabilitation, School of Dentistry, Federal  
University of Goiás, Goiânia, Brazil.

**Érica Miranda de Torres**  
PhD, Associate Professor, Department of Oral  
Rehabilitation, School of Dentistry, Federal  
University of Goiás, Goiânia, Brazil.

**Fernanda Paula Yamamoto-Silva**  
PhD, Associate Professor, Department of Oral  
Sciences, School of Dentistry, Federal University  
of Goiás, Goiânia, Brazil.

**Kim Ir-Sen Santos Teixeira**  
PhD, Associate Professor, Department Imaging,  
Medical School, Federal University of Goiás,  
Goiânia, Brazil.

**José Valladares-Neto**  
PhD, Associate Professor, Division of  
Orthodontics, School of Dentistry, Federal  
University of Goiás, Goiânia, Brazil.

**Maria Alves Garcia Silva**  
PhD, Titular Professor, Department of Oral  
Sciences, School of Dentistry, Federal University  
of Goiás, Goiânia, Brazil.

### RESUMO

O espaço aéreo faríngeo (EAF) reduzido pode indicar a presença de apneia obstrutiva do sono ou síndrome de hipopneia, com repercussões na qualidade de vida do indivíduo. Para o estudo do PAF, podem ser usadas ressonância magnética, telerradiografia, tomografia computadorizada de feixe cônico (TCFC) ou tomografia computadorizada de feixe amplo (TCFL). O objetivo deste estudo foi testar a confiabilidade do TCFC e do TCFL nas medições do PAF. Foram utilizados cinco hemi-cadáveres humanos, seccionados na linha média, para realizar um exame de CBCT e um exame de FBCT. As medições do PAF foram realizadas por seis examinadores experientes, treinados de acordo com pontos anatômicos previamente estabelecidos. Os mesmos pontos foram medidos com um paquímetro digital nas amostras anatômicas. As medições foram repetidas ao longo da amostra com um intervalo de dez dias. Os dados foram testados quanto à normalidade de distribuição pelo teste de Shapiro-Wilk e submetidos à análise estatística usando o software IBM SPSS 22.0, com nível de significância de 5%. Na análise de confiabilidade, o Coeficiente de Correlação Intraclass (CCI) foi utilizado para verificar a concordância intra e interexaminadores. Comparações entre as medições realizadas nas peças anatômicas e nas imagens de TCFC e TCFL foram feitas para cada região de estudo (nasofaringe, orofaringe e hipofaringe) por meio do teste ANOVA para Medidas Repetidas. Os resultados indicaram que tanto o TCFC quanto o TCFL podem ser importantes auxiliares na avaliação do EAF, mas, como não houve diferença estatística entre as duas modalidades, sugere-se que o TCFC seja preferido ao TCFL para esse propósito, considerando sua menor dose de radiação e menor custo.

**Palavras-chave:** Tomografia Computadorizada por Raios X. Tomografia Computadorizada de Feixe Cônico. Apneia Obstrutiva do Sono. Espaço Aéreo Faríngeo.

## RELIABILITY OF CONE-BEAM COMPUTED TOMOGRAPHY AND FAN-BEAM COMPUTED TOMOGRAPHY IN PHARYNGEAL AIRWAY SPACE LINEAR MEASUREMENTS

### ABSTRACT

Pharyngeal airway space (PAS) Reduced may mean the presence of obstructive sleep apnea or hypopnea syndrome, with repercussions on the individual's quality of life. For PAS study, magnetic

resonance imaging, teleradiography, cone-beam computed tomography (CBCT) or fan-beam computed tomography (FBCT) can be used. The aim of this study was to test reliability of CBCT and FBCT in the measurements of PAS. Five human hemi - heads, sectioned in the middle line, were used to perform a CBCT and a FBCT scan. The measurements of PAS were performed by six experienced examiners trained according to previously established anatomical points. The same points were measured with a digital caliper in the anatomical specimens. Measurements were repeated throughout the sample with a ten day interval. The data were tested for normality of distribution by the Shapiro- Wilk test and were submitted to statistical analysis using IBM SPSS 22.0 software, at a significance level of 5%. In the reliability analysis, Intraclass Correlation Coefficient (ICC) was used to verify intra- and inter-examiner agreement. Comparisons between the measurements performed on the anatomical pieces and the CBCT and FBCT images were performed for each study region (nasopharynx, oropharynx and hypopharynx) by means of ANOVA for Repeated Measures test. The results indicated that both CBCT and FBCT imaging may be important adjuvants in the evaluation of the PAS, but since there was no statistical difference between the two modalities, it is suggested that CBCT should be preferred over FBCT for this purpose, considering it is lower radiation dose and lower cost.

**Key words:** X-Ray Computed tomography. Cone-beam computed tomography. Obstructive Sleep Apnea. Pharyngeal airway space.

## 1. INTRODUÇÃO

Obstructive sleep apnea syndrome (OSAS) is a common sleep-disordered breathing suffered by population with prevalence of 23,4 and up to 49% in Europe.<sup>1</sup> OSAS is characterized as an obstruction of the pharyngeal airway space (PAS) leading to apnea with a drop of oxygen saturation resulting in an awakening. Direct effects are sleepiness and lack of concentration during the day. Major implications are hypertension, cardiovascular diseases, and even diabetes mellitus type II.<sup>2,3</sup>

Several types of image exams are used to analyze PAS such as lateral normalized teleradiography (TL), magnetic resonance imaging, concomitant cone-beam computed tomography (CBCT), and fan-beam computed

tomography (FBCT).<sup>4</sup> Despite the lower radiation dose, the evaluation of PAS by TL is limited by the two-dimensional nature of the examination, which cannot identify the contour of soft tissues, besides limiting the observation of area and volume.<sup>5</sup> The choice of the type of tomographic examination is also due to the convenience in obtaining the exams and payment by covenants. The use of any imaging method, especially with the use of ionizing radiation should be based on scientific evidence and follow protocols previously defined.<sup>6</sup> The indication of the best image exam should consider several factors, including image accuracy, feasibility, cost, radiation dose, advantages and disadvantages of the technique. Mainly, it should be guided by the ALARA / ALADA principle (*as low as*

*reasonably achievable - as low as reasonably possible*)<sup>7</sup>.

CBCT has been frequently used to evaluate PAS for being accurate resulting in measurements at a 1:1 scale rate,<sup>8-11</sup> relatively non-invasive, low-cost, relatively low-dose radiation and capable of providing consistent data for the evaluation of PAS after orthognathic surgeries has been highlighted in the literature.<sup>12-14</sup> However, FBCT has often been indicated because it allows the supine position during the examination, which can not be maintained in most CBCT equipment, maintaining the position of soft tissue relationships during sleep and also because it presents better contrast of soft tissues<sup>12, 16-18</sup> leading to different results, especially in PAS diagnosis<sup>3</sup>.

Despite Guijarro-Martinez and Swennen<sup>19</sup> confirmed in a systematic review that CBCT is an accurate and reliable tool for PAS evaluation both types of tomography are indicated by health professionals to analyse the PAS. Therefore, further studies are necessary to overcome many inconsistencies and comparing the two methods for reliability in measurements for nasopharynx (NP), oropharynx (OP) and hypopharynx (HP) and to remedy the lack of agreement in the literature regarding the gold standard and reliability procedure in relation to the best image exam for the evaluation of PAS. The aim of this study is to evaluate the reliability of the CBCT and FBCT in linear measures of the PAS for the NP, OP and HP regions.

The null hypothesis was that no difference would be found between CBCT and FBCT for PAS (NP, OP and HP regions) in linear

measurements when measured using a software system; the system are replicable and valid.

## 2. MATERIAL E MÉTODOS

The present cross-sectional study was approved by the International Review Board (protocol number 1.644.302) of the Federal University of Goiás, Brazil.

The sample size was calculated according to the recommendations by Walter et al.<sup>20</sup> in reliability studies. Ten human heads were used in this study, sectioned in the midline with conditions to show the entire PAS between the hard and soft palates up to the vallecular epiglottis. The standardization of a polystyrene model was made for each hemi-head to minimize the bias, which did not interfere with tomographic techniques, to support each hemi-head in the same position and allow standardization during the performance of tomographic examinations and anatomical measurements. The model also allowed the maintenance of anatomical soft tissue relationships related to PAS. All heads were transported from the Biological Sciences Institute of the Federal University of Goiás (ICB-UFG), as instructed by the technician responsible for the ICB-UFG laboratory, in a sealed polystyrene box directly to the Clinics Hospital of Goiás of the Federal University of Goiás (HC-UFG) to perform FBCT and to a private dental radiology clinic to perform CBCT and to Dental School of Federal University of Goiás (FO-UFG) to perform the measurements and returned to the ICB-UFG human anatomy laboratory immediately after the

measurements and CBCT and FBCT scans are completed.

Human hemi-heads which presented NP, OP and HP structures preserved and good conditions of evidencing the PAS between the hard palate and soft palate up to the vallecular epiglottis were included; CBCT and FBCT images showing poorly image quality of contrast and brightness or images with difficulty in visualizing the anatomical structures under study were excluded. Total of 5 CBCT and 5 FBCT were included.

Six examiners with more than ten years of experience in analyzing tomographic images and in manipulating image software, performed all the measurements independent and individually. The examiners were trained and calibrated as follows: for the measurements performed on the anatomical pieces, individual training was performed with each examiner in a closed room and a clear environment that allowed a good visualization of the start and end points of each structure measured (NP, OP, HP). With the aid of the digital caliper (Stainless Hardened, MTX, Shangai, China), they were asked to measure the distance between these two reference points for each structure according to Figure 1.

**Figure 1** - Cephalometric points identified in the anatomical pieces, CBCT and FBCT images. Landmarks, linear and angular measurements on 2D cephalometric scan. Landmarks: S (sella, the center of sella turcica), N (nasion, the most anterior point on the fronto-nasal suture), PNS (posterior nasal spine, the most posterior point on the bony hard palate), Ba (basion, the most posterior-inferior point of the front edge of the foramen magnum), C2s (upper second cervical vertebrae, the most posterior-superior point of

the second cervical vertebrae), C2i (lower second cervical vertebrae, the most posterior-inferior point of the second cervical vertebrae), C3 (third cervical vertebrae, the most anterior-inferior point of the third cervical vertebrae), Ct (constriction, the most posterior of the minimum cross-sectional wall of the pharynx), and V (vallecula, the intersection of the epiglottis and the base of the tongue).

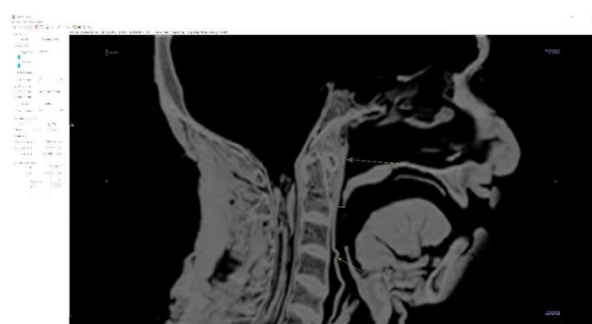


For the measurements performed in the InVivoDental software, version 5.4 (Anatomage, San Jose, CA), individual training was performed with each examiner in diagnostic imaging exams laboratory which provides a closed room and dark environment with the aim of providing a better evaluation of the imaging examinations under analysis. The examiners were presented with the necessary tools to carry out the CBCT and FBCT measures and how to use them.

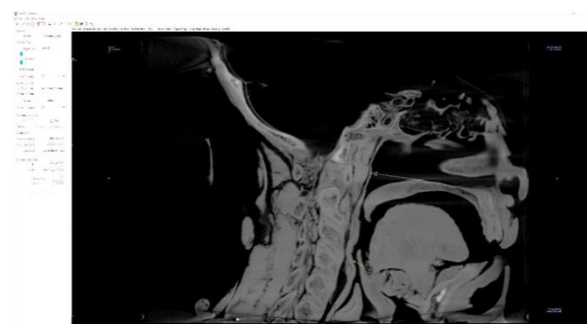
The tomographics images files were exported in digital imaging and communication in medicine format (DICOM), and reconstructed in the sagittal, coronal, and axial planes processed

using InVivoDental software. The images were analyzed on a desktop computer (XPS Dell, Austin, Texas, USA) with the settings necessary to ensure proper use of software and 24.1 " LCD monitor (Dell, Austin, Texas, USA) with 3840 x 2160 pixel resolution screen resolution for better interpretation of anatomical structures. They were analyzed in an environment appropriate to the radiographic interpretation: darkened room and silent environment. The images of each hemi-head were automatically positioned by the software, and no adjustments were necessary to ensure the orthogonal relationship between the Frankfurt plane and the median sagittal plane. The measurements were performed in the sagittal cut that corresponds to the midline of the head. The anatomical points were identified and the measurements performed directly on the screen using the cursor and the measurement tools of InVivoDental software (Figures 2 and 3).

**Figure 2** - InVivo5 Software Interface for FBCT demonstrating the location of Nasopharynx, Oropharynx and Hypopharynx measurements.



**Figure 3** - InVivo5 Software Interface for FBCT demonstrating the location of Nasopharynx, Oropharynx and Hypopharynx measurements



The PAS was divided into three lines perpendicular to the median sagittal plane: following the line connecting the posterior nasal spine (PNS) and the basal, the PNS measurement to the soft tissue corresponding to the posterior wall of the pharynx. This measure corresponds to the measurement of the nasopharynx. The region of the oropharynx was measured by the line connecting the lower tip of the soft palate to the posterior wall of the pharynx. The line connecting the vallecula epiglottis to the point C3 guided the measurement of the vallecula epiglottis to the posterior wall of the pharynx and corresponds to the measurement of the hypopharynx. The points and lines used in the measurement are outlined in Figure 1, adapted from Valladares-Neto et al.<sup>21</sup>.

The anatomical measurement served as a gold standard for the analysis of the reliability of the tomographic exams and was performed by the researcher in charge using a digital caliper, with reference to the same anatomical points and references of the tomographic images (Figures 4 to 7). To analyze intra-examiner reliability all measurements were repeated by all examiners after an interval of ten days.

**Figure 4-** Anatomical pieces and digital caliper





**Figure 5** - Nasopharynx measurement with digital caliper



**Figure 6** - Oropharynx measurement with digital caliper



**Figure 7** – Hypopharynx measurement with digital caliper



The data measurements were submitted to statistical analysis with IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, CA, USA), with a significance level of 5%. The data were tested for normality of distribution by the Shapiro-Wilk test. In the reliability analysis, the Intraclass Correlation Coefficient (ICC) was used to verify intra- and inter-examiner agreement. Comparisons between the measurements on the anatomical pieces and the CBCT and FBCT images were performed for each study region (NP, OP, HP) using ANOVA for Repeated Measures test.

### 3. RESULTADOS

The 10 CBCT and 10 FBCT performed on human heads, 5 CBCT and 5 FBCT were included and evaluated in accordance with the previously

established eligibility criteria. Comparisons between measurements of the NP, OP and HP were performed on anatomical pieces, CBCT and FBCT by six examiners experienced in image analysis.

Tables 1, 2 and 3 show results of intra-examiner reliability for the measurements performed in the first evaluation (T1) and second evaluation (T2) in the anatomical pieces, CBCT and FBCT, respectively. The intra-examiner agreement was low in NP the measurement in the anatomical pieces and in the InVivoDental software for both CBCT and FBCT (examiner 4, ICC anatomical piece = 0.041; ICC CBCT = 0.014; ICC FBCT = 0.101). Intra-examiner agreement was also low in OP measurement (examiner 2, ICC anatomical piece = 0,054), (examiner 4, ICC anatomical piece = 0,041), (examiner 5, ICC anatomical piece = 0,162) and for intra-examiner CBCT NP measurement (examiner 2, ICC CBCT = 0.171), (examiner 4, ICC CBCT = 0.014). The others agreement values presented reasonable to excellent between the groups ( $0,258 \leq \text{ICC} \leq 0,998$ ).

Tables 4, 5 and 6 show results of the inter-examiner reliability analysis on the anatomical parts, CBCT and FBCT. The averages of the measurements obtained at T1 and T2 were considered for each examiner. All inter-examiner agreement values varied between good and excellent ( $0.613 \leq \text{ICC} \leq 0.983$ ).

For comparisons between the measurements obtained in the anatomical pieces (real), in the CBCT and FBCT images, the averages of the measurements made by the six examiners for each region of interest NP, OP and HP were considered. The data obtained have a normal distribution, and a parametric statistical test was applied and the

results of ANOVA for Repeated Measures are shown in table 7. No statistically significant differences ( $P > 0.05$ ) were detected for the measurements performed in NP ( $P = 0.09$ ) and in the OP ( $P = 0.66$ ) and HP ( $P = 0.08$ ) images assessed using the InVivoDental software.

#### 4. DISCUSSÃO

This study aimed to compare and evaluate the reliability of CBCT and FBCT for linear measurements of the PAS in order to estimate the best and most suitable exam imaging for analysis of these anatomical region. The data did not present a statistically significant difference ( $p > 0.05$ ) between the three-dimensional imaging methods (CBCT and FBCT) analysed in the InVivoDental software. This can be explained by the three-dimensional nature of these exams in comparasion, although each type of exam has indications for evaluate hard or soft tissues.

In the study by Aboudara et al.<sup>22</sup> PAS was analyzed between computed tomography and lateral cephalometric radiography and differently of the present study there was a statistically significant difference, which can be explained by the three-dimensional nature of computed tomography and two-dimensional lateral cephalometric. Abé-Nickler et al.<sup>23</sup> evaluated linear measures of PAS and emphasized that drawing conclusions from two-dimensional PAS images to evaluate an PAS configuration that is three-dimensional is not reliable, since there is not enough correlation between the anterior distances and the corresponding transverse areas.

The intra-examiner agreement was low in NP the measurement in the anatomical pieces and in the InVivoDental software for both CBCT and FBCT. And intra-examiner agreement was also low in OP measurement and for intra-examiner CBCT NP. The others agreement values presented reasonable to excellent between the groups ( $0,258 \leq ICC \leq 0,998$ ) suggesting a difficulty measurement. This poorly agreement may be due to the difficulty in determining the beginning and end of the anatomical structures under study with perfect accuracy due to the lack of consensus on a standard method for measuring the EAF. However, in the global assessment among all examiners, there was no difference between the measurements, which allows us to consider the result with some certainty. Torres et al.<sup>24</sup> suggest two standard methods of measurement and describe the boundaries used for each one of the methods and indicates a method easily to identified the anatomical structures<sup>25</sup>, also used in the manual of the software system<sup>26</sup>.

The reliability inter-examiner in our study varied between good and excellent to anatomical pieces, CBCT and FBCT ( $0,613 \leq ICC \leq 0,983$ ), suggesting high agreement among all six examiners in NP, OP and HP measures to anatomical pieces, CBCT and FBCT. These results are supported by other studies<sup>3,25,27-30</sup>.

In the analysis of ANOVA for Repeated Measures test, *P* values allows to infer that the methods of image acquisition CBCT and FBCT did not present a statistically significant difference and have the same degree of reliability for linear measures of PAS.

Ayoub et al.<sup>3</sup> showed that radiological CBCT and FBCT scans are able to record,

process, and display anatomical structures of PAS with equal image quality. Nonetheless, they found a significant difference in PAS height comparing the supine position of patients in FBCT scans and the upright seating position in CBCT scans and concluded that it is influenced by the vertical position of the mandible and the hyoid. PAS seems to be influenced by changes in the position of the head and can be considerably affected by gravitational forces<sup>3,4,31</sup>.

The present study sought to contribute to the scientific literature on the reliability between CBCT and FBCT in measuring PAS. The null hypothesis was accepted, because was not found statistically significant difference among the measurements in tomography methods. We are aware of the limitations of the study in terms of the low sample size wich was reduced by 50% after the eligibility criteria for tomographic images. However, these results might have an impact on preoperative diagnostics for decision-making concerning surgical treatment of OSAS<sup>3</sup>. It also serves as a preliminary study and allows discussion about the theme corroborating with future studies to verify the accuracy and reliability of the types of tomography for evaluating the PAS with a larger sample until we have complete confidence about which is the most appropriate type of tomography indicated for PAS analysis.

## 5. CONCLUSÃO

In conclusion, NP, OP are HP measurements in PAS are measured with the same degree of reliability by CBCT or FBCT. CBCT scans might be preferred over FBCT for this purpose, considering its lower radiation dose and cost.



## REFERÊNCIAS

- GARVEY, J. F.; PENG, M. F.; DRAKATOS, P.; KENT, B. D. Epidemiological aspects of obstructive sleep apnea. *Journal of Thoracic Disease*, v. 7, p. 920-929, 2015.
- FRIEDMAN, O.; LOGAN, A. G. The price of obstructive sleep apnea-hypopnea: hypertension and other ill effects. *American Journal of Hypertension*, v. 22, p. 474-483, 2009.
- AYOUB, N.; EBLE, P.; KNIHA, K.; PETERS, F.; MÖHLHENRICH, S. C.; GOLOBORODKO, E.; HÖLZLE, F.; MODABBER, A. Three-dimensional evaluation of the posterior airway space: differences in computed tomography and cone beam computed tomography. *Clinical Oral Investigations*, v. 23, n. 2, p. 603-609, 2019.
- ZINSLEY, S. R.; MORAES, L. C.; MOURA, P. U. W. Avaliação do espaço aéreo faríngeo por meio da tomografia computadorizada de feixe cônico. *Dental Press Journal of Orthodontics*, v. 15, n. 5, p. 150-158, 2010.
- SILVA, M. A.; WOLF, U.; HEINICKE, F.; BUMANN, A.; VISSER, H.; HIRSCH, E. Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation. *American Journal of Orthodontics and Dentofacial Orthopedics*, v. 133, n. 5, p. 640.e1-640.e5, 2008.
- SEDENTEXCT – EUROPEAN COMMISSION ON RADIATION PROTECTION. Guideline Development Panel. *Radiation protection N° 172. Cone beam CT for dental and maxillofacial radiology. Evidence based guidelines*. Luxembourg: European Commission Directorate-General for Energy, 2012.
- FARMAN, A. G. ALARA still applies. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, v. 100, n. 4, p. 395-397, 2005.
- KIM, K. B. How has our interest in the airway changed over 100 years?. *Journal of Orthodontics and Dentofacial Orthopedics*, v. 148, p. 740, 2015.
- YAMASHINA, A.; TANIMOTO, K.; SUTTHIPRAPAPORN, P.; HAYAKAWA, Y. The reliability of computed tomography (CT) values and dimensional measurements of the oropharyngeal region using cone beam CT: Comparison with multidetector CT. *Dentomaxillofacial Radiology*, v. 37, p. 245, 2008.
- OSORIO, F.; PERILLA, M.; DOYLE, D. J.; PALOMO, J. M. Cone beam computed tomography: An innovative tool for airway assessment. *Anesthesia & Analgesia*, v. 106, p. 1803, 2008.
- ABOUDARA, C.; NIELSEN, I.; HUANG, J. C.; et al. Comparison of airway space with conventional lateral headfilms and 3-dimensional reconstruction from cone-beam computed tomography. *American Journal of Orthodontics and Dentofacial Orthopedics*, v. 135, p. 468-479, 2009.
- SUKOVIC, P. Cone beam computed tomography in craniofacial imaging. *Orthodontics & Craniofacial Research*, v. 6, n. 1, p. 316-326, 2003.
- GONÇALVES, E. S. et al. Retrospective analysis of the effects of orthognathic surgery on the pharyngeal airway space. *Journal of Oral and Maxillofacial Surgery*, v. 72, p. 2227-2240, 2014.
- HERNÁNDEZ-ALFARO, F.; GUIJARRO-MARTINEZ, R.; MAREQUE-BUENO, J. Effect of mono- and bimaxillary advancement on pharyngeal airway volume: cone-beam computed tomography evaluation. *Journal of Oral and Maxillofacial Surgery*, v. 69, n. 11, p. 395-400, 2011.
- ABRAMSON, Z. et al. Three-dimensional computed tomographic airway analysis of patients with obstructive sleep apnea treated by maxillomandibular advancement. *Journal of Oral and Maxillofacial Surgery*, v. 69, n. 16, p. 677-686, 2011.
- FAIRBURN, S. C. et al. Three-dimensional changes in upper airways of patients with obstructive sleep apnea following maxillomandibular advancement. *Journal of Oral and Maxillofacial Surgery*, v. 65, n. 1, p. 6-12, 2007.
- ARAI, Y.; TAMMISALO, E.; IWAI, K.; HASHIMOTO, K.; SHINODA, K. Development of a compact computed tomographic apparatus for dental use. *Dentomaxillofacial Radiology*, v. 28, n. 4, p. 245-248, 1999.
- EL H, PALOMO, J. M. Measuring the airway in 3 dimensions: a feasibility and accuracy study. *American Journal of Orthodontics and Dentofacial Orthopedics*, v. 137, n. 4, p. 501-509, 2010.
- GUIJARRO-MARTINEZ, R.; SWENNEN, G. R. Cone-beam computerized tomography imaging and analysis of the upper airway: a systematic review of the literature. *International Journal of Oral and Maxillofacial Surgery*, v. 40, p. 1227-1237, 2011.
- WALTER, S. D.; ELIASZIW, M.; DONNER, A. Sample size and optimal designs for reliability studies. *Statistics in Medicine*, v. 17, p. 101-110, 1998.
- VALLADARES-NETO, J.; SILVA, M. A.; BUMANN, A.; PAIVA, J. B.; RINO-NETO, J. Effects of mandibular advancement surgery combined with minimal maxillary displacement on the volume and most restricted cross-sectional area of the pharyngeal airway. *International Journal of Oral and Maxillofacial Surgery*, v. 42, n. 11, p. 1437-1445, 2013.

ABOUDARA, C.; NIELSEN, I.; HUANG, J. C.; MAKI, K.; MILLER, A. J.; HATCHER, D. Comparison of airway space with conventional lateral headfilms and 3-dimensional reconstruction from cone-beam computed tomography. *American Journal of Orthodontics and Dentofacial Orthopedics*, v. 135, n. 4, p. 468-479, 2009.

ABÉ-NICKLER, M. D.; PÖRTNER, S.; SIEG, P.; HAKIM, S. G. No correlation between two-dimensional measurements and three-dimensional configuration of the pharyngeal upper airway space in cone-beam computed tomography. *Journal of Craniomaxillofacial Surgery*, v. 45, n. 3, p. 371-376, 2017.

TORRES, H. M.; EVANGELISTA, K.; TORRES, É. M.; ESTRELA, C.; FIGUEIREDO, P. T. S.; VALLADARES-NETO, J.; SILVA, M. A. G. Comparison of dimensions of the nasopharynx and oropharynx using different anatomical references: Is there equivalence? *Journal of Oral and Maxillofacial Surgery*, v. 77, n. 12, p. 2545-2554, 2019.

TORRES, H. M.; EVANGELISTA, K.; TORRES, É. M.; ESTRELA, C.; LEITE, A. F.; VALLADARES-NETO, J.; SILVA, M. A. G. Reliability and validity of two software systems used to measure the pharyngeal airway space in three-dimensional analysis. *International Journal of Oral and Maxillofacial Surgery*, v. 49, n. 5, p. 602-613, 2020.

IN VIVO DENTAL 5.0 REFERENCE MANUAL. San Jose, California: Anatomage, 2010.

MATTOS, C. T.; CRUZ, C. V.; DA MATTA, T. C.; PEREIRA, L. de A.; SOLON-DE-MELLO, P. de A.; RUELLAS, A. C.; SANT'ANNA, E. F. Reliability of upper airway linear, area, and volumetric measurements in cone-beam computed tomography.

Você disse:

faça novamente

O ChatGPT disse:

ChatGPT

Claro! Aqui está a formatação das referências de acordo com as normas da ABNT (Associação Brasileira de Normas Técnicas):

GARVEY, J. F.; PENG, M. F.; DRAKATOS, P.; KENT, B. D. Epidemiological aspects of obstructive sleep apnea. *Journal of Thoracic Disease*, v. 7, p. 920-929, 2015.

FRIEDMAN, O.; LOGAN, A. G. The price of obstructive sleep apnea-hypopnea: hypertension and other ill effects. *American Journal of Hypertension*, v. 22, p. 474-483, 2009.

AYOUB, N. et al. Three-dimensional evaluation of the posterior airway space: differences in computed tomography and cone beam computed tomography. *Clinical Oral Investigations*, v. 23, n. 2, p. 603-609, 2019.

ZINSLEY, S. R.; MORAES, L. C.; MOURA, P. U. W. Avaliação do espaço aéreo faríngeo por meio da tomografia computadorizada de feixe cônico. *Dental Press Journal of Orthodontics*, v. 15, n. 5, p. 150-158, 2010.

SILVA, M. A. et al. Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation. *American Journal of Orthodontics and Dentofacial Orthopedics*, v. 133, n. 5, p. 640.e1-640.e5, 2008.

SEDEXCT – EUROPEAN COMMISSION ON RADIATION PROTECTION. Guideline Development Panel. *Radiation protection N° 172: Cone beam CT for dental and maxillofacial radiology. Evidence based guidelines*. Luxembourg: European Commission Directorate-General for Energy, 2012.

FARMAN, A. G. ALARA still applies. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, v. 100, n. 4, p. 395-397, 2005.

KIM, K. B. How has our interest in the airway changed over 100 years? *Journal of Orthodontics and Dentofacial Orthopedics*, v. 148, p. 740, 2015.

YAMASHINA, A. et al. The reliability of computed tomography (CT) values and dimensional measurements of the oropharyngeal region using cone beam CT: Comparison with multidetector CT. *Dentomaxillofacial Radiology*, v. 37, p. 245, 2008.

OSORIO, F.; PERILLA, M.; DOYLE, D. J.; PALOMO, J. M. Cone beam computed tomography: An innovative tool for airway assessment. *Anesthesia & Analgesia*, v. 106, p. 1803, 2008.

ABOUDARA, C. et al. Comparison of airway space with conventional lateral headfilms and 3-dimensional reconstruction from cone-beam computed tomography. *American Journal of Orthodontics and Dentofacial Orthopedics*, v. 135, p. 468-479, 2009.

SUKOVIC, P. Cone beam computed tomography in craniofacial imaging. *Orthodontics & Craniofacial Research*, v. 6, n. 1, p. 316-326, 2003.

GONÇALVES, E. S. et al. Retrospective analysis of the effects of orthognathic surgery on the pharyngeal airway space. *Journal of Oral and Maxillofacial Surgery*, v. 72, p. 2227-2240, 2014.

HERNÁNDEZ-ALFARO, F.; GUIJARRO-MARTÍNEZ, R.; MAREQUE-BUENO, J. Effect of mono- and bimaxillary advancement on pharyngeal airway volume: cone-beam computed tomography evaluation. *Journal of Oral and Maxillofacial Surgery*, v. 69, n. 11, p. 395-400, 2011.

ABRAMSON, Z. et al. Three-dimensional computed tomographic airway analysis of patients with obstructive sleep apnea treated by maxillomandibular

advancement. *Journal of Oral and Maxillofacial Surgery*, v. 69, n. 16, p. 677-686, 2011.

FAIRBURN, S. C. et al. Three-dimensional changes in upper airways of patients with obstructive sleep apnea following maxillomandibular advancement. *Journal of Oral and Maxillofacial Surgery*, v. 65, n. 1, p. 6-12, 2007.

ARAI, Y. et al. Development of a compact computed tomographic apparatus for dental use. *Dentomaxillofacial Radiology*, v. 28, n. 4, p. 245-248, 1999.

EL H; PALOMO, J. M. Measuring the airway in 3 dimensions: a feasibility and accuracy study. *American Journal of Orthodontics and Dentofacial Orthopedics*, v. 137, n. 4, p. 501-509, 2010.

GUIJARRO-MARTÍNEZ, R.; SWENNEN, G. R. Cone-beam computerized tomography imaging and analysis of the upper airway: a systematic review of the literature. *International Journal of Oral and Maxillofacial Surgery*, v. 40, p. 1227-1237, 2011.

WALTER, S. D.; ELIASZIW, M.; DONNER, A. Sample size and optimal designs for reliability studies. *Statistics in Medicine*, v. 17, p. 101-110, 1998.

VALLADARES-NETO, J. et al. Effects of mandibular advancement surgery combined with minimal maxillary displacement on the volume and most restricted cross-sectional area of the pharyngeal airway. *International Journal of Oral and Maxillofacial Surgery*, v. 42, n. 11, p. 1437-1445, 2013.

ABOUDARA, C. et al. Comparison of airway space with conventional lateral headfilms and 3-dimensional reconstruction from cone-beam computed tomography. *American Journal of Orthodontics and Dentofacial Orthopedics*, v. 135, n. 4, p. 468-479, 2009.

ABÉ-NICKLER, M. D. et al. No correlation between two-dimensional measurements and three-dimensional configuration of the pharyngeal upper airway space in cone-beam computed tomography. *Journal of Cranio-maxillofacial Surgery*, v. 45, n. 3, p. 371-376, 2017.

TORRES, H. M. et al. Comparison of dimensions of the nasopharynx and oropharynx using different anatomical references: Is there equivalence? *Journal of Oral and Maxillofacial Surgery*, v. 77, n. 12, p. 2545-2554, 2019.

TORRES, H. M. et al. Reliability and validity of two software systems used to measure the pharyngeal airway space in three-dimensional analysis. *International Journal of Oral and Maxillofacial Surgery*, v. 49, n. 5, p. 602-613, 2020.

IN VIVO DENTAL 5.0 REFERENCE MANUAL.  
San Jose, California: Anatomage, 2010.

MATTOS, C. T. et al. Reliability of upper airway linear, area, and volumetric measurements in cone-beam

computed tomography. *American Journal of Orthodontics and Dentofacial Orthopedics*, v. 145, p. 188-197, 2014.

CHEN, H. et al. Reliability and accuracy of three imaging software packages used for 3D analysis of the upper airway on cone beam computed tomography images. *Dentomaxillofacial Radiology*, v. 46, p. 20170043, 2017.

CHEN, H. et al. Reliability of three-dimensional measurements of the upper airway on cone beam computed tomography images. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology*, v. 122, p. 104-110, 2016.

NEELAPU, B. C. et al. The reliability of different methods of manual volumetric segmentation of pharyngeal and sinonasal subregions. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology*, v. 124, p. 577-587, 2017.

SUTTHIPRAPAPORN, P. et al. Positional changes of oropharyngeal structures due to gravity in the upright and supine positions. *Dentomaxillofacial Radiology*, v. 37, p. 130-135, 2008.